DEVELOPMENT OF ELECTRONIC DEVICE FOR DETECTING, MEASURING AND VISUAL MONITORING OF RADIATION DOSES FOR HIGHLY RADIOACTIVE SOURCES

MD ROKONUZZAMAN

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

2019

DEVELOPMENT OF ELECTRONIC DEVICE FOR DETECTING, MEASURING AND VISUAL MONITORING OF RADIATION DOSES FOR HIGHLY RADIOACTIVE SOURCES

MD ROKONUZZAMAN

2019

DEVELOPMENT OF ELECTRONIC DEVICE FOR DETECTING, MEASURING AND VISUAL MONITORING OF RADIATION DOSES FOR HIGHLY RADIOACTIVE SOURCES

MD ROKONUZZAMAN

(BSc Engg, KUET)

A THESIS SUBMITTED

FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING

DEPARTMENT OF NUCLEAR SCIENCE AND ENGINEERING

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

2019

The thesis titled "DEVELOPMENT OF ELECTRONIC DEVICE FOR DETECTING, MEASURING AND VISUAL MONITORING OF RADIATION DOSES FOR HIGHLY RADIOACTIVE SOURCES." submitted by Md Rokonuzzaman, Student ID-1015280002, Session 2015-2016 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Science on Nuclear Science and Engineering.

BOARD OF EXAMINERS

Dr Ruhul Amin Khan — Chairman

Director, Institute of Radiation and Polymer Technology,
Bangladesh Atomic Energy Research Establishment, Savar, Dhaka.

Dr M. A. Rashid Sarker — Member

Professor, Department of Nuclear Science and Engineering, MIST, Dhaka

Colonel Md Rosaidul Mawla, psc — Member (Ex Officio)

Head, Department of Nuclear Science and Engineering, MIST, Dhaka.

Dr A. M. Sarwaruddin Chowdhury — Member (External)

Professor, Department of Applied Chemistry and Chemical Engineering
University of Dhaka, Dhaka.

“Declaration

I hereby declare that this thesis is my original work and it has written by me in it’s entirely. I have duly acknowledged all the sources of information which have been used in the thesis. The thesis (full or partially) has not been submitted for any degree or diploma in any university or institute previously.”

Md Rokonuzzaman

Dated:

Abstract

Ionization radiation is the major concern to use radiation energy. The professional radiation workers cannot go near to highly radioactive sources. At present robotic technologies are used for these purposes. But the robots are made with sophisticated technology, high cost, not user friendly, difficult to move from one country to another due to restriction by the country law, safety and security. For these reasons, this research has been carried out to find a simple, affordable and effective alternative device which can be used for the same purpose. Amber and red Perspex, camera/cc camera with shielding and Lead mirror has been loaded on microprocessor based controlled carrier for placing at the source room near to Co-60 source located at IRPT, Dhaka, Bangladesh. The carrier has been designed with the help of microprocessor based circuit elements and power source. The camera is shielded by Lead box in such a way that the lens of the camera focusing toward the Lead mirror through hole to capture the images from mirror. Physical properties (color) of radiation sensitive ambers and red Perspex has been changed during irradiation which indicates the detection of radiation. The absorbed doses are measured from amber and red Perspex with the help of ultra violet spectrophotometer and Harwell standard chart. The source position and real situation of the source room has been monitored from fixed and video images captured by the developed device operated from safe zone connecting camera with computer through Wi-Fi. The presence of radiation has been validated by camera glittering. This device is simple, affordable and does not include any complex robotic technologies due to its simplicity of design, technique and technologies which can be used as an effective alternative device for detecting, monitoring and visual monitoring of radiation doses for highly radioactive sources instead of costly robots.

Acknowledgement

First of all the author would like to thanks to Almighty Allah for completing the thesis. The author would like to express his sincere gratitude to Commandant, dean of all faculties, controller of examination and all of the teachers, faculty member and stuffs of department of Nuclear Science and Engineering (NSE), Military Institute of Science and Technology (MIST) for their wholehearted support and inspiration and the unique opportunity given to study in the post-graduation in Nuclear Science and Engineering.

Special thanks to the supervisor, Dr. Ruhul Amin Khan, Director, The Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh who has guided the researcher with his utmost sincerity for the completion of the research. It was impossible to complete the research without his sincere support and guidance.

The researcher would also like to give thanks to the all officer and stuffs of Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh and every single person who had extended their hand to make this research into a success.

Finally the author would like to give special thanks to the all classmates who had extended their cooperation for making the success of the research.

Table of Contents

List of Figures

List of Tables

List of Graphs

Chapter-1

Introduction

1.1. Radiation

Radiation is energy in the form of waves or streams of particles. There are many kinds of radiation all around us. When people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms. Sound and visible light are familiar forms of radiation; other types include ultraviolet radiation (that produces a suntan), infrared radiation, (form of heat energy), radio and television signals. So the radiation can be explained:

- ✓ Emission of energy in the form of waves or particle.
- ✓ Travels through a medium until absorbed by matter.
- ✓ Energy emission continues unless the nucleus becomes stable.

All life has evolved in an environment filled with radiation. The forces at work in radiation are revealed upon examining the structure of atoms. Atoms are a million times thinner than a single strand of human hair, and are composed of even smaller particles some of which are electrically charged [1].

1.1.1 Radioisotopes

Isotopes that are not stable and emit radiation are called radioisotopes. A radioisotope is an isotope of an element that undergoes spontaneous decay and emits radiation as it decays. During the decay process, it becomes less radioactive over time, eventually becoming stable [1] - [2].

1.1.2 Classification

Radiation is energy in the form of waves of particles. There are two forms of radiation:

i) Non-ionizing radiation

ii) Ionization radiation

An electromagnetic spectrum is shown in Fig-1.1 for nonionizing and ionizing radiation.

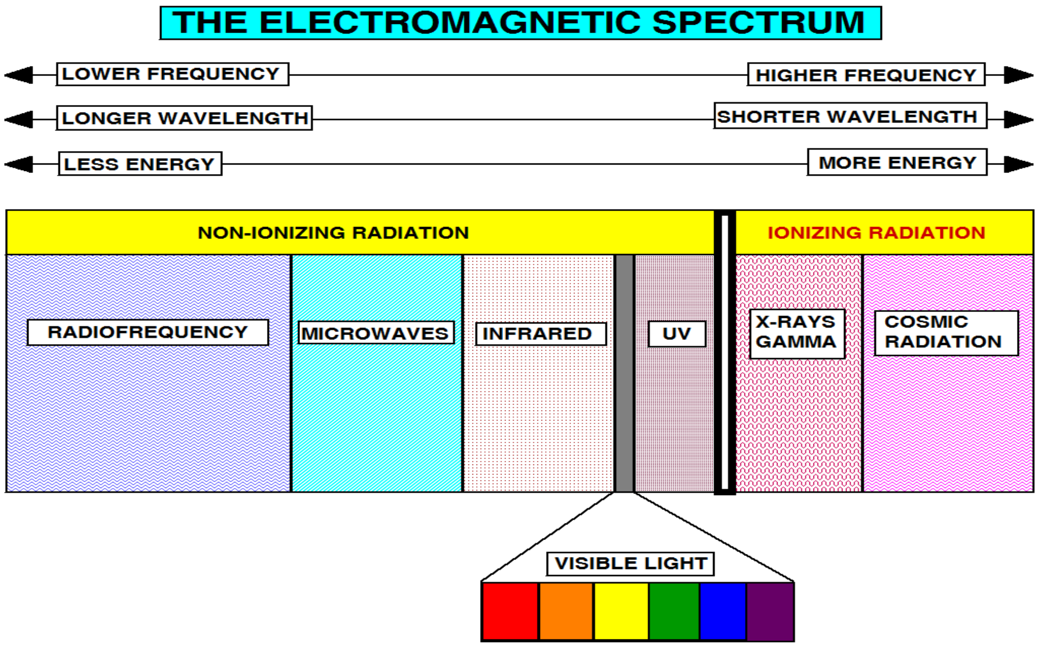


Fig. 1.1: Properties of Nuclear Radiations [1] - [3]

1.1.2.1 Non ionizing radiation

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight. The energy levels of these types of radiation are less than 10eV. Examples of non-ionizing radiation include Microwaves, Visible light, Radio waves, TV waves, Ultraviolet radiation (except for the very shortest wavelengths). The different types of non- ionization radiation are shown in Fig. 1.1 [1] - [3].

1.1.2.2 Ionizing radiation

Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials. The energy levels of these types of radiation are more than 10eV. There are several types of ionizing radiation are explained below [1] - [3]:

1.1.2.2.1 Alpha radiation (α)

Alpha radiation consists of alpha particles that are made up of two protons and two neutrons each and that carry a double positive charge. Due to their relatively large mass and charge, they have an extremely limited ability to penetrate matter. Alpha radiation can be stopped by a piece of paper or the dead outer layer of the skin. Consequently, alpha radiation from nuclear substances outside the body does not present a radiation hazard [1] - [4]

1.1.2.2.2 Beta radiation (β)

Beta radiation consists of charged particles that are ejected from an atom’s nucleus and that are physically identical to electrons. Beta particles generally have a negative charge, are very small and can penetrate more deeply than alpha particles. However, most beta radiation can be stopped by small amounts of shielding, such as sheets of plastic, glass or metal. When the source of radiation is outside the body, beta radiation with sufficient energy can penetrate the body’s dead outer layer of skin and deposit its energy within active skin cells [1] - [4].

1.1.2.2.3 Photon radiation (gamma [γ] and X-ray)

Photon radiation is electromagnetic radiation. There are two types of photon radiation of interest for the purpose of this document: gamma (γ) and X-ray. Gamma radiation consists of photons that originate from within the nucleus, and X-ray radiation consists of photons that originate from outside the nucleus, and are typically lower in energy than gamma radiation [1] - [4].

1.1.2.2.4 Neutron radiation (n)

Apart from cosmic radiation, spontaneous fission is the only natural source of neutrons (n). A common source of neutrons is the nuclear reactor, in which the splitting of a uranium or plutonium nucleus is accompanied by the emission of neutrons. The neutrons emitted from one fission event can strike the nucleus of an adjacent atom and cause another fission event, inducing a chain reaction.

Alpha particles are capable to travel several centimeters in air but it cannot penetrate a sheet of paper. Beta rays are little more powerful than alpha particle. It can penetrate the paper but it can be stopped by the Al sheet. Gamma rays have much stronger penetrating power and required thick concrete to stop. Lead or other special concrete or composite materials can be used to block them. Neutron particles have much stronger penetrating power. To stop neutron special concrete, wax, rubber and hydrogenous materials are mostly used. A summary of properties of nuclear radiation, penetration power and emission of different types of ionization radiation are shown in Table-1.1, Fig. 1.2 and Fig. 1.3 respectively [1] - [4].

Table-1.1: Properties of Nuclear Radiations [1] - [4]

Radiation	Mass (u)	Charge	Range in air	Range in tissue
Alpha	4	+2	0.03 m	0.04 mm
Beta	1/1840	-1 +1 (positron)	3.00 m	5 mm
X and Gamma Ray	0	0	Very large	Through body
Fast neutron	1	0	Very large	Through body
Thermal neutron	1	0	Very Large	0.15 m

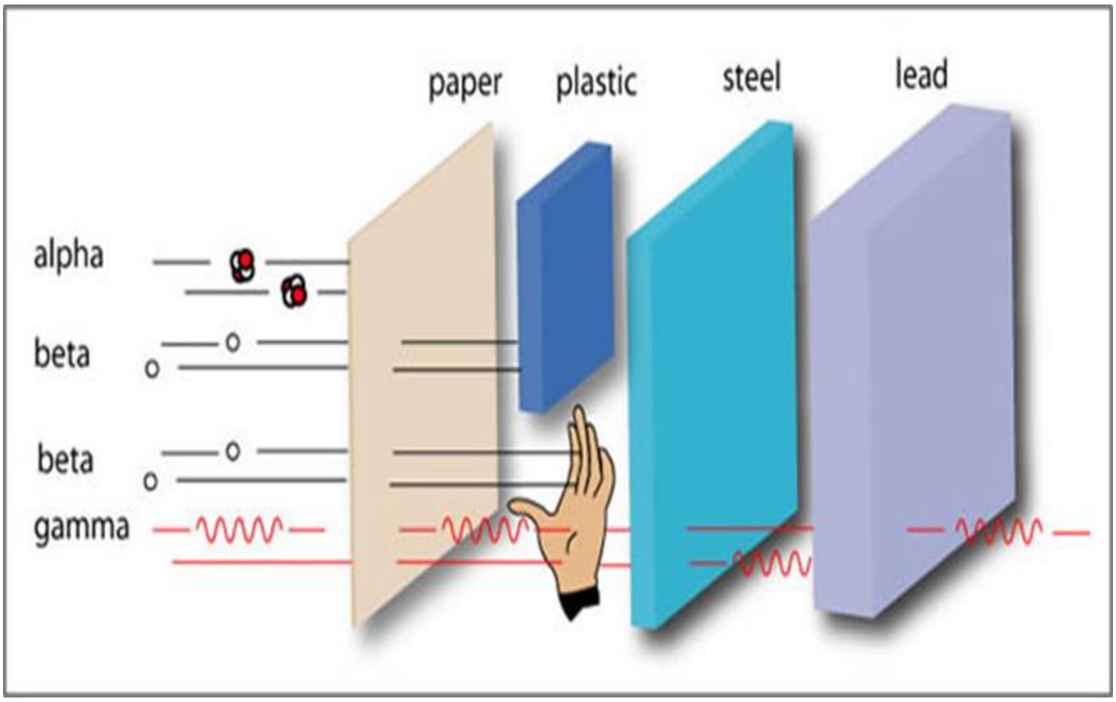


Fig. 1.2: Penetration Power of Ionization Radiation [1] - [4]

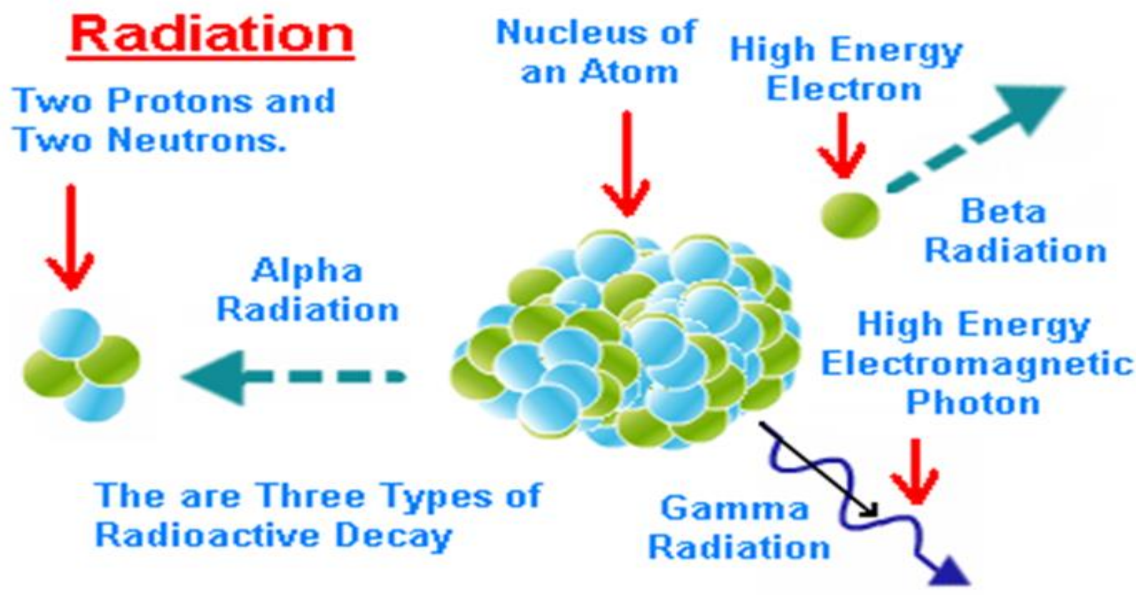


Fig. 1.3: Different Types of Ionization Radiations [5]

1.1.2.3 Sources of ionization radiation

1.1.2.3.1 Natural sources of ionizing radiation

Radiation has always been present and is all around us in many forms. Life has evolved in a world with significant levels of ionizing radiation, and our bodies have adapted to it. Many radioisotopes are naturally occurring, and originated during the formation of the solar system and through the interaction of cosmic rays with molecules in the atmosphere. Tritium is an example of a radioisotope formed by cosmic rays' interaction with atmospheric molecules. Some radioisotopes such as uranium and thorium that were formed when our solar system was created have half-lives of billions of years, and are still present in our environment. Background radiation is the ionizing radiation constantly present in the natural environment [6] - [12].

1.1.2.3.2 Cosmic radiation sources

The earth's outer atmosphere is continually bombarded by cosmic radiation. Usually, cosmic radiation consists of fast moving particles that exist in space and originate from a variety of sources, including the sun and other celestial events in the universe. Cosmic rays are mostly protons but can be other particles or wave energy. Some ionizing radiation will penetrate the earth's atmosphere and become absorbed by humans which results in natural radiation exposure [6] - [12].

1.1.2.3.3 Terrestrial radiation sources

The composition of the earth's crust is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium and thorium which, in the process of natural decay, will release small amounts of ionizing radiation. Uranium and thorium are found essentially everywhere. Traces of these minerals are also found in building materials so exposure to natural radiation can occur from indoors as well as outdoors [6] - [12].

1.1.2.3.4 Artificial (man-made) sources

People are also exposed to man-made radiation from medical treatments and activities involving radioactive material. Radioisotopes are produced as a by-product of the operation of nuclear reactors, and by radioisotope generators like cyclotrons. Many man-made radioisotopes are used in the fields of nuclear medicine, biochemistry, the manufacturing industry and agriculture [6] - [12].

1.1.2.3.5 Medical sources

Radiation has many uses in medicine. The best-known application is in X-ray machines, which use radiation to find broken bones or to diagnose diseases. X-ray machines are regulated by Health Canada and provincial authorities. Another example is nuclear medicine, which uses radioactive isotopes to diagnose and treat diseases such as cancer. A gamma camera is one piece of medical equipment commonly used in diagnosis .The CNSC regulates these applications of nuclear medicine, as well as related equipment. It also licenses reactors and particle accelerators that produce isotopes destined for medical and industrial applications [6] - [12].

1.1.2.3.6 Industrial sources

Radiation has various industrial uses, which range from nuclear gauges used in the building of roads to density gauges that measure the flow of material through pipes in factories. Radioactive materials are also used in smoke detectors and some glow-in-the dark exit signs, as well as to estimate reserves in oil fields. Other applications include sterilization, which is performed using large, heavily shielded irradiators. Industrial activities are licensed by the Canadian Nuclear Safety Commission (CNSC) [6] - [12].

1.1.2.3.7 Nuclear fuel cycle sources

Nuclear power plants (NPPs) use uranium to produce a chain reaction that produces steam, which in turn drives turbines to produce electricity. As part of their normal activities, NPPs release small quantities of radioactive material in a controlled manner to the surrounding environment. These releases are regulated to ensure doses to the public are well below regulatory limits. Uranium mines, fuel fabrication plants and radioactive waste facilities are also licensed so the radioactivity they release that can contribute to public dose can be controlled by the Canadian Nuclear Safety Commission. Presently 31 countries are generating by nuclear fuel and 2 countries are going to establish nuclear power plants. Soonest these 2 countries will generate power from nuclear fuel. At present 11% of global power is generated by nuclear fuel. As on today, in 31 countries 442 nuclear power plant units are installed electric net capacity of about 384 GW in operations and 66 plants with an installed capacity of 65 GW are in 16 countries under construction. Globally, 11% of total power is generated from nuclear fuel. The situation is increasing the ionization radiation in the environment [6] – [12].

1.1.2.3.8 Atmospheric testing sources

The atmospheric testing of atomic weapons from the end of the Second World War until as late as 1980 released radioactive material, called fallout, into the air. As the fallout settled to the ground, it was incorporated into the environment. Much of the fallout had short half-lives and no longer exists, but some continues to decay. People and the environment receive smaller and smaller doses from the fallout every year. Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. They are produced by the hottest and most energetic objects in the universe, such as neutron stars and pulsars, supernova explosions, and regions around black holes. On earth, gamma waves are generated by nuclear explosions, lightning, and the less dramatic activity of radioactive decay [6] - [12].

1.1.2.3.9 Main ionization radiation sources in Bangladesh

During the last three decades, Bangladesh Atomic Energy Commission (BAEC) has undertaken an elaborate R & D program covering a wide spectrum of activities in different fields of radiation processing research and its technological applications. The major nuclear facilities of Bangladesh are:

i) 03 MW TRIGA MARK-II Research Reactor,

ii) 03 MeV Van de Graaff Accelerator,

iii) 14 MeV Neutron Generator,

iv) 90 kCi Co-60 Gamma Source,

v) 350 kCi Co-60 Gamma Source with its present capacity 120kCi. [13].

1.1.2.4 Applications of ionization radiation

Although scientists have only known about radiation since the 1890s, they have developed a wide variety of uses for this natural force. Today, to benefit humankind, radiation is used in medicine, academics, and industry, as well as for generating electricity. In addition, radiation has useful applications in such areas as agriculture, archaeology (carbon dating), space exploration, law enforcement, geology (including mining), and many others. However, the use and sources of radiation are shown in Fig-1.4.

i) Medical Uses,

ii) Academic and Scientific Applications,

iii) Industrial Uses,

iv) Nuclear Power Plants,

v) Agricultural applications,

vi) Applications in consumer products,

vii) Archaeological application,

viii) Destructive uses of the atomic bomb [14] - [15] .

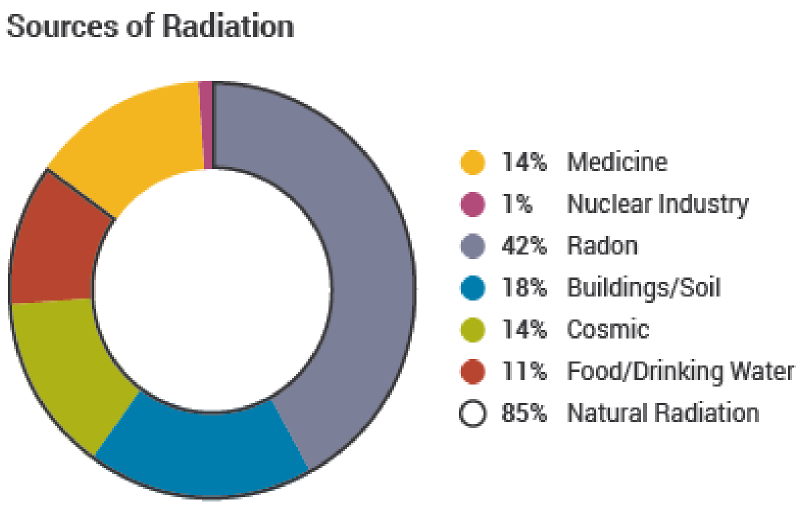


Fig. 1.4: Applications of Ionization Radiation [14] - [15]

1.2 Radiation Exposure

Gamma ray exposure is measured in mRem. One-time exposure on a daily basis for most people is 25 mRem at most, while people working in radioactive environments with adequate protection may absorb up to 5,000 mRem at once. Anything more than 10,000 mRem is considered dangerous even if exposure is short. Beyond this point, health concerns become immediate and the risk of illness is very high. These numbers reflect studies into populations that survived the Japan bombings of WW-II. Unlike other types of radiation, gamma rays travel so fast they pass through the entire body very quickly, affecting all organs and tissue. Their ionizing patterns mean exposed body parts can become ionized, their properties changed even after the gamma radiation itself has long evaporated [2], [6], [15] - [17].

1.2.1 Exposure through Inhalation

Most of the variation in exposure to natural radiation results from inhalation of radioactive gases that are produced by radioactive minerals found in soil and bedrock. Radon is an odorless and colorless radioactive gas that is produced by the decay of uranium. Thoron is a radioactive gas produced by the decay of thorium. Radon and thoron levels vary considerably by location depending on the composition of soil and bedrock. Once released into the air, these gases will normally dilute to harmless levels in the atmosphere but sometimes they become trapped and accumulate inside buildings and are inhaled by occupants. Radon gas poses a health risk not only to uranium miners, but also to homeowners if it is left to collect in the home. On average, it is the largest source of natural radiation exposure. For more information on radon, read the CNSC's Radon and Health document at nuclearsafety.gc.ca or visit Health Canada's Web site to learn more about the means to control it in your home [2], [6], [15] - [17].

1.2.2 Exposure through Ingestion

Trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation.

Naturally occurring radioactive isotopes, such as potassium-40 and carbon-14, have the same chemical and biological properties as their non-radioactive isotopes. These radioactive and non-radioactive elements are used in building and maintaining our bodies. Natural radioisotopes continually expose us to radiation and are commonly found in many foods, such as Brazil nuts [2], [6], [15] - [19].

1.2.3 Health Effect through Radiation Exposure

The mission of Environmental Protection Agency's (EPA) Radiation Protection Program is to protect human health and the environment from unnecessary exposure to radiation. It will provide basic information about the health effects of radiation. EPA uses current scientific understanding of the health effects of radiation exposure to create protective standards and guidance.

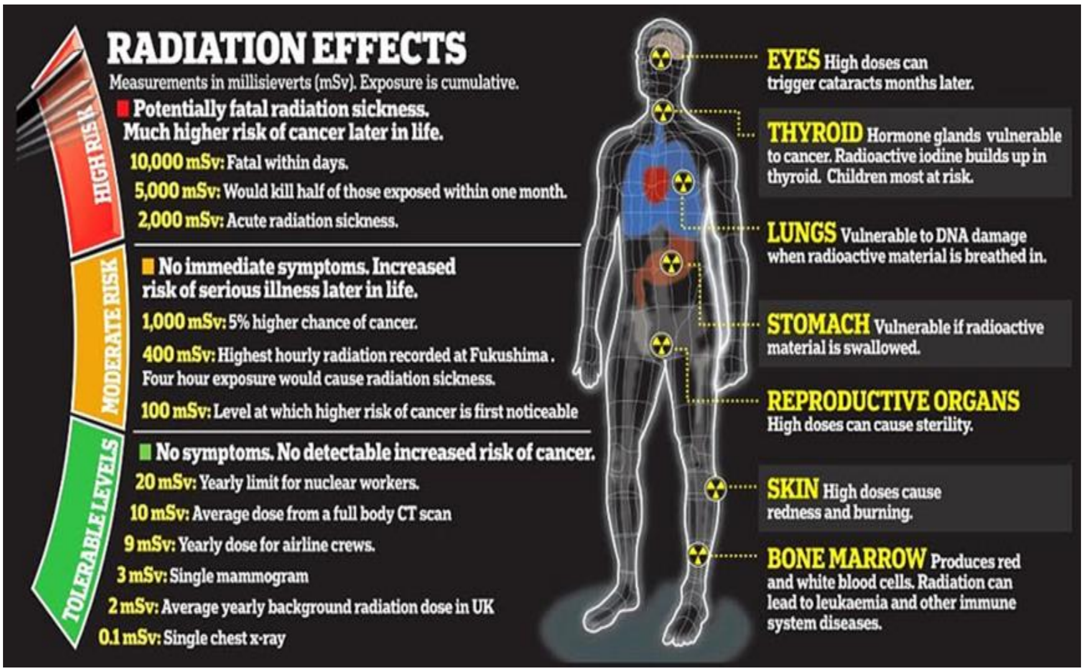


Fig. 1.5: Effect of Radiation on Human Body Tissues [15] - [19].

Ionizing radiation has sufficient energy to cause chemical changes in cells and damage them. Some cells may die or become abnormal, either temporarily or permanently. By damaging the genetic material (DNA) contained in the body's cells, radiation can cause cancer. Fortunately, our bodies are extremely efficient at repairing cell damage. The extent of the damage to the cells depends upon the amount and duration of the exposure, as well as the organs exposed. A very large amount of radiation exposure (acute exposure) can cause sickness or even death within hour or days. Such acute exposures are extremely rare [2] – [6], [15] – [19].

The effect of ionization (Gamma) radiation on human body tissues are shown in Fig. 1.5 and Radiation doses, dose limits and potential health effects are shown in Table 1.2.

Table-1.2: Radiation Doses, Dose Limits and Potential Health Effects [2] – [6], [16] - [19]

Dose	Limit or Health Effect
More than 5,000 mSv	Dose that may lead to death when received all at once.
1,000 mSv	Dose that may cause symptoms of radiation sickness (symptoms include tiredness and nausea) if received within 24 hours.
100 mSv	Lowest acute dose known to cause cancer
30–100 mSv	Radiation dose from a full-body computed axial tomography (CAT) scan.
50 mSv	Annual radiation dose limit for nuclear energy workers.
1.8 mSv	Average annual Canadian natural background dose.
1 mSv	Annual public radiation dose limit in Canada.
0.1–0.12 mSv	Dose from lung X-ray.
0.01 mSv	Dose from dental X-ray
0.01 mSv	Average annual dose due to air travel.

1.3 Gamma Radiation

Gamma radiation is one of the three types of natural radioactivity. It is the product of radioactive atoms. Gamma rays are electromagnetic radiation, like X-rays. The other two types of natural radioactivity are alpha and beta radiation, which are in the form of particles. Gamma rays are the most energetic form of electromagnetic radiation, with a very short wavelength of less than one-tenth of a nanometer. Depending upon the ratio of neutrons to protons within its nucleus, an isotope of a particular element may be stable or unstable. When the binding energy is not strong enough to hold the nucleus of an atom together, the atom is said to be unstable. Atoms with unstable nuclei are constantly changing as a result of the imbalance of energy within the nucleus. Over time, the nuclei of unstable isotopes spontaneously disintegrate, or transform, in a process known as radioactive decay. Various types of penetrating radiation may be emitted from the nucleus and/or its surrounding electrons. Nuclides which undergo radioactive decay are called radionuclides. Any material which contains measurable amounts of one or more radionuclides is a radioactive material [20] – [21].

Gamma rays from radioactive decay are in the energy range from a few Kilo electron volts (KeV) to approximately 8 Mega electron Volts (MeV), corresponding to the typical energy levels in nuclei with reasonably long lifetimes. The energy spectrum of gamma rays can be used to identify the decaying radionuclides using gamma spectroscopy [16] - [17]. Gamma rays are created by nuclear decay, while in the case of X-rays, the origin is outside the nucleus. In astrophysics, gamma rays are conventionally defined as having photon energies above 100 keV and are the subject of gamma ray astronomy, while radiation below 100 keV is classified as X-rays and is the subject of X-ray astronomy. This convention stems from the early man-made X-rays, which had energies only up to 100 keV, whereas many gamma rays could go to higher energies. A large fraction of astronomical gamma rays are screened by Earth's atmosphere. Gamma rays are ionizing radiation and are thus biologically hazardous. Due to their high penetration power, they can damage bone marrow and internal organs. Unlike alpha and beta rays, they pass easily through the body and thus pose a formidable radiation protection challenge, requiring shielding made from dense materials such as lead or concrete [20] – [21].

1.3.1 Sources of Gamma Radiation

Gamma emitting radionuclides are the most widely used radiation sources. The three radio nuclides are most useful:

(i) Cobalt- 60

(ii) Cesium-137

(iii) Technetium-99m

Other than above mentioned sources soil and water, and therefore food sources, are primary vectors for gamma ray exposure, although levels are typically very low and do not pose a major risk. Most other sources are medical or industrial in nature. The general public may be exposed to gamma radiation through the use of medical scans and other investigative technology. Of course, nuclear detonation and accidents can be large-scale sources. [22] – [24].

1.3.2 Gamma Radiation Plants around the World

The total dataset of the directory currently contains 83 organizations which operate 123 irradiation units in 45 Member States. Lists of these Member States (MS) and their regional classification which is partly based on the IAEA classification system Gamma radiation plants around the world are shown in Table 1.3. The number in parenthesis following the name of Member State indicates the number of irradiation units operating there.

Table -1.3: Gamma Radiation Plants Around the World [22] – [24]

Region (number of MS)	Participating Member States
Africa (3 Member States)	Egypt(1), Ghana(1), South Africa(3) Regional total = 5 irradiation units
East Asia and the Pacific (12)	Australia(2), Bangladesh(2), China(21), India(3), Indonesia(1), Japan(2), Korea (Republic of)(1), Malaysia(4), Philippines(1), Taiwan(2), Thailand(4), Vietnam(1) Regional total = 44 irradiation units
Europe (18)	Austria(1), Belgium(2), Bulgaria(1), Croatia(1), Germany(3), Greece(1), Hungary(3), Ireland(1), Italy(2), Portugal(1), Romania(1), Serbia & Montenegro(1), Sweden(1), Switzerland(1), Netherlands(3), Turkey(2), Ukraine(1), United Kingdom(5) Regional total = 31
Latin America (5)	Argentina(1), Brazil(4), Chile(1), Mexico(2), Peru(1) Regional total = 9 irradiation units
North America (2)	Canada(1), United States of America(28) Regional total = 29 irradiation units
West Asia (5)	Iran(1), Israel(1), Jordan(1), Saudi Arabia(1), Syria(1) Regional total = 5 irradiation units

1.3.3 Largest Gamma Source in Bangladesh

The Co-60 Gammas sources are used for this research purpose as a highly radioactive source for visual monitor of the radiation doses for highly radioactive source and the real situation of the source room during its operational and non-operational conditions. Radioactive Co-60 slugs is placed inside the inner capsule. The inner cap-slug is kept in the source pencil then put into the source module. Several source modules were positioned in the source rack which was put into the pool water. The Co-60 Gamma

Source is shown in the Fig. 1.6 and The Co-60

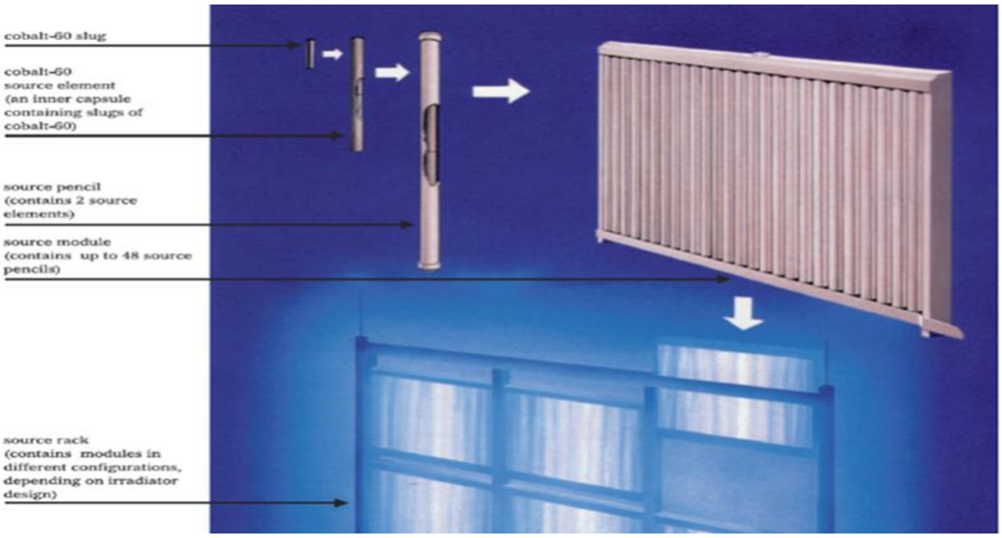


Fig. 1.6: Co-60 Gamma Source and Source Rack at AERE, IRTP

Gamma radiation plant shown in Fig. 1.7 is the highest Gamma radiation source in Bangladesh which is located at IRPT, Savar, Dhaka, Bangladesh respectively [25] – [27].

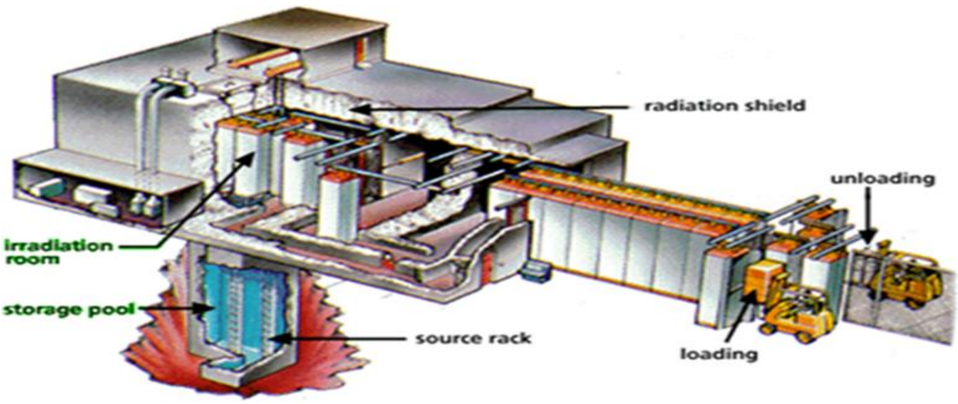


Fig. 1.7: Co-60 Gamma Plant Used in Research [25] - [27]

1.3.4 Characteristics of Gama Radiation

Key features of gamma rays are summarized in following few points:

i) Gamma rays are high-energy photons.

ii) The same photons as the photons forming the visible range of the electromagnetic spectrum – light.

iii) Photons have no mass and no electrical charge; therefore they cannot directly ionize matter, neither gamma ray.

iv) Despite this fact, gamma rays ionize matter via indirect ionization.

v) Although a large number of possible interactions are known, there are three key interaction mechanisms with matter named Photoelectric effect, Compton scattering and Pair production

vi) Gamma rays travel at the speed of light and they can travel thousands of meters in air before spending their energy.

vii) Since the gamma radiation is very penetrating matter, it must be shielded by very dense materials, such as Lead or Uranium.

viii) The distinction between X-rays and gamma rays is not so simple and has changed in recent decades. According to the currently valid definition, X-rays are emitted by electrons outside the nucleus, while gamma rays are emitted by the nucleus. Gamma rays frequently accompany the emission of alpha and beta radiation [28] – [30].

1.4 Sources of Cobalt

1.4.1 Natural Sources

Stable cobalt, Co-59, occurs in the earth's crust at a concentration ranging from 2 $\mu g.g^{-1}$ in carbonate rocks to 25 $\mu g.g^{-1}$ in igneous rocks. Its principal ores are Sulphide or arsenic Sulphide ores (Obaltite, Smaltite and Linnaeite). Cobalt is used to make many alloys with applications in the electrical and aeronautical industries. It is also used in making permanent magnets, refractory metals and pigments and as an additive in agriculture. Cobalt is present in ocean water at a concentration ranging from approximately 0.5 to 10 ng per liter. Off the coasts of England, it occurs in North Sea surface coastal water at an approximate concentration of 2 to 50 ng. Its average concentration is 1 $\mu g.L^{-1}$ in fresh water and from 0.4 to 2.0 $ng.m^{-3}$ in air. The chief natural sources of the stable isotope are wind erosion, sea spray, volcanic eruptions and forest fires. The radioactive isotopes are man-made. It is an essential trace element, particularly as the nucleus of vitamin B12, which is a coenzyme in many enzyme reactions including those of hematopoiesis [31] – [33].

1.4.2 Artificial Sources

Cobalt-60 is a neutron activation product formed from structural materials in nuclear reactors. It can also be produced industrially through neutron activation of stable cobalt. It is used in nuclear medicine. Radioactive isotopes of cobalt are found in nuclear power reactors. They currently account for 39% of total gamma activity discharged as liquid effluent, with a total of 2.7 x 10^9 Bq of ^{58}Co and 3.5 x 10^9 Bq of ^{60}Co from all EDF (Electricity de France) plants in 2007. The period from 2003 to 2007 saw a 72% drop in ^{58}Co discharge and a 35% drop for ^{60}Co in 2009. In spent fuel reprocessing facilities, cobalt comes from fuel assemblies on which activation products have bound as oxides. ^{60}Co is among the radionuclides also found in nuclear waste [31] – [33].

1.4.3 Radionuclide's of Cobalt

Radionuclides of Cobalt, its atomic mass, natural abundance and half-life are shown in Table 1.4.

Table -1.4: Radionuclide's of Cobalt [34], [35] – 38]

Nuclide	^{59}**Co**	^{56}**Co**	^{57}**Co**	^{58}**Co**	^{60}**Co**
Atomic Mass	58.933	55.940	56.936	57.936	59.934
Natural Abundance	100%	0%	0%	0%	0%
Half Life	Stable, non-radioactive	77 days	270 days	71.3 days	5.27 years

1.5 Significance of the Present Research

Ionization radiation is the main concern to use radiation energy. Radiation detection, measurement and monitoring are an indispensable task for any radiation facility. The professional radiation workers cannot go near to highly radioactive sources. [1] - [4]. IOT or Internet of Things is a system of connecting physical device or sensors and everyday objects with computer based internet. This study intended to identify the poisonous gas and radiation leakage by using gas and radiation sensors and connecting them to IOT [38] - [39]. At present robotic technologies are used for these purposes. But the robots are made with sophisticated technology and high cost, not user friendly, difficult to move from one country to another country due to restricted by the country law, safety and security [40] - [41].

Developing a Gamma camera can visualize the gamma-ray intensity distribution in real time. The Gamma rays intensity distributions were successfully visualized. Prominent Gamma rays radiation was found from the penetration holes, which connect the inside and outside of the primary containment vessel. From this result, it was also found that shielding the penetration holes improved the work environment during decontamination and cleanup activities. These results indicate the Gamma camera can contribute to decontamination work and radiation exposure reduction for workers. This developed Gamma camera which can visualize the gamma-ray intensity distribution in real time and analyze the emitting radionuclides without any cooling system. The energy resolution of Cs-137 was found good enough to separate it from Cs-134 spectroscopically. By using the developed Gamma camera highly radioactive source can be visually monitored with the help display device but it is too much costly. Developing country may not be able to afford the cost [40] - [41].

Mobile robot had been developed to use for remote radiation measurement, however due to exposure of high level of absorbed dose, robot's component's durability was doubtful. The developed robot consists of a wheeled chassis and the radiation sensor and telescopic mechanism. In the radiation sensor and the telescopic mechanism, radiation sensor mounting at the end of the telescopic assembly, has been used as radiation sensor. The entire system can be rotated in elevation and azimuth. The developed robot is controlled by robot controlled software. This device was successful in radiation measurement without risking unwanted personnel radiation exposure. This system is expensive and controlled by the sophisticated technology. Recently, another researcher designed radiation measurement device using Geiger Muller detector, microcontroller and smartphone to display the result of radiation measurement. However, it cannot monitor the highly radioactive source and the real situation of the source room [42] - [47], [65].

After updated through previous research papers mentioned above, this research has been carried out to find a simple, affordable and effective alternative device to use for the same purpose. The researcher is highly motivated to develop such a device which does not have the limitations mentioned above. The developed device may be helpful for the developing countries of the world with the following benefits:

i) Safe entrance of radiation workers

Without putting appropriate Personal Protective Equipment (PPE) the radiation workers cannot inter into the highly radioactive source room for maintenance or any other purpose. The highly radioactive sources also need to inspect in case of any need or accidental issue. It is very difficult to handle the highly radioactive source for radiation workers due to health concern.

ii) Minimize the use of Robotic System

Robots are used for safe handling of radioactive sources by the radiation workers. However, robots are made of sophisticated and expensive technologies which are administratively and technically very difficult to move from one country to another.

iii) Least possible use of Gamma Ray Protection Camera

Also radiation protective (Gamma protective) camera is used for continuous monitoring the real situation of highly radioactive source position and real situation of source room. Gamma ray protective cameras are also very expensive and sophisticated. To overcome the above mentioned limitations this research has been carried out under the titled "Development of Electronic Device for Detecting, Measuring and Visual Monitoring of Radiation Doses for Highly Radioactive Sources [43] – [48].

1.6 Specific Aim and Objectives of the Research

The specific aim and objectives of this research is to develop an electronic device for detecting, measuring and visual monitoring of radiation doses for highly radioactive sources and its position with the help of a computer monitor by which causes of unexpected situation can be minimized. However, the main objectives of the research are:

i) In this research electronic device for detecting, measuring and visual monitoring of radiation doses for highly radioactive sources have been developed.

ii) To analyze the dose level in Gamma radiation source room near to Gamma radiation source (Co-60) by using Amber and red Perspex to achieve the deviation of experimental results within the acceptable limits ($\leq \pm 2.00\%$).

iii) To investigate the effectiveness of the developed device experimentally.

1.7 Organization of the Thesis

The dissertation has been configured into six chapters.

i) Introduction

The chapter begins with a General Introduction, radiation exposure, Gamma radiation; Sources of Cobalt and significance of present research. The objectives of the Thesis works and organization of the Thesis are also included.

ii) Literature Review

In this chapter, literature surveys from various published papers which are reviewed closely related to this research works.

iii) Methodology and Experimental Procedure

This chapter describes step by step experimental procedure along with the required materials, details of laboratory equipment used to fabricate and experiments.

iv) Experimental Results and Observation

In this chapter it is described briefly on the results and discussion of "Development of Electronic Device for Detecting, Measuring and Visual Monitoring of Radiation Doses for Highly Radioactive Sources."

v) Discussion on Results and Relevance

In this chapter discuss on the results found in the research and relevance to the previous works to validate the experiments.

vi) Conclusion and Recommendation for Future Studies

This chapter highlights some concluding remarks on present work and gives recommendation for future research on related to "Development of Electronic Device for Detecting, Measuring and Visual Monitoring of Radiation Doses for Highly Radioactive Sources." It includes also the requirement of list of references to carry out the thesis works and appendix.

Chapter-2

Literature Review

2.1 History of Invention of Radiation

The chronological histories of invention of radiation are mentioned below:

i) In 1895 X-rays were discovered by W. Roentgen.

ii) In 1896, the French physicist Antoine-Henri Becquerel found that certain substances, (such as salts of uranium) produce invisible penetrating energy from an unknown source. This phenomenon was termed as radioactivity.

iii) 1898 the French marriage of Pierre and Marie Curie in their research found the existence of another element higher than the activity of uranium; in honor to his country they called it polonium. They also discovered a second element called radium.

iv) In 1944, Father of Nuclear Chemistry, Dr. Otto Hahn, the German chemist and pioneer in the fields of radioactivity and radiochemistry who won the Nobel Prize in Chemistry for the discovery and the radiochemical proof of nuclear fission.

v) In 1939-1945, Robert Oppenheimer is called the "Father of the Atomic Bomb" for leading the Manhattan Project, the program that developed the first nuclear weapon during 2nd World War.

vi) On December 20, 1951, at the Experimental Breeder Reactor EBR-I in USA, for the first time electricity - illuminating four light bulbs - was produced by nuclear energy. EBR-I was not designed to produce electricity but to validate the breeder reactor concept.

vii) On June 26, 1954 in Russia, the nuclear power plant APS-1 with a net electrical output of 5 MW was connected to the power grid, the world's first nuclear power plant that generated electricity for commercial use.

viii) On August 27, 1956 the first commercial nuclear power plant, Calder Hall-1 in England, with a net electrical output of 50 MW was connected to the national grid [48] – [52].

2.2 Review Previous Research Papers

The objectives of this literature review are to highlight the previous research works related to this research. The purposes may also be considered to enhance the knowledge on the relevance study. Massive works had been carried out including robotic system by the nuclear scientists in the world for detecting, measuring and monitoring the radiation from different sources. Every scientist achieved desire outcome from their research activities and they were given some future recommendation on research and invention. A significant numbers of relevant literatures have been studied in order to do successful completion of the study and to emphasize the relevance with the present study. This background information shows some new path of research and invention.

A. E. Waltar [14] worked on "The Medical, Agricultural, and Industrial Applications of Nuclear Technology." In this research it is explained the application of nuclear energy in the field of Medical, Agriculture and industrial appliances. Most of people are aware of the use of nuclear fuel and technologies to the production of electricity by commercial nuclear power plants. Bu many of them are not known that the impact of this technology is much higher for medicine, agriculture, and modern industry substantially improved by the harnessing of radioisotopes, and new applications continue to make our healthy and confortable life. In the paper it is also clearly written that the peaceful use of nuclear atoms for the human comfort of the world. The positive impacts that have been achieved in the past 50 years are nothing short of astonishing. Successful endorsement of food irradiation alone could easily double the impacts achieved to date. Such non-power applications remain a challenging and rewarding field for the best and brightest of our next generation of radiation scientists and engineers.

D. R. McAlister, Ph.D. [26] worked on, “Gamma Ray Attenuation Properties of Common Shielding Materials”. In this research different types of materials used to reduce the amplitude of gamma rays. Researcher used different types of shielding materials including composite materials. It is essential to provide shielding to reduce direct exposure to gamma radiation. Common shielding materials are with limited portability, such as high density concrete, lead bricks, steel plates and cooling pools filled with water. The composite materials are mostly popular as shielding materials due to its special characteristics. During evaluation the merits of these composite materials relative to the more classic forms of shielding, it is important to understand the basic principles that lead to reduction of amplitude of gamma ray. Simply, shielding of gamma radiation occurs through the interaction of the gamma radiation with matter. The extent to which gamma radiation is reduced is dependent upon the energy of the incident gamma radiation, the atomic number and density of the elements in the shielding material, and the thickness of the shielding. The reduction of amplitude of gamma radiation can be achieved by using varieties of substances. Reduction of amplitude is possible for gamma radiation using materials especially for a specific type of application. Using the knowledge and considering the physical, chemical and fiscal constraints it is possible to develop appropriate type of shielding. The uses of various types of materials for shielding are very much clear from the paper.

Paulo de S. S. *et al* [36] worked on “C-188 Co-60 Sources Installation and Source Rack Loading Optimization Processes in Gamma Irradiation facilities.” The research was carried out on the Gamma source carry, handling and installation process for multipurpose use of Gamma facility at the Nuclear and Energy Research Institute. This facility uses usually designed and made by Nordion and the model is C-188. C-188 double-encapsulated radioactive Cobalt-60 sources kwon as pencils from manufactures outside of country. The Gamma source has been used in radiation processing for disinfection and sterilization of health care. It is also used for disposable medical products as well to support research studies on modification of physical, chemical and biological properties of several materials. The activity of the cobalt sources decays into a stable nickel isotope with a half-life 5.27 years. It indicates the annual loss is 12.3%. Additional pencils of Cobalt-60 are added periodically to the source rack to maintain the required capacity or installed activity of the facility. The sources are carried in a container; it is required to remove the pencils from inside deep pool water with source geometry in a predetermined diagram. The dose variation can be reduced placing the higher activity source pencils near the periphery of the source rack. In this work are presented the procedures for perform the boiling leaching tests applied to the container, the Cobalt-60 sources installation, the loading processes and the source rack loading optimization. It is also explained in the paper that the process require six radiological security standards. It shows the complexity of the loading process to ensure that there is no risk for the currently operations, despite of the apparent simplicity of the process. This work showed a description of the loading process, in such way that can be a reference to an eventual installation manual for the cobalt-60 radioactive sources. The installation of Co-60 must be handled with special care as it is highly radioactive.

A. Kannapan *et al* [38] worked on “Toxic Gas and Radiation detection monitoring using IOT.” This research was carried out for the detecting radiation detection monitoring in hazardous and chemical industries giving more emphasize on those of developing countries where safety and environment are not given priority. IOT or Internet of Things is a system of connecting physical device or sensors and everyday objects with computer using internet. This study intended to identify the poisonous gas and radiation leakage by using gas and radiation sensors and connecting them to IOT. The system developed by using Wi-Fi module transmitting and receiving information at 54 Mbps (Mega bite per second). The researcher fabricated the circuit by using Arduino Uno r3, MQ2 gas sensor, MQ7 gas sensor, MQ135 gas sensor, Radiation count sensor, Alarm, Temperature sensor lm35, Wi-Fi module, IOT module, LCD display and Website. The MQ2 gas sensor can sense methane, MQ7 can detect Carbon Monoxide from 20 to 200 PPM, MQ135 can detect ammonia. Temperature sensor lm35 detects temperature in closed rooms; Radiation count sensor can detect radiation. In this research an intelligent system was programmed to detect and monitor poisonous gas and radiation integrating Arduino controller and IOT. However, no visual monitoring the real situation during incident was not possible from the developed system. Also the radiation absorbed dose measurement could not be possible from the developed system.

O. Koichi *et al* [40] carried out research works on “Development of a gamma camera to image radiation fields.” Gamma camera had been developed successfully for monitoring and measurement of radioactive contamination and confirmation of the decontamination effects which are important for the recovery from the nuclear accident at the Fukushima Dai-ichi Nuclear Power Plant. In the study developed a Gamma camera which can visualize the gamma-ray intensity distribution in real time.

Experiments were conducted to investigate its performance. In addition, field tests were conducted in the Fukushima Dai-ichi Nuclear Power Plant. The Gamma-ray intensity distribution was successfully visualized. Prominent Gamma-ray radiation was found from the penetration holes, which connect the inside and outside of the primary containment vessel. From this result, it was also found that shielding the penetration holes improved the work environment during decontamination and cleanup activities. These results indicate the Gamma camera can contribute to decontamination work and radiation exposure reduction for workers. This developed Gamma camera which can visualize the gamma-ray intensity distribution in real time and analyze the emitting radionuclides without any cooling system. The energy resolution of Cs-137 was found good enough to separate it from Cs-134 spectroscopically. It is found that inside some penetration holes turned out to be highly contaminated with Cs-137 and Cs-134, and others were less contaminated. By using the developed Gamma camera highly radioactive source can be visually monitored with the help display device.

U. Sarker *et al* [42] carried out a research works on "Development of a Mobile Robot for Remote Radiation Measurement." In this research a mobile robot had been developed to use for remote radiation measurement, however due to exposure of high level of absorbed dose, robot's component's durability was doubtful. The developed robot consists of a wheeled chassis and the radiation sensor and telescopic mechanism. The wheeled chassis was made of stainless-steel including battery, the electronics systems, the actuator and drives. In the radiation sensor and the telescopic mechanism, radiation sensor GM sensor, mounting at the end of the telescopic assembly, has been used as radiation sensor. The entire system can be rotated in elevation and azimuth. The developed robot is controlled by robot controlled software, a joy stick and button in a desktop computer. This device was successful in radiation measurement without risking unwanted personnel radiation exposure. This system is expensive and controlled by the sophisticated technology. However, it cannot monitor the highly radioactive source and the real situation of the source room.

M. J. Bakari *et al* [43] worked on “Development of a Multi-Arm Mobile Robot for Nuclear Decommissioning Tasks”. In nuclear decommissioning practice there is a risk of exposure of radiation to workers and wider range of environment. Currently the robotic cranes are used in Decommissioning of radiation facilities, like a large power plant. In this research the design of two-arm mobile delivery platform adopted from human arm in maneuverability, scale and handiness to operate in nuclear decommissioning sites. Using Proportional-integral-derivative and proportional-integral-plus control algorithms real time control method was examined. The mobile platform is contained 40 decommissioning robot which can be operated in small and confined space consisting moving vehicle with single five degree of freedom manipulator, Hydraulic tank, controller and remote-control device. The architectural design consists of system structure which defines major component organization and decomposition, second form is the system behavior which defines the inherent dynamics in the system and shows the system behavior during operation and the system layout. Using this robot tasks like pipe manipulation, complex pipe cutting has been performed successfully using single and both arms. This system uses graphical simulations which enables the correctness of the robot. Although, this study focused mainly on complex activity in the decommissioning task using multi arm robot. However, radiation detection, measurement and monitoring were not the scope of this research.

Almgren, S. [60] carried out the research works on “Studies on the Gamma Radiation Environment in Sweden with Special Reference to ^{137}Cs.” Gamma radiation in the environment mainly originates from naturally occurring radionuclides, but anthropogenic radionuclides, such as ^{137}Cs, contribute in some areas. In order to assess population exposure in case of fallout from nuclear weapons or accidents, knowledge and monitoring of external gamma radiation and radionuclide concentrations in the environment is important. 34 sampling sites were established in western Sweden and repeated soil sampling, field gamma spectrometry and dose rate measurements were performed. The variations in the activities between the different sampling occasions were found to be quite large. The paper also explained about nuclear weapon test and Chernobyl nuclear accidental issues. A wide spread deposition of radionuclides was caused by the Chernobyl accident and parts of Sweden were highly affected. Since the latest deposition, ^{137}Cs can still be measured in the environment and contributes to additional doses to people. However, today people generally spend much time in their dwellings, and therefore, the radiation environment indoors is more important for the personal exposure. The additional contribution from the Chernobyl ^{137}Cs fall out in Hille was estimated to be about 0.2 mSv/year. The dose level became higher after the Chernobyl accident. It is also explained in the paper that the people living in concrete houses received on average higher doses from terrestrial radionuclides than those living in wooden houses.

S. Alexander [61] carried out research works on “Use of Concrete as a Biological Shield from Ionizing Radiation.” A research works was carried out on the use of Concrete as a Biological Shield from Ionizing Radiation. The purpose of the shielding is very important to use nuclear energy. The researcher explained some important matter need to keep in mind to use of nuclear energy comes down to three main considerations, safety of use, ability of nuclear energy generation to reduce greenhouse gas emissions and long term sustainability. The paper addressed the problem of safety in the industrial and medical use of nuclear energy, as it is affected by the design and construction of light and heavy weight concrete biological shields from ionizing radiation. In shielding concrete, designed to provide the highest attenuation of gamma and neutron radiation, a delicate balance must be achieved between the proportion of high density aggregate and the ingredients, which contain hydrogen in a form of chemically bound or adsorbed water.

B. P. Gloria *et al* [62] carried out research works on "An Implantable MOSFET Dosimeter had been used for the Measurement of Radiation Dose in Tissue during Cancer Therapy. The functionality, radiation characteristics, and clinical implementation of an implantable MOSFET radiation detector (dosimeter) had been successfully done in this research. The dosimeter is powered by radio frequency telemetry eliminating the need for a power source inside the dosimeter. The data can be accessed telemetrically for each treatment day during the course of therapy. The accuracy and validation can be confirmed by detector. The variation between predicted and measured doses in patients is compared. The paper also explained that patient setup, treatment plan error, and physiologic motion can affect the accuracy of dose. The initial data suggests that the dosimeters can play a useful role in tracking dose discrepancies, both random and systematic, in patients treated with external beam radiation therapy. The implantable dosimeter can be used, together with the current radiation delivery and planning techniques, to optimize radiation treatment on an individual basis. This dosimeter can be used for the individual purpose only.

C. Adam *et al* [63] worked on "Radionuclide fact sheet cobalt-60 and the environment." In this research, described the behavior of the chemical element in the principal compartments of terrestrial and aquatic ecosystems using the following assumptions. Isotope discrimination is negligible, which is verified for most of the elements considered. When the element has stable isotopes, the behavioral analogy between the stable and radioactive isotopes is accepted implicitly, with the understanding that for naturally occurring elements, the chemical form and emission environment for anthropogenic discharge may involve pathways and transfer processes different from those identified for the stable natural element. The radioactive isotope designated in the title of the fact sheet has major radio ecological importance with regard to quantity and persistence in the environment, with other isotopes, both radioactive and stable, being cited as well. The information, which has intentionally been simplified, is intended to reflect the state of knowledge on the topic at the time of publication and provide values for the principal radio ecological parameters normally used to estimate transfer in the environment and in the food chain in particular.

O. Makiko *et al* [64] carried out research works on “Measurement of Individual Doses of Radiation by Personal Dosimeter is Important for the Return of Residents from Evacuation Order Areas after Nuclear Disaster.” In this research it is successfully found that the confirm the availability of individual dose evaluation for the return of residents after the accident at the Fukushima Dai-ichi Nuclear Power Plant (FNPP), we evaluated individual doses of radiation as measured by personal dosimeters in residents who temporarily stayed in Evacuation Order Areas in Kawauchi village, which is partially located within 20 km radius of the FNPP. It is also compared individual doses with the external radiation doses estimated from the ambient dose rates and with doses estimated from the concentrations of radionuclides in the soil around each individual's house. Individual doses were significantly correlated with the ambient doses in front of the entrances to the houses in the backyards and in the nearby fields. The ideas of the dose level are explained in this paper. The individual doses were moderately correlated with external effective doses in the back yards and in the fields however, the individual doses were not significantly correlated with the external effective doses in front of the entrances. In this study it is confirmed that individual doses are low levels even in the evacuation order area in Kawauchi village, and external effective dose levels are certainly decreasing due to the decay of artificial radionuclides and the decontamination of contaminated soil. Long-term follow-up of individual doses as well as internal-exposure doses, environmental monitoring and reconstruction of infrastructure are needed so that residents may return to their home towns after a nuclear disaster. The clear picture of radiation level was given for the safety of the person whom is staying in the Kawauchi village.

A. Budiman *et al* [65] carried out research works on “The design of digital instrument connected to android based smartphone to measure radiation.” It has been done on the basis of Indonesian Government Regulation of 2007 on Safety and Health of Ionizing Radiation Utilization. The Regulations stated that it is necessary to take preventive measure of radiation exposure for X-ray machine to protect officers, patients and the public from radiation. At present in Indonesia there are few devices that can measure the dose of radiation. Indonesia holds very less radiation dose measurement device in health care institutions which is great problem in the country. So, it is difficult to protect the professional radiation workers. The researcher designed radiation measurement device using Geiger Muller detector, microcontroller and smartphone to display the result of radiation measurement. The study consisted of one intervention group and one control group. The intervention group used design of radiation measurement device while the control group used a standard radiation measurement device. The designed device is a digital radiation measurement device that could be connected with android-based smartphone via Bluetooth connectivity commonly used by the mobile users but the researcher did not mentioned about operational protect of the developed device.

2.3 Summary of Review of Previous Research Papers

In the recent couple of years numerous studies have been carried out on the radiation measuring, detecting and monitoring. From reviewing the above literatures, effects of radiation and different way of going to highly radioactive source room near to the sources have been learned. The previous researchers used IOT [38], Gamma camera [40], mobile robots [42]; multi arms mobile robots [43], MOSFET dosimeter [62] and smart phone with micro controller [65] for monitoring, measuring dose rates and decommissioning of nuclear establishment and facilities. Most of the researches carried out their research works with very sophisticated and expensive technologies which is also very difficult to handle and relocate from one place to another. So, in this research works, researcher developed a simple alternative device of existing complex and highly technical devices to overcome the above mentioned complex situations. The developed device is user friendly, cheaper, easy to handle and no specialized trainings are required to operate and monitor highly radioactive source.

Chapter-3

Materials and Experimental Procedure

3.1 Materials

3.1.1 Selection Criteria

The selection and fabrication of materials are carried out with its utilization of optimum capacity and economy. However, the materials have been selected on the basis of following:

i) Budgetary cost of materials

ii) Purpose of use

iii) Appropriate capacity

iv) Optimum use of capacity

v) Experimental suitability

vi) Durability and reliability

vii) Availability

viii) Easy to handle

ix) Easy to shift from one location to another

x) Sustainability in radiation hazard.

The flow chart of the material selection, fabrication and performance test are shown in the Fig.3.1.

3.1.2 Flow Charts for Materials Selection, Fabrication and Developing Device

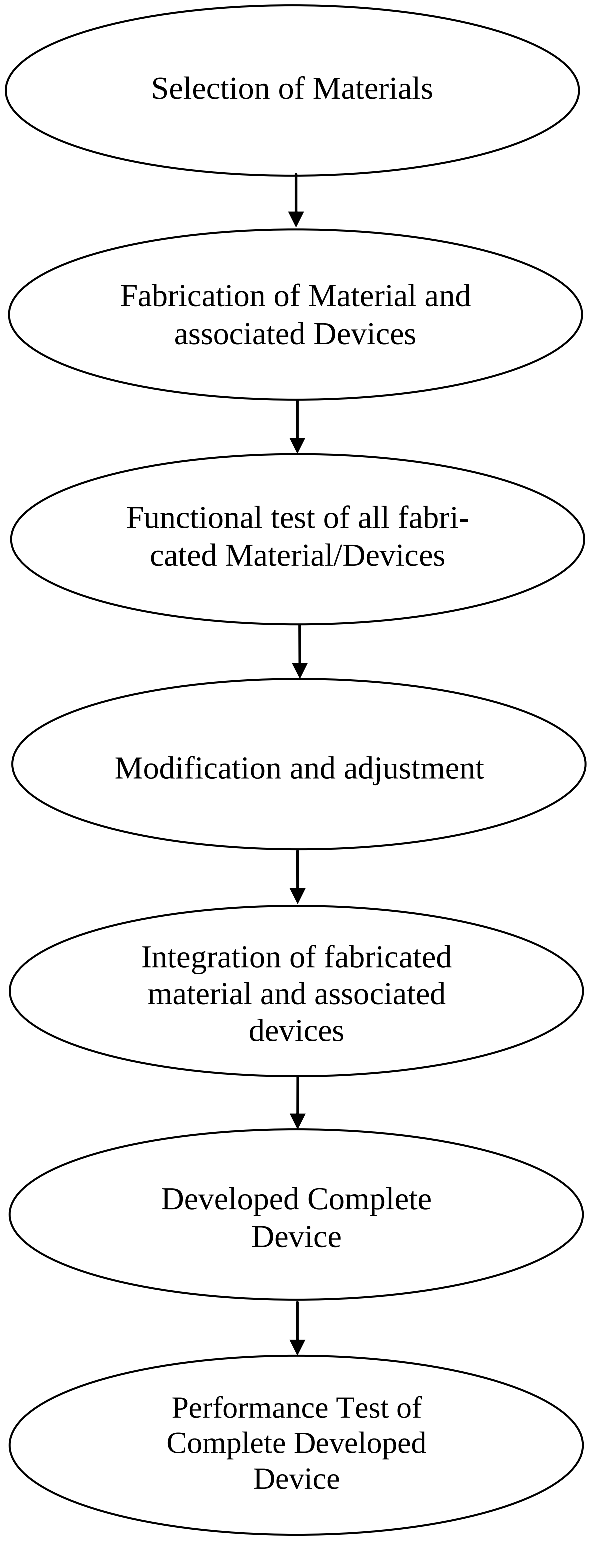


Fig. 3.1 Flow Charts for Materials Selection, Fabrication and Developing Device

3.1.3 Materials Used in Experiments

To make effective develop device the materials is very important. It has been selected on the basis of requirement, purpose of use, availability, quality and affordable cost. However, the selected materials and devices have been divided into three categories

i) Major material and devices

ii) Associated material and devices

iii) Radiation related materials

3.1.3.1 Major materials and device

3.1.3.1.1 Microprocessor controller (ESP8266)

Microcontroller is an integrated circuit that contains a microprocessor along with memory and associated circuits and that controls some or all of the functions of an electronic device. It interfaces with router via Wi-Fi and execute the command given by user. Its operating voltage is 3 to 5V DC.

3.1.3.1.2 Motor driver module (L298D)

Driver module is used to drive inductive loads that requires forward and reverse function with speed control. The module is used to control the speed of the carrier. Its minimum and maximum operating voltage is 5 to 24V DC.

3.1.3.1.3 Metal Gear Motor (GM25-370) and wheels

These components are used to supply torque to the carrier. A 250 rpm with 350 mA gear motor has been used which has a torque of 15 kg-cm. Capacity of this gear motor is 20W. This torque is providing power to the rear wheels but front wheel is having acute angle rotational facilities so that it can move in a narrow space. The motor can be operated by the motor driver module with its three modes of speed, slow, medium and high speed. Operating voltage is 9 to 24V DC.

3.1.3.1.4 Groove MOSFET

For voltage amplifier and switching Groove MOSFET has been used. It can be operated by 3 to 5V DC.

3.1.3.1.5 Bread board

A Mini bread board has been used to give connection and power supply to different circuits. The size of the Bread Board is 3.0cmX5.0cm.

3.1.3.1.6 Project box and main carrier box

The project box has been made by the plastic fabricated sheet, nut and bolts with the dimension of 40.00cmX25.00cmX10.00cm with the help of local workshop. It consist the base plate on the top to fix the main carrier box. Metal gear motor with wheels, motor drive modules and acute angle wheels are connected with the project box in the rear and front respectively according to the design. The main circuits with its all equipment and battery have been placed inside the box. The main carrier box has been made by the steel sheet, steel bar and nut-bolts with the dimension of 45.00cmX30.00cmX11.00cm.

3.1.3.1.7 Wi-Fi device

A 240/5V, 0.60A duel land port designed, 150Mbps, 2.4GHzs wireless router (TP Link, Model TL-WR720N) has been used as wireless communication device. The router and the Microcontroller has axis to communicate each other.

3.1.3.1.8 Arduino UNO r_3

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino. Open source platform consists of both a physical programmable circuit board and a pitch of software that runs on computer, "Uno" means one in Italian and was chosen to mark the release of Arduino Software generating timer signal. Its operating voltage is 5 to 12V DC.

3.1.3.1.9 Lipo battery and charger

To power supply to different circuits 12V, 4500mAh rechargeable battery has been used which can be recharged by the charger operated by input/output 220V AC/12V DC.

3.1.3.1.10 Buzzer (Alarm)

Audio signaling device is a mechanical or electromechanical device. Typical uses of buzzers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke. Operating voltage is 3 to 5V DC.

3.1.3.1.11 Real time counter (RTC DS1307)

It is a specialized type clock used for measuring specific time interval. The operating voltage is 3-5V DC.

3.1.3.1.12 Ordinary remote controlled carrier

The Ordinary remote controlled carrier is a simple ordinary car with remote control operated by 12V DC battery. It is constructed with four small wheels, carrier and built in sensor circuit. The carrier is having two parts, lower part holds chassis and wheels and upper part holds carrier box to carry all experimental devices (Lead box, camera, amber dosimeter, etc.).

3.1.3.2 Associated materials and devices

3.1.3.2.1 Lead block and Lead sheet

Six lead blocks are used in the experiment in the first stage of the developed device with dimension 30.00cmX30.00cmX15.00cm. The purpose of use is to make block for the camera to protect from the radiation. The Lead sheet is used for fabrication of lead box.

3.1.3.2.2 Lead box with steel frame

To Shield the camera lens and electronic device from radiation a lead casing has been used. Lead has a very good shielding characteristic against gamma radiation. A lead box is fabricated from the lead sheet measuring 18cmX14cmX18cm with the thickness of 2.5 cm.

3.1.3.2.3 Lead mirror

A lead mirror is a leaded glass and can be used as a shielding material. The main objective of the glass is to reflect the actual scene of the source. The lead present in the glass increases the attenuation of ionizing photons emitted by source because this property increases dramatically as the atomic number of the attenuating material increases. The mirror has the properties of refractive index 1.50; Thermal expansion coefficient is 80 X 107/°C. The Lead mirror used in the experiment is shown in Fig. 3.2.

Fig.3.2: Lead Mirror (61cmX46cmX0.50cm)

3.1.3.2.4 Electrical cable with connector

To connect the CC camera with computer, coaxial cables have been used. Power cables are used for the computer. RJ 45 and USB connector has been used for camera and computer.

3.1.3.2.5 Basic electrical tools

Some basic electrical tools have been used in this investigation. These basis electrical tools are used for testing power supply to all relevant circuits and its functionality test. Voltmeter, ammeter, Ohmmeter, tester, screw driver, glue gun etc are used in the experiment.

3.1.3.2.6 Computer/Laptop

A personal computer has been used with a following specification.

i) Intel Core i5 processor

ii) 8GB RAM

iii) solid-state hard drive with 256GB

iv) operating system: Windows 10 (64 bit encryption),

v) 802.11 N wireless card or better (5GHz or faster recommended)

vi) 100Mbps network card or faster, with RJ-45 cable (for wired connections).

3.1.3.2.7 Camera/CC Camera

A CCD (couple-charged device) camera is an image capture device that utilizes an image sensor to register visible light as an electronic signal. These types of cameras do not use photochemical film to capture stills or video. Instead, the electronic signal is recorded to either an internal memory or a remotely connected device. The Specifications of camera are Brand-Panasonic, Country-Japan, Style-bullet Camera, Resonance-6 mega pixel and IR Range 0-30m. The use camera and cc camera are shown in Fig.3.3.

Fig. 3.3: Camera/CC Camera Used in the Experiments

3.1.3.3 Radiation related materials

3.1.3.3.1 Amber and red Perspex

The trade name of the dosimeter is amber and red Perspex but chemical compositions are Poly-Methyl Methacrylate (PMMA) $(C_5H_8O_2)n$. They darken when irradiated, and the radiation-induced darkening, accurately measurable by means of UV Spectrophotometer, is a function of the radiation dose absorbed. Three types of Perspex are used for measuring absorbed doses depending upon sources but in this experiment amber and red Perspex have been used.

i) Amber Perspex is suitable to use for absorbed dose range 1-30 kGy which is used in this experiment.

ii) Red Perspex is suitable to use for absorbed dose range 5-50 kGy which is also used in the experiment. It can also be used instead of amber Perspex. Both Amber and red Perspex is shown in Fig.3.4.

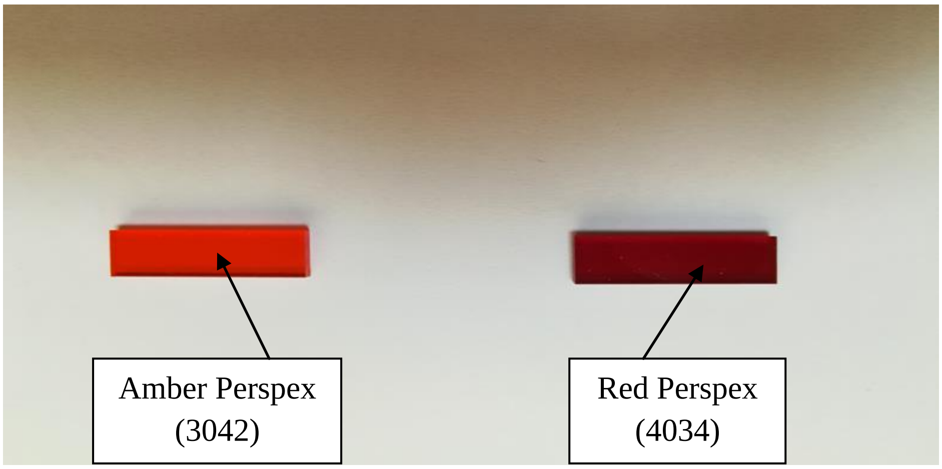


Fig. 3.4: Amber and Red Perspex

3.1.3.3.2 Co-60 Source

The largest Co-60 source is located at Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh. In the year of 2009 the initial activity was 350 kCi but the present activity is 120 kCi or 44, 40,000 GBq. This Gamma plant is used for commercial irradiation of food and medical appliances.

3.1.3.3.3 Pocket dosimeter

Pocket dosimeters are used to provide the researcher with an immediate reading of exposure to X-rays and gamma rays. As the name implies, it is commonly worn in the pocket. Two types are commonly used Direct Read Pocket Dosimeter and Digital Electronic Dosimeter.

3.1.3.3.4 Survey meter

Survey meters are portable radiation detection and measurement devices used to detect and measure external or ambient ionizing radiation fields. They are also used to detect and monitor personnel, equipment and facilities for radiation and radioactive contamination.

3.1.3.3.5 Ultra violet spectrophotometer

UV spectroscopy is a type of absorption spectroscopy in which light of ultra-violet region (200-400 nm) is absorbed by the molecule. Absorption of the ultra-violet radiations results in the excitation of the electrons from the ground state to higher energy state. The absorbed energy of the ultra-violet radiation is equal to the energy difference between the ground state and higher energy states. It obeys the Beer-Lambert law, which states that when a beam of monochromatic light is passed through a solution of an absorbing substance, the rate of decrease of intensity of radiation with thickness of the absorbing solution is proportional to the incident radiation as well as the concentration of the solution. In the experiment, the Ultra violet spectrophotometer has been used to measure the absorbed dose in the amber and red Perspex with the help of Harwell (UK) provided standard chart.

3.2 Fabrication of Material and Associated Devices

3.2.1 Fabrication of Lead Box

At first Lead is melted and lead sheet had been prepared with the help of local workshop. A lead box is fabricated from the lead sheet measuring 180mmX135mmX 175mm with the thickness of 25 mm by the lathe machine of local workshop. One hole is kept at the lead box in such a way that camera can be placed inside the lead box and the lens of the camera to be placed to the hole in such a way the lens of the camera can capture the images from the lead mirror to avoid the damage of lens due to direct effect radiation. The fabricated Lead box is shown in Fig.3.5.

Fig. 3.5: Fabricated Lead Box for Shielding Camera

3.2.2 Fabrication of Microcontroller Circuit

The selected materials and the circuit element are place inside the project box. The equipment is fixed by glue with the help of glue gun on the platform of project box. Power supplies of all equipment are ensured from common power supply of mini bread board. Necessary wirings have been completed shown in Fig.3.6. The wiring of microprocessor controlled carrier is shown in 3.7.

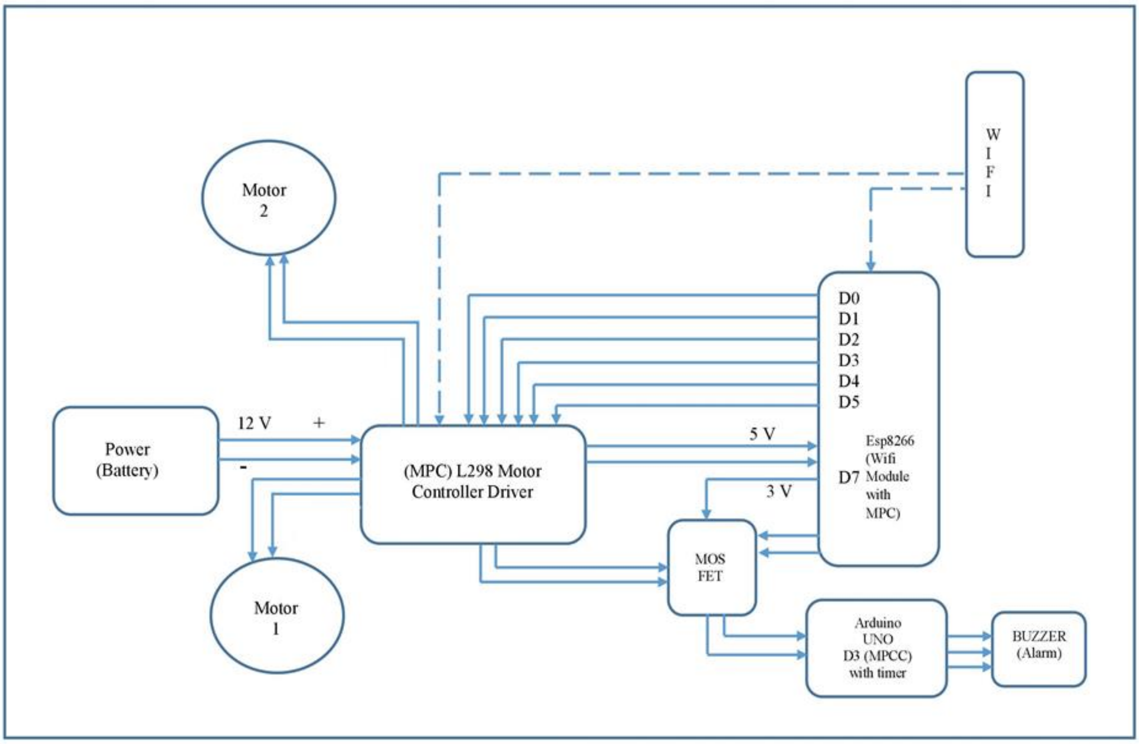
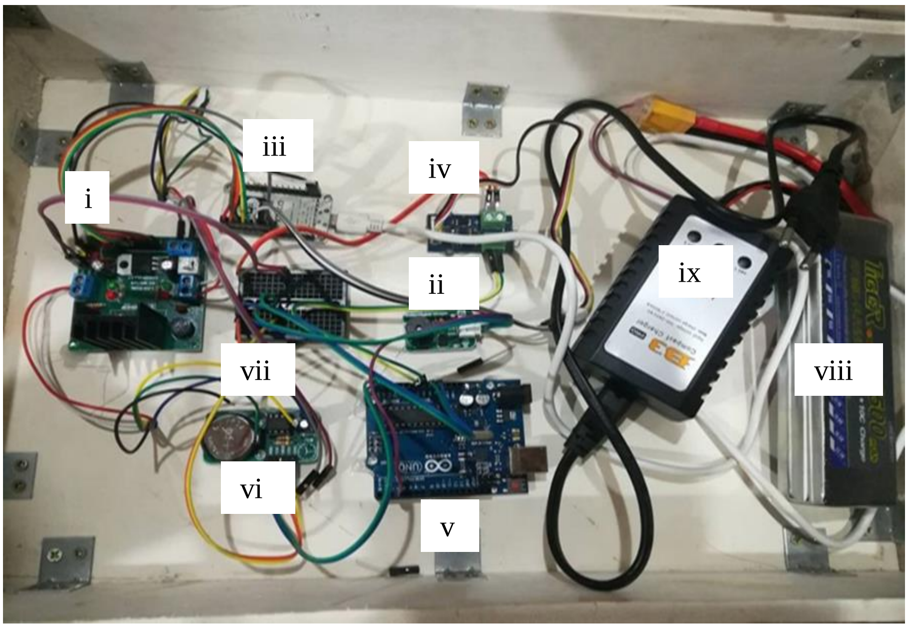


Fig. 3.6: Connection Diagram of Microprocessor Controlled Circuit

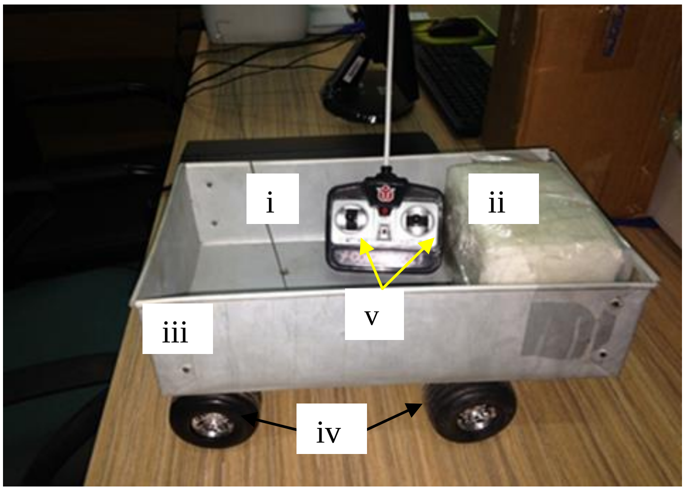


- i) Motor Control Driver (L298D)
- ii) Buzzer
- iii) Microcontroller (ESP8266)
- iv) Groove MOSFET
- v) Arduno UNO r3
- vi) Real Time Counter (DS1307)
- vii) Mini Bread Board
- viii) Lipo battery
- ix) Charger

Fig. 3.7: Wiring of Microprocessor Controlled Circuit

3.2.3 Ordinary Remote Controlled Car

The ordinary car is purchased from local market. An ordinary remote controlled car consists of a tray; four wheels front and rear axles as like small toy car. Source of power is the DC battery. It can carry the lead box, camera, amber dosimeters and red Perspex and lead mirror to place near to the source at the source room. The ordinary car used in the experiment shown in Fig.3.8.



i) Remote
ii) Lead box
iii) Tray
iv) Wheel
v) Operating button

Fig.3.8: Ordinary Remote Controlled Car

3.2.4 Functional Test of all Fabricated Material and Devices

It is essential to carry out functional tests of the material and devices. In microcontroller circuit an encoder is used for conversion of information from one format or code to another for the purpose of standardization, speed or compression. However, the individual element functional tests of fabricated microcontroller circuit are done and the test sheet is shown in table-3.1.

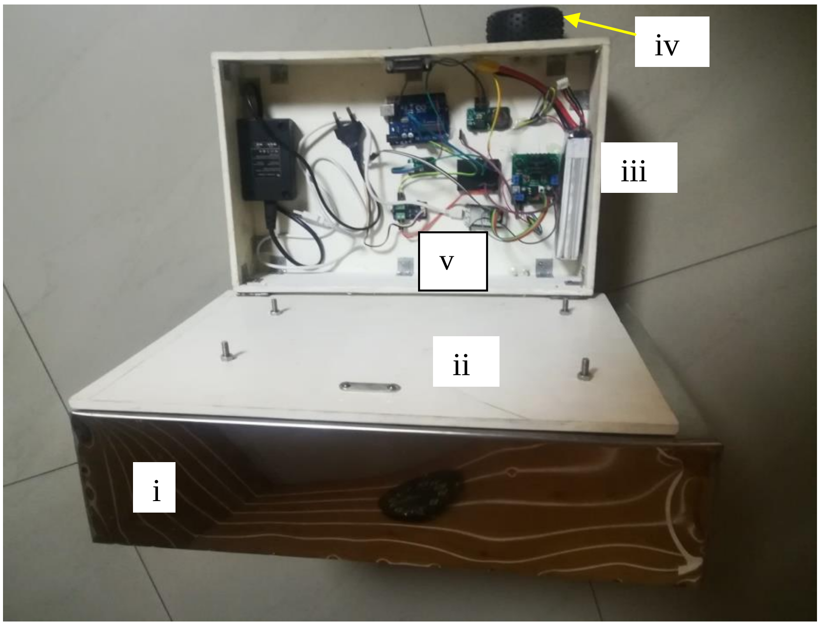
Table-3.1: Functional Test of Equipment and its Input and Outputs

Name of Equipment	Input Voltage DC	Output Voltage/ current DC	Remarks
Metal gear motor (GM25-370)	9-24V 350mA	-	To supply torque to the micro controlled carrier wheel- tested.
Driver (L298D)	12V	5/24V	Speed controller of carrier-tested.
Micro controller (ESP 8266)	5V	3V	Microcontroller an integrated circuit that contains a microprocessor along with memory and associated circuits and that controls some or all of the functions of an electronic device. It interfaces with router via WiFi and execute the command given by user-Tested.
Groove MOSFET	5V	12V	Voltage Amplifier and switching –Tested.
Buzzer	5V	-	Audio signaling device which may be mechanical, electromechanical. Typical uses of buzzers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke-Tested.
RTC DS1307 (Timer counter)	5V	-	Time Counter, Specialized type of clock used for measuring specific time interval-tested.
Arduino UNO r3	12 V	12/5V	The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino. Open source platform consists of both a physical programmable circuit board and a pitch of software that runs on computer, "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0 [1]. Generating Timer Signal-tested.
Battery	12V, 4500mAh	-	Power supply to the system.
Bread Board	-		To give connection and power supply to different circuit-tested.
Battery Charger	220V AC	12V DC	To recharge the battery-tested.
Wifi Device	220V AC	5V DC	Used as wireless communication device-tested.

3.2.5 Modification and Adjustment

After carrying out the functional test of the individual devices some modification and adjustment have been done. Necessary modification has been made in the fabricated Lead box due to non-appropriate placing camera in the hole. The tightness of camera installation found very slack. Modifications have been done for the better experimental results. All points of the fabricated microcontroller circuit are checked as per the connection diagram and necessary actions have been taken to make the individual equipment functional.

3.2.6 Integration of Fabricated Material and Associated Devices



i) Main carrier box
ii) lock
iii) Project box
iv) Motor with wheel
v) Control circuit

Fig 3.9: Integration of Fabricated Material and Associated Devices

The fabricated individual parts have been assembled as per the planning and requirement of the experiments. Every individual fabricated device has been assembled in such a way that the individual and integrated output does not hampered. However, assemble fabricated materials and associated devices are shown in Fig.3.9.

3.2.7 Complete Developed Device

The individual fabricated device and material has been connected each other and complete device has been developed for the experiments. The movement of the developed device can be controlled by the microcontroller with the help of computer/smart phone. Safety and security of operations are ensured by the individual IP address and password. The flow diagram and complete developed device is shown in Fig.3.10 and Fig.3.11 respectively.

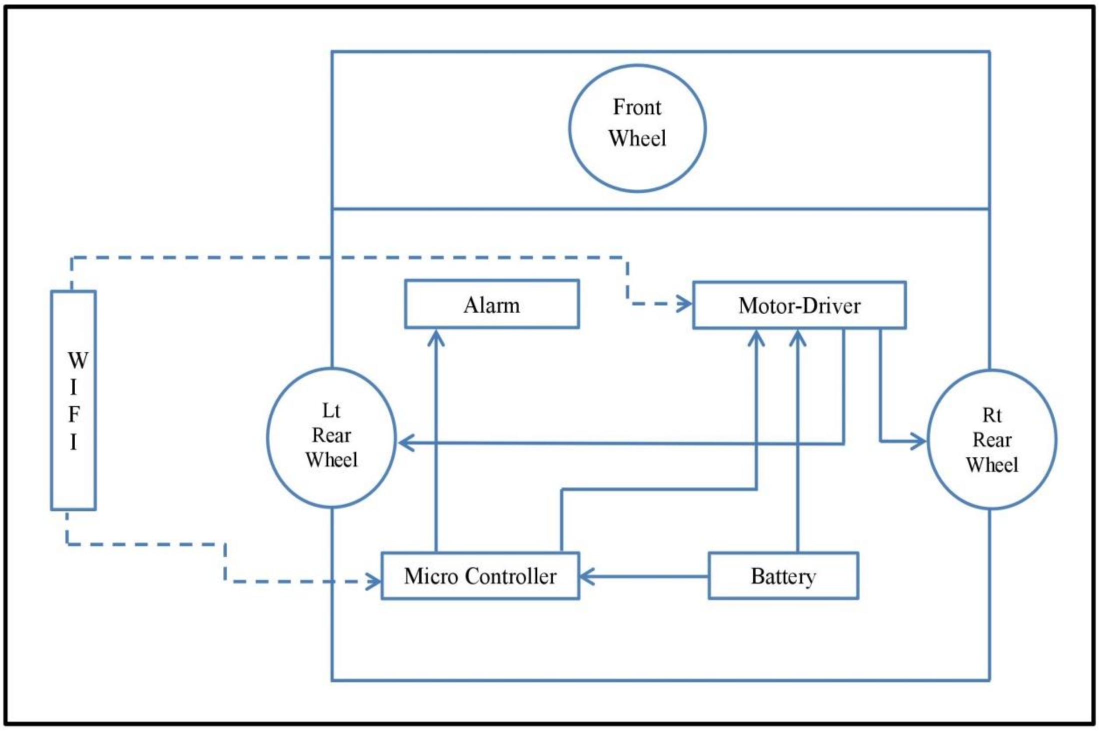


Fig. 3.10: Flow Diagram of Complete Micro Controlled Developed Device

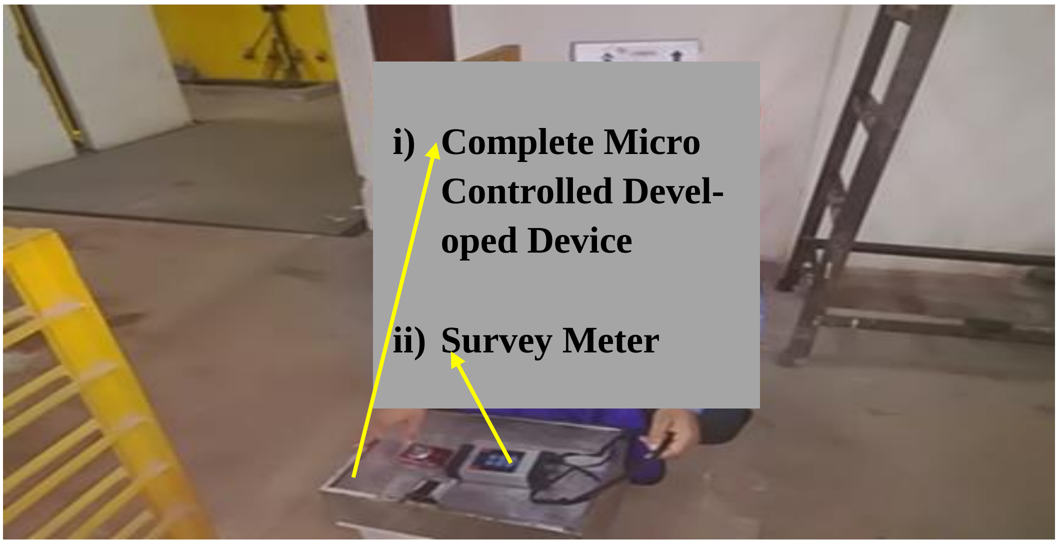


Fig. 3.11: Complete Micro Controlled Developed Device

3.2.8 Command Sequence of Developed Device

The command sequences of the developed device are stated below and shown in Fig.3.12:

Step 1: Start

Step 2: Declare variables for server.

Step 3: Declare variables for timer.

Step 4: Define the constant for Motor Driver.

Step 5: Initialize Server.

Step 6: Initialize Digital Pins.

Step 7: Initialize Analog Pins.

Step 8: Command from Server.

Step 9: Execute Command at the Rover.

Step 10: If counts = !0

  Drive the Rover

  Else

  Stop the Rover && Rest the Timer

Step 11: Stop

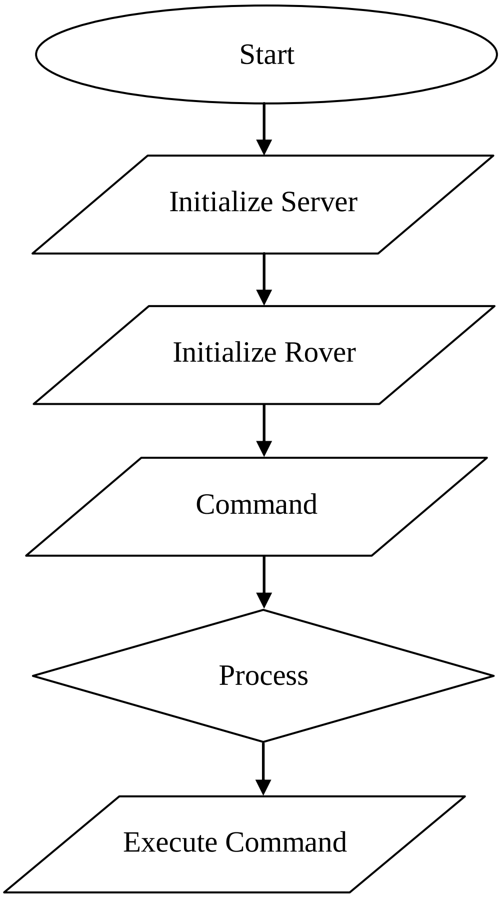


Fig. 3.12 Command Sequence of Developed Device

3.2.9 Performance Test of Complete Developed Device

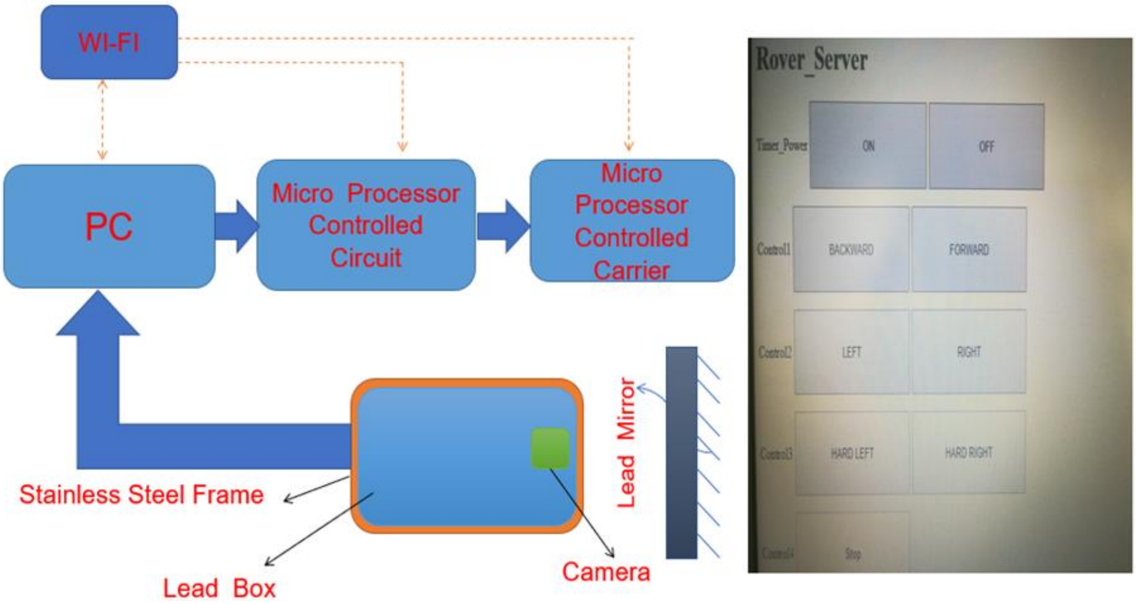


Fig. 3.13: Performance Test of Complete Developed Device

The performance test of the complete device has been done after necessary connection. The power supply is given to the computer and microcontroller based circuit to ensure the available of power in all input and respective output stages. The movement of the microcontroller carrier is tested with the help of IP address and password loading Lead box keeping inside camera and fixing the Lead mirror in front of camera lens. The performance test of complete developed device is shown in Fig. 3.13.

3.3 Experimental Procedures

3.3.1 Flow Charts of Methodology

Flow charts of methodology are shown below and explain in Fig. 3.14

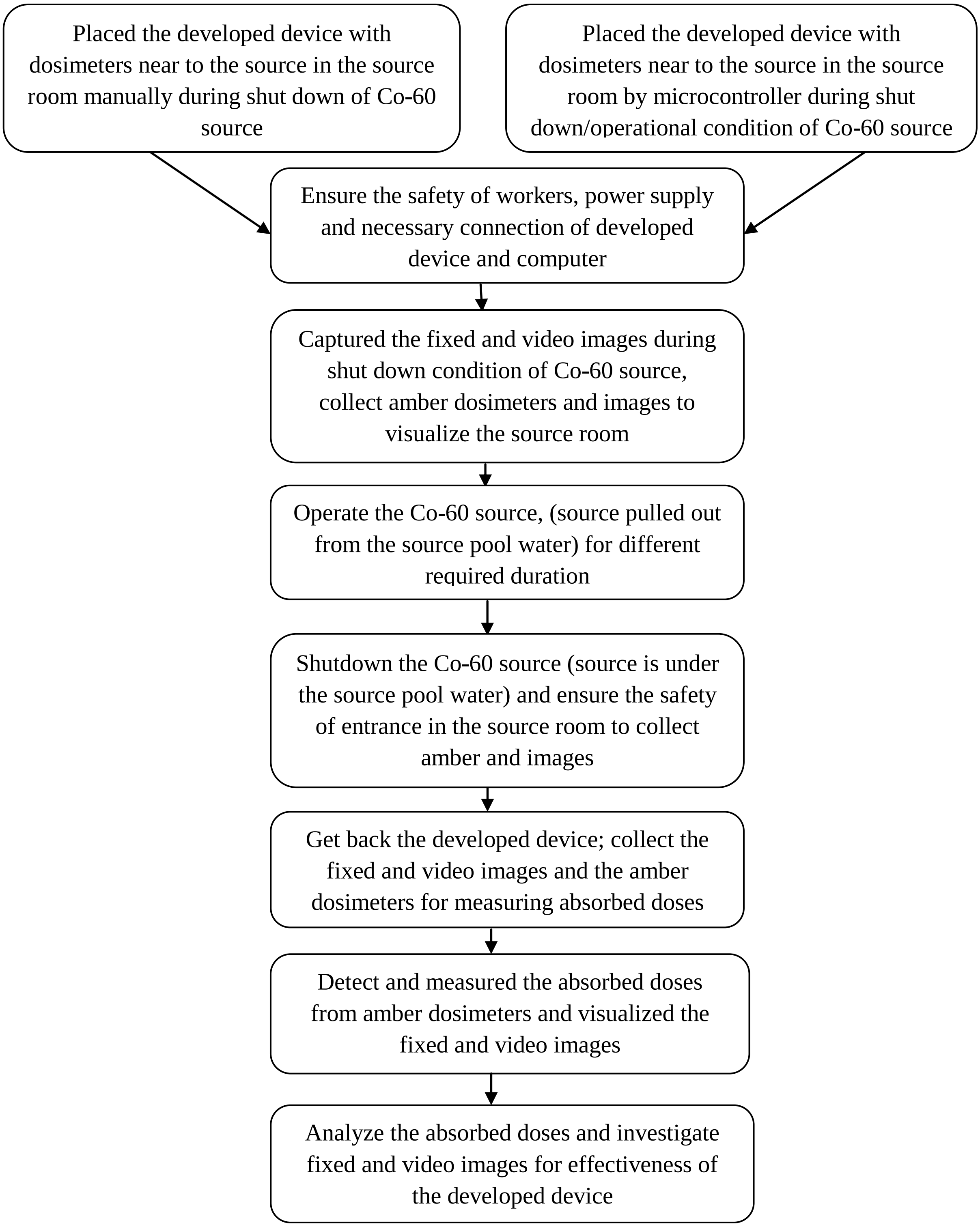


Fig. 3.14: Flow Charts of Methodology for Experiment of Developed Device

3.3.2 Overview of Experiments

Initially, dosimeter, camera and Lead mirror and Lead block are required to develop the device for radiation measurement, detection and monitoring. However, proper shielding is needed to protect the device from radiation effect. Lead is used as shielding material in this study due to its atomic properties and availability. Also, Lead mirror is used for obtaining more viewing angles. Placing the developed device (dosimeter, lead box, camera and lead mirror connected with computer etc) near to the source was a great challenge during operational condition of source. Due to this reason the device has been developed in three stages but the third stage is the most successful part for both manual and microcontroller movement of the carrier to place the device near to highly radioactive source in the source room.

i) **Experiment at First Stage:** Developing the device consisting camera, shielding blocks, amber and red Perspex, Lead (Pb) mirror. In this stage there is no provision of remote controller with the developed device. The device is placed near to the source manually only.

ii) **Experiment at Second Stage:** Developing the device consisting ordinary remote controlled carrier, power source, camera/cc camera shield by Lead box, Lead mirror, amber and red Perspex, computer connected with cc camera/camera. It is easy to place the developed device near to the source in the source room manually. But it is not possible to place the device near to source in the source room by remote controller due to narrow space and high turning radius with the carrier.

iii) **Experiment at Third Stage:** Developing the device consisting Micro controlled carrier with designed electronic control circuit with box for electronic circuit, carrier box with platform, camera/cc camera shield by Lead box, Lead mirror, amber and red Perspex, Wi-Fi device, power source (battery) and computer connected with cc camera/camera. Placing the developed device near to the source in the source room by manually and as well as microcontroller which is having protected IP address and password.

3.4 Experiment by First Stage Developed Device

In the first attempt of the study, the developed device has been placed manually near to the source in the source room before irradiation to capture the real time fixed and video image and absorbed doses by the amber dosimeter. The device has been developed consisting camera, shielding block, amber and red Perspex and Lead mirror. After placing the device at the desired place near to the source and the source is pulled out from the source pool water for 15 minutes. After 15 minutes the source is pulled down to the source pool water. Amber, red Perspex and camera have been collected from source room. After necessary investigation, it is found that the fixed and video images have been captured by the camera. The fixed and video images are found satisfactory with a little bit haziness to understand the source position.

The Amber and red Perspex is tested in the laboratory with the help of ultra violet spectrophotometer and Harwell (UK) provided standard chart. Thus, the absorbed doses are found for 15 minutes duration. The similar works have been done for the duration of 30, 60, 120, 180 minutes respectively for capturing fixed and video images and absorbed doses for mentioned duration.

But the developed device can be placed near to the source in the source room manually during source is under source pool water. It can only be placed when there is no radiation which is not practically useful for active radiation facilities. When the source is above the source pool professional radiation workers cannot placed the device safely near to the source in the source room. Thus, the developed device has not been adopted for further study and tries to develop the suitable device to overcome these constraints. The first developed device has got the following observations:

i) The developed device is a very traditional and experiment has been carried out for the possibility of success.

ii) To avoid radiation effect on the camera, simple Lead block, Lead mirror and camera are used for capturing the image by the camera.

iii) The developed device cannot be taken anywhere as the individual devices are not integrated by the frame.

iv) The integrated developed device cannot be placed near to the highly radioactive source in the source room by any remote controller. It can be place/remove manually during shut down condition of the source.

3.5 Experiment by Second Stage Developed Device

Second step has been taken for further study after achieving partial success in the first stage. To avoid these problems; an ordinary remote controlled carrier has been added in the developed device to place the device near to the source with the help of remote controller. In this stage lead box with steel frame has been used instead of lead block to protect the camera from the radiation effect. An electronic device has been made with the help of remote control carrier. It consists of a tray, four wheels and two axels as like small car. It can carry the lead box, camera, amber and red Perspex and lead mirror to place near to the source at the source room.

Amber and red Perspex are used in the investigation to measure the absorbed doses for the particular time duration. When amber and red Perspex are irradiated, radiation sensitive material darkens. These absorbed doses can be measured with the help of ultra violet spectrophotometer and Harwell (UK) provide standard chart. This is how, the dose levels of Cobalt-60 source at IRPT, AERE are measured at source room by using Amber and red Perspex with help of ultra-Violet Spectroscopy and Harwell (UK) provided standard chart. Amber and red Perspex have been kept in five groups (One Amber and red Perspex in each group) at the five places on the remote controlled carrier at a time as Group identity 1 to 5 for 15, 30, 60, 120, and 180 minutes respectively. After all necessary protective measures, the source has been pulled out from the source pool water and put in source rack for 15 minutes. After 15 minutes the source has been pulled down to put inside the source pool water and Amber and red Perspex of group identity Group-1 is collected safely. The repeated works have been done for identity Group 2, 3, 4 and 5 for the time duration of 30, 60, 120 and 180 minutes respectively. The dose levels are then examined in the laboratory of IRPT with the help of ultra violet spectrophotometer and Harwell (UK) provided standard charts. The obtained dose levels of Gamma irradiation source room have been analyzed. The experimental data are plotted in the graph and found it linearly increasing which indicates the absorbed does increase with the increasing of time duration as per theoretical explanation.

The Lead mirror is used to capture video and fix image of source and source room during the source is inside the source pool or above the source pool. An ordinary camera/cc camera has been used in the system having good resonance and standard lens. The objective to place cc camera/camera is to monitor the radiation source visually to observe the real situation of the source room. The cc camera of electronic device is shielded by fabricated Lead (Pb) in such a way that the lens of the camera can visualize Lead glass to capture the fixed and video images. It is kept in mind to place the cc camera that the radiation cannot fall directly on lens; hence it cannot be damaged due to high radiation effect. During the application of the source, the source is pulled out from the source pool water and cc camera is able to take the fix and video images which can be monitor visually and detecting the source position for the times of operation and the real situation of the source room. In order to investigate the effectiveness of the developed device the video and fixed images are closely observed with different angles, rotation and zooming. The developed device has got two major limitations:

i) Manually the device can be placed at source room near to the source. But the remote controlled car has a large turning radius, so it is almost impossible to move in narrow space to take it in the desired place of source room.

ii) The developed device does not have any operational safety tools like IP address and password, so anyone can operate the device which is not at all secure and safe for handling such highly radioactive sources.

3.6 Experiment by Third Stage Developed Device

To overcome the observations found in the stage one and two another way the device has been developed using microprocessor with software to carry the integrated developed device. The experiments have been performed in the same way like First and Second stage but the benefits of the device comparing with the other two previous stages are mentioned below:

i) It can be moved in narrow approach by the micro controller facilities.

ii) It has built-in specific IP address, pass word and the device is connected through Wi-Fi device.

iii) Ensuring the safety of operation as without knowing the IP address and password it cannot be operated.

iv) Also the device has been designed in such a manner that it has got acute angle of turning (360^0) which enables its movement in narrow spaces.

3.7 Method for Detecting, Measuring and Visual Monitoring of Radiation Doses

The CC camera/camera as both detection and monitoring device, Lead Mirror, five Groups (Gp-01, for 15Min, Gp-02 for 30Min, Gp-03 for 60Min, Gp-04 for 120Min and Gp-05 for 180 Min respectively) Amber and red Perspex have been placed in the microprocessor controlled carrier for measuring the radiation. The cc camera of electronic device has been shielded by fabricated Lead (Pb) box so that the lens of the camera can visualize Lead glass. It is kept in mind to place the CC camera that the radiation cannot fall directly on lens; hence it cannot be damaged due to high radiation effect. Detection of gamma radiation is based on the interaction between the radiation and the detector material. The detector's response should be proportional to the radiation. The photon scatters from the electrons of the material so called Compton scattering, and in each scattering process it loses a part of its energy. If the piece of material is large enough and the scatterings take place suitably, all the energy of the initial gamma ray is absorbed in the material. Thus, the energy of the photon is found by measuring the energy absorbed by the material. This energy is determined depends on the detector type and its functioning presents various processes that occur when a photon interacts with matter. After power supply to the microprocessor-controlled carrier the server has been connected with microprocessor.It has been placed to the source room by using the IP address, Wi-Fi device and its programing with the help of computer or smart cell phone. After placing the device in the desired place of source room, the source has been pulled out from the source pool water. Fix and Video images have been captured continuously from the reflected image of mirror and uninterrupted monitoring is possible from the safe room. During the application of the source, the source is pulled out from the source pool water and CC camera is able to take the fix and video images. The objective to place CC camera/camera is to monitor the source position visually to observe the real situation of the source room. The radiation doses have been absorbed by the amber and Red Perspex. After 15 minutes the source has been pulled into the source pool water and Gp-01 Amber and Red Perspex has been collected and preserve in a suitable place. The whole process has been repeated for 30, 60, 120 and 180 minutes duration for both amber and rep Perspex dosimeter as marked Gp-02 to Gp-05 respectively. Used amber and red Perspex of all Groups have been preserved to measure absorbed dose using Ultra violet spectrophotometer with the help of Harwell standard chart. So, the radiation detection, measurement and monitoring have been done experimentally with the developed device by manual and microcontroller operations. Operation of the Final developed device from safe zone is shown in Fig.3.15.

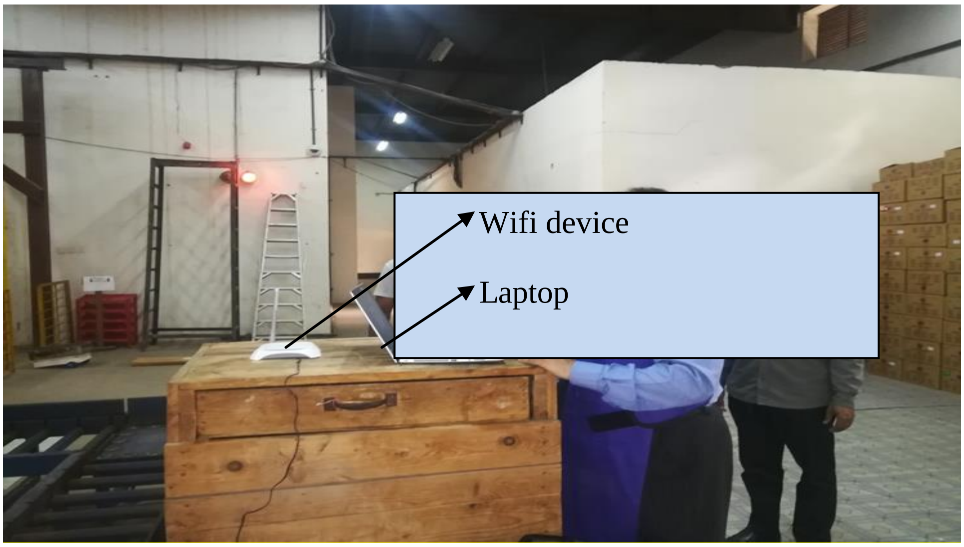


Fig. 3.15: Operation of Third Developed Device from Safe Zone

Chapter-4

Experimental Results and Observations

4.1 Radiation Dosimetry of Cobalt-60 Gamma Source

Absorption of the ultra-violet radiations results in the excitation of the electrons from the ground state to higher energy state. The absorbed energy of the ultra-violet radiation is equal to the energy difference between the ground state and higher energy states. It obeys the Beer-Lambert law, which states that when a beam of monochromatic light is passed through a solution of an absorbing substance, the rate of decrease of intensity of radiation with thickness of the absorbing solution is proportional to the incident radiation as well as the concentration of the solution.

In this experiment, it is clearly observed that the physical properties of amber and red Perspex have been changed after absorbing the radiation doses (energy); the color has been changed from lightest to darken. Hence, the wave length has been changed from longer to shorter. The dose rates are measured by using both amber and Red Perspex with the help of Ultra-Violet Spectroscopy and Harwell (UK) provided standard chart in laboratory of IRPT. The results have been plotted in the graph and found linear along with time duration for all stages of experiment. Physical (color) change has been observed with the radiation exposures of different time duration in both dosimeters are shown in Fig. 4.1.

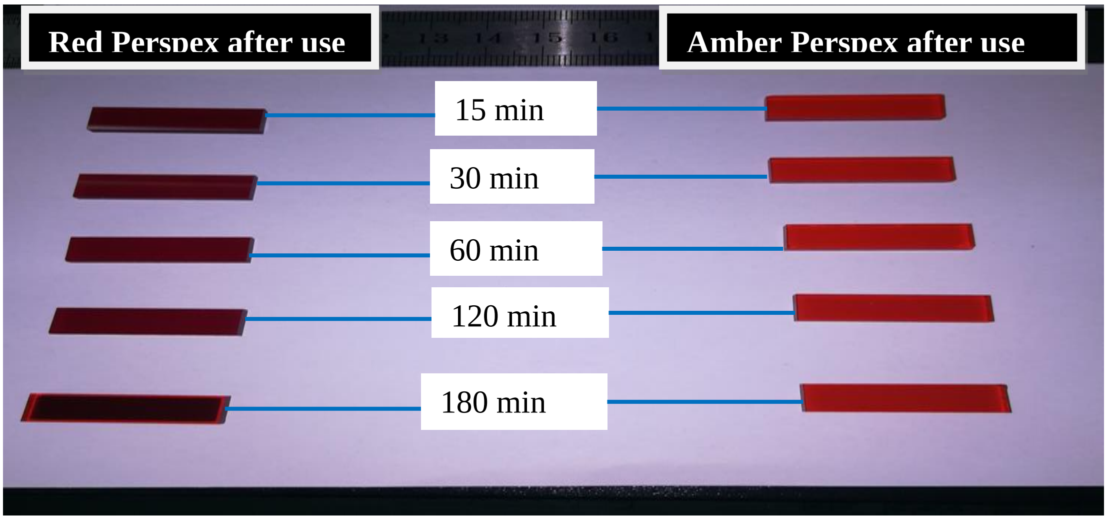
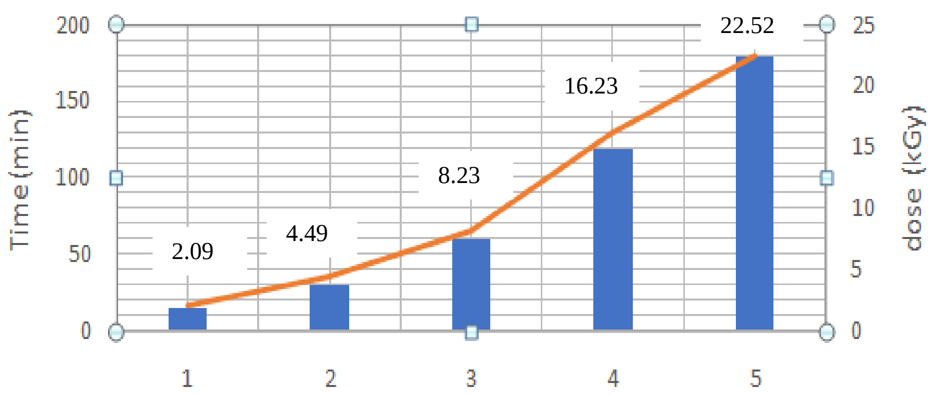


Fig. 4.1: Physical Properties (color) Changed in both Dosimeters with Radiation Exposure (First, Second and Third Stages of Experiments)

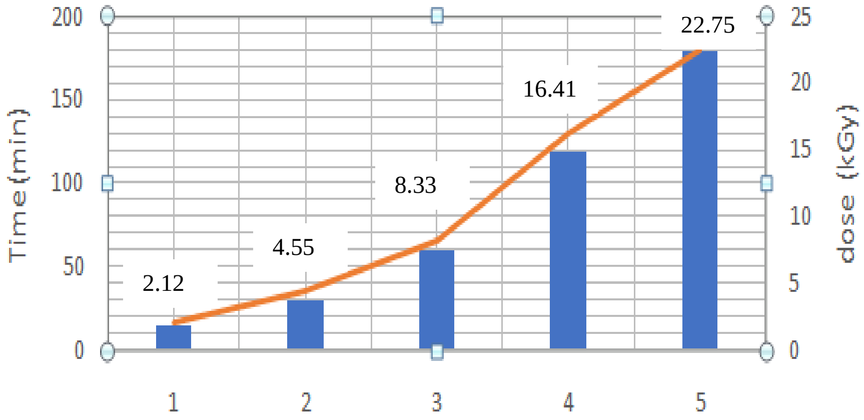
The absorbed dose rate obtained from the Red Perspex dosimeter is slightly higher than doses obtained from amber dosimeter due to reading obtained from different categories of dosimeters. Amber is normally used for 01 to 30 kGy and Red Perspex is normally used 05 to 50 kGy. This variation may appear due to different types of dosimeter and measuring error but the variation is within the recommended range of manufacturer ($\leq\underline{+}$2.00%). Two types dosimeter are used to validate the result obtained from the dosimeters. The deviation of dose rates are 1.43%, 1.34%, 1.22%, 1.11%, 1.02% for 15, 30, 60, 120 and 180 minutes in the first stage respectively. But the deviation ranges are not exactly same in the second stage as like as in the first stage. The experiment results have shown little bit difference between first and second stages due to human error and ultra violet spectrophotometer sensitivity as well as minor variation properties of ambers. However, the deviations of dose rates are sequentially 1.42%, 1.33%, 1.21%, 1.11% and 1.06% for 15, 30, 60, 120 and 180 minutes in the second stage. Similarly the deviations are also not found same in the third stage compering to first and second stages. The results show 1.44%, 1.33%, 1.20%, 1.10% and 1.04% deviation between amber and red Perspex with same time duration as like as stage one and two. So, it is evidenced from the experimental results that the percentage of error decreases with increase of absorbed doses in the dose measurement. However, the experimental results for the First, Second and Third stages using Amber and red Perspex are shown in Table-4.1 to 4.3 respectively. The graphical presentations of experimental results are shown in Graph-4.1 to 4.9 for First, Second and Third stages of experimental results respectively.

Table-4.1: Experimental Results from First Stage Developed Device (Amber and red Perspex)

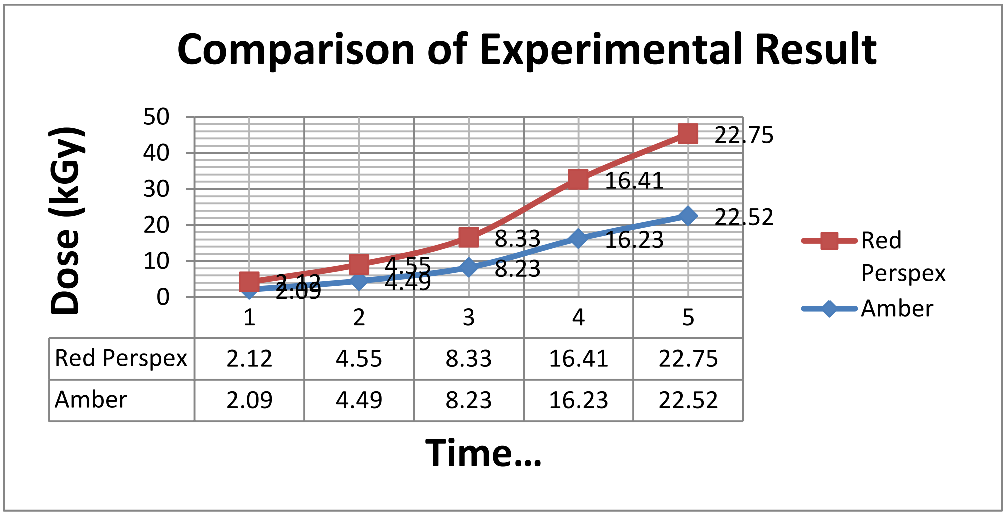
Duration in Min	Absorbed dose in Amber dosimeter (kGy)	Absorbed does in red Perspex (kGy)	Difference % in both dosimeter
15	2.09	2.12	1.43
30	4.49	4.55	1.34
60	8.23	8.33	1.22
120	16.23	16.41	1.11
180	22.52	22.75	1.02



Graph-4.1: Graph for Absorbed Doses using Amber Perspex from First Stage Developed Device



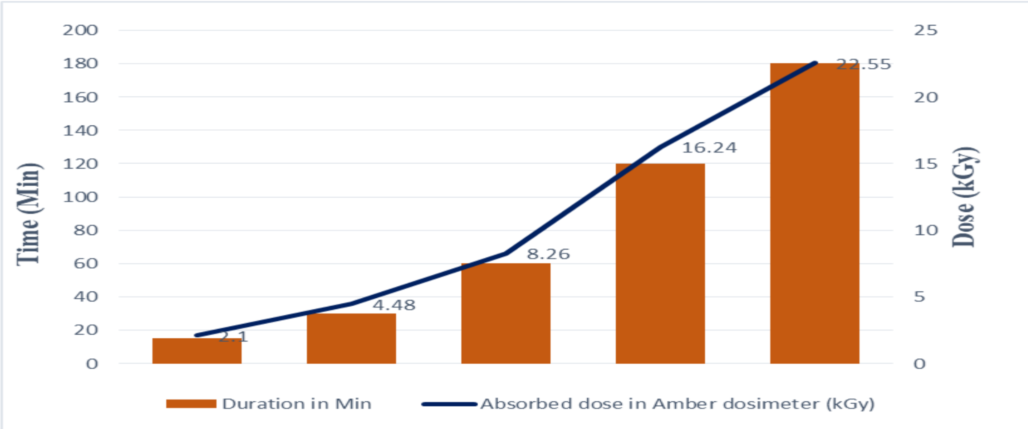
Graph-4.2: Graph for Absorbed Doses using Red Perspex from First Stage Developed Device



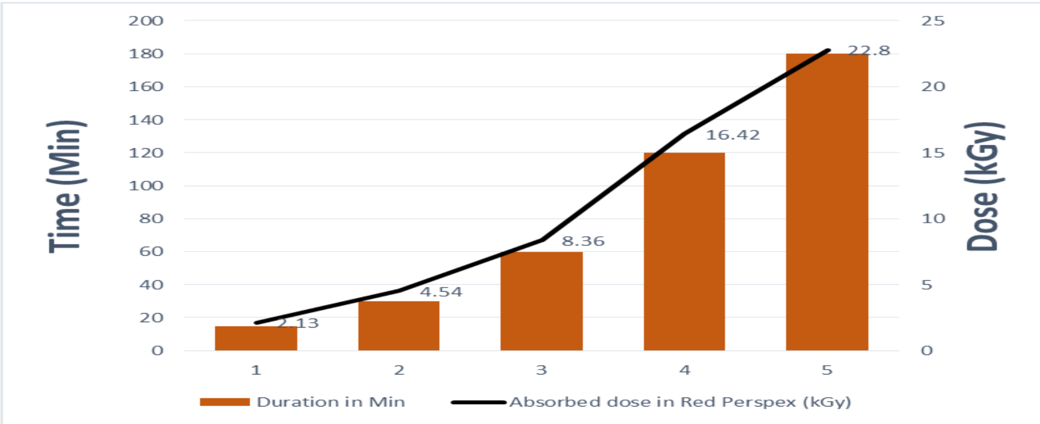
Graph-4.3: Graph for Deviation of Absorbed Doses between Amber and Red Perspex from First Stage Developed Device

Table-4.2: Experimental Results from Second Stage Developed Device (Amber and red Perspex)

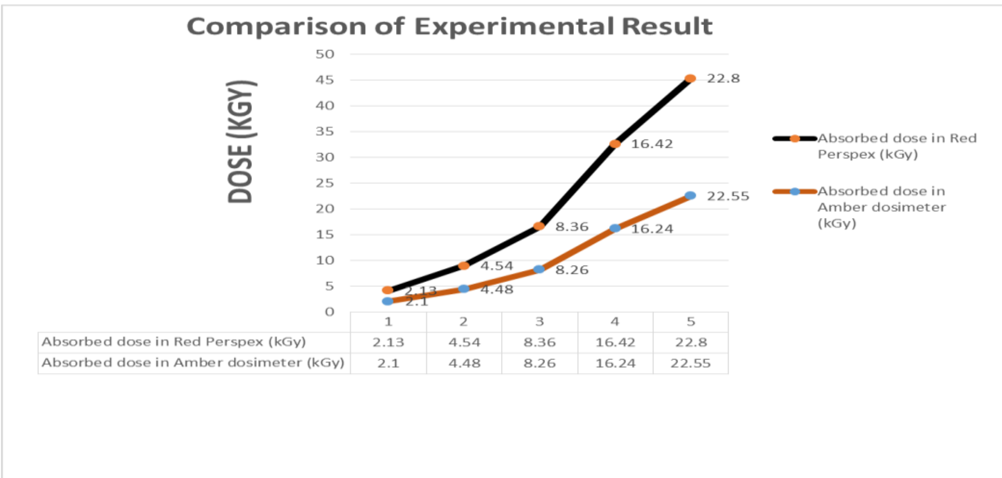
Duration in Min	Absorbed dose in Amber dosimeter (kGy)	Absorbed does in red Perspex (kGy)	Difference % in both dosimeter
15	2.10	2.13	1.42
30	4.48	4.54	1.33
60	8.26	8.36	1.21
120	16.24	16.42	1.11
180	22.55	22.80	1.06



Graph-4.4: Graph for Absorbed Doses using Amber Perspex from Second Stage Developed Device



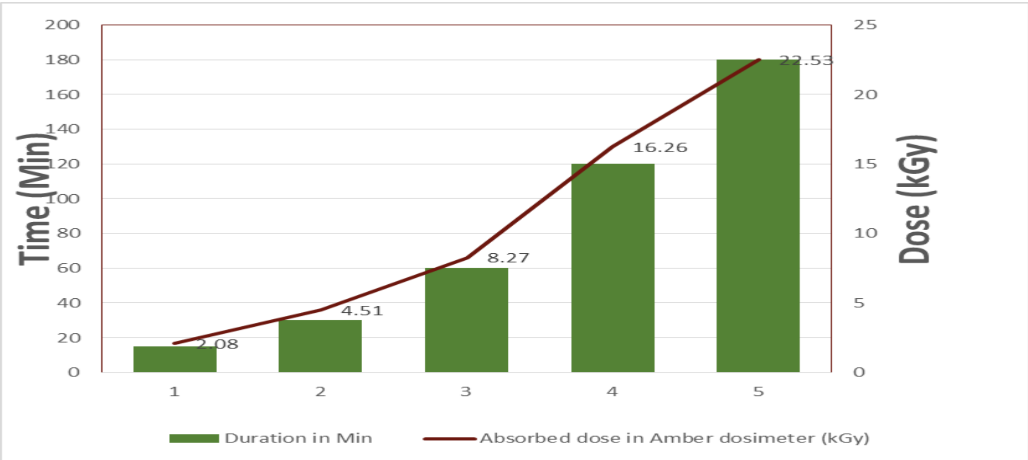
Graph-4.5: Graph for Absorbed Doses using Red Perspex from Second Stage Developed Device



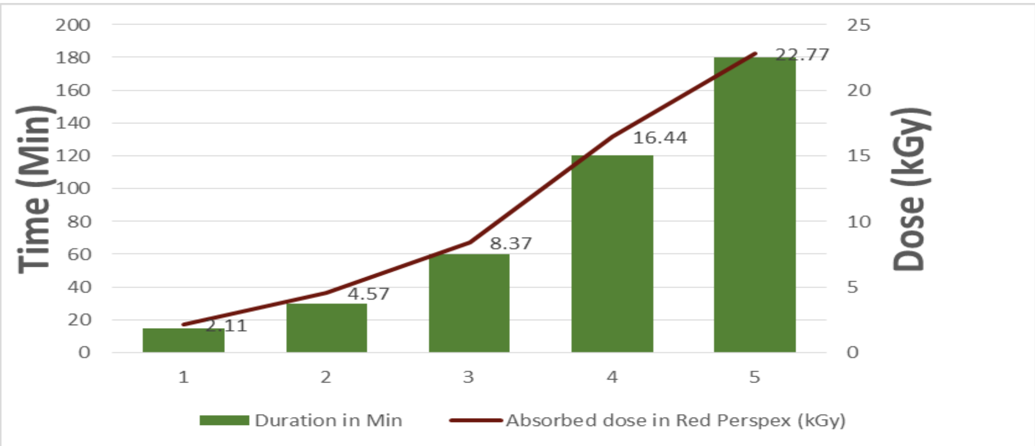
Graph-4.6: Graph for Deviation of Absorbed Doses between Amber and Red Perspex from Second Stage Developed Device

Table-4.3: Experimental Results from Third Stage Developed Device (Amber and Red Perspex)

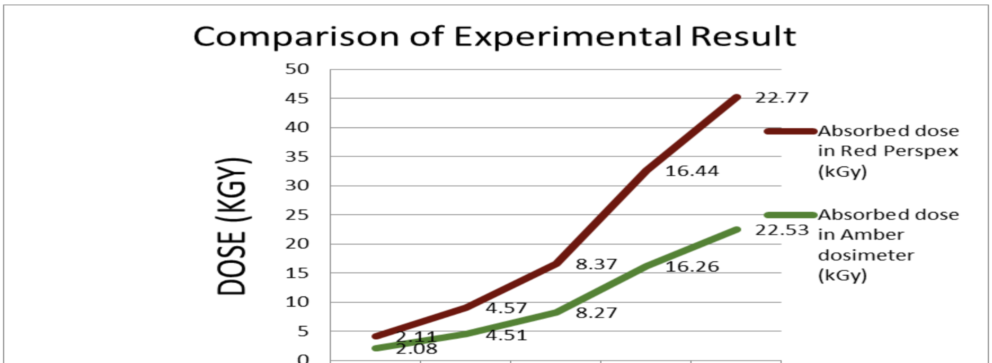
Duration in Min	Absorbed dose in Amber dosimeter (kGy)	Absorbed does in red Perspex (kGy)	Difference % in both dosimeter
15	2.08	2.11	1.44
30	4.51	4.57	1.33
60	8.27	8.37	1.20
120	16.26	16.44	1.10
180	22.53	22.77	1.04



Graph-4.7: Graph for Absorbed Doses using Amber Perspex from Third Stage Developed Device



Graph-4.8: Graph for Absorbed Doses using Red Perspex from Third Stage Developed Device



	1	2	3	4	5
Absorbed dose in Red Perspex (kGy)	2.11	4.57	8.37	16.44	22.77
Absorbed dose in Amber dosimeter (kGy)	2.08	4.51	8.27	16.26	22.53

Graph-4.9: Graph for Deviation of Absorbed Doses between Amber and Red Perspex from Third Stage Developed Device

4.2 Monitoring Radiation Doses and Source Room

The visual monitoring is gradually improved in the first and second stages of the developed device and finally it is successful at the third stage of developed device. However, some noise has been noticed due to irradiation of highly radioactive Gamma source during the application of the source but it does not damage the device or interrupt the signal. The captured fixed and video images at different stages (1, 2 and 3) of the developed device revealed the source position and the real situation of the source room. Fixed images captured by the first stage developed device with existence of radiation, source is above the source pool water is shown in Fig-4.2 and video images captured by the first stage developed device with existence of radiation, source is above the source pool water is shown in Fig -4.3.

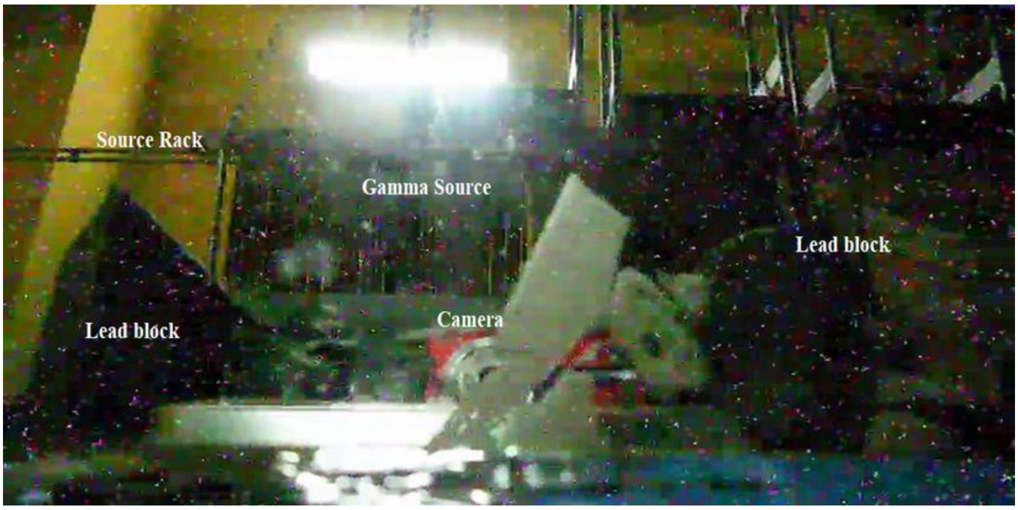


Fig. 4.2: Fixed Image Captured by First Stage Developed Device with the Existence of Radiation

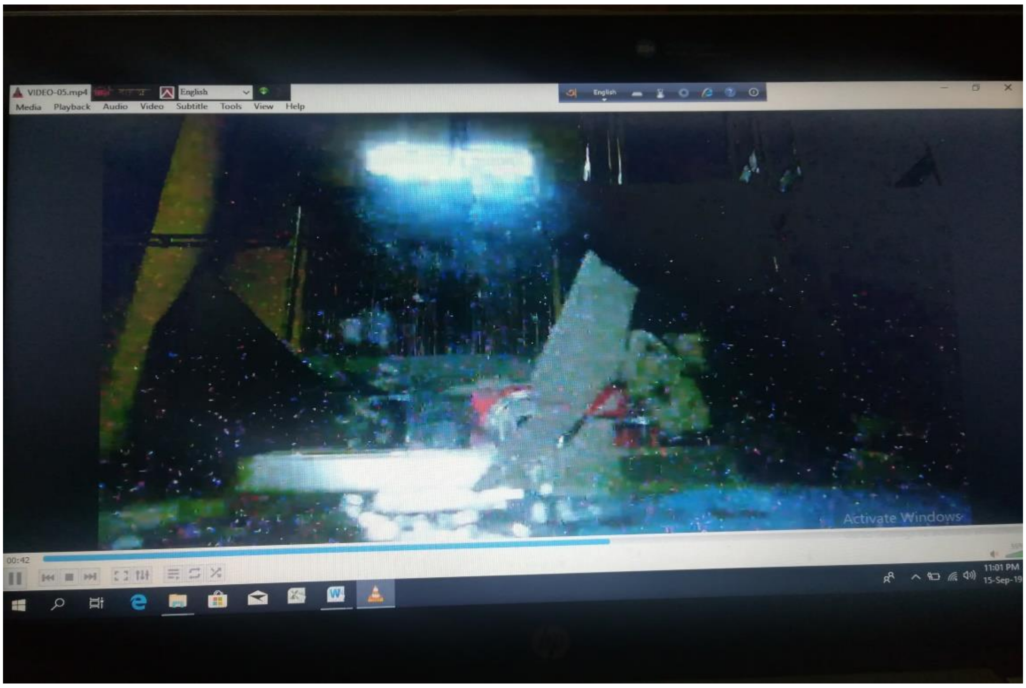


Fig. 4.3: Video Image Captured by First Stage Developed Device with the Existence of Radiation

In the Second stage a device has been developed to overcome the limitations belong to the developed device in stage one. Fixed image is captured by the second stage developed device, no radiation; the source is under the source pool water shown in Fig. 4.4.

Fixed image is captured by the second stage developed device, radiation exists, the source is above the source pool water and fixed image is captured by the second stage developed device with the existence of radiation shown in Fig. 4.5. Again, source is pulled out from the source pool water; video images are captured by the second stage developed device with the existence of radiation shown in the Fig.4.6.

Fig. 4.4: Fixed image Captured by Second Stage Developed Device with no Radiation.

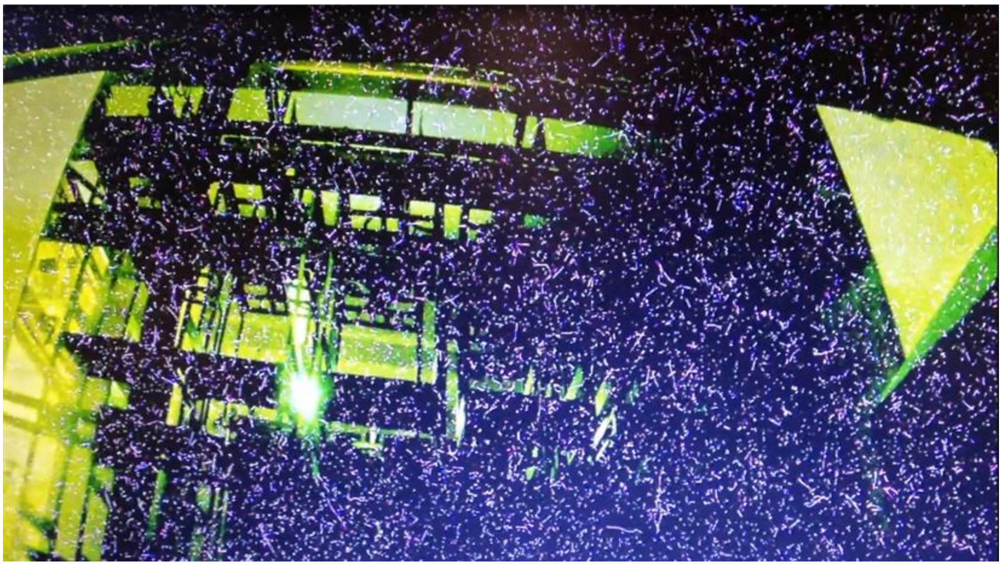


Fig. 4.5: Fixed Image Captured by Second Stage Developed Device with the Existence of Radiation

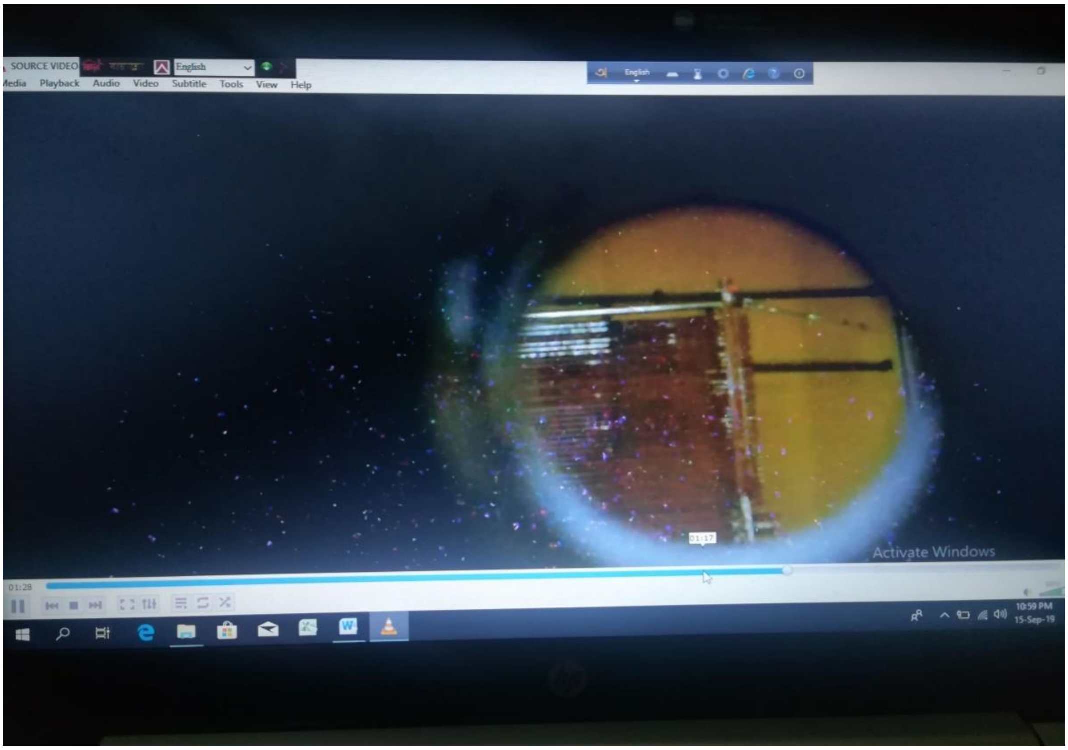


Fig. 4.6: Video Image Captured by Second Stage Developed Device with the Existence of Radiation

There are some limitation in the second stage of developed device. So, to overcome the limitations belong to the developed device in the second stage, the device has been redesigned called third stage to overcome the limitations. Fixed images are captured by third stage developed device, no radiation shown in Fig.3.7, In this sitauation the source is under the source pool. Fixed images are captured by the third stage developed device, radiation exists shown in Fig 3.8, the source is above the source pool in this situation. Video images are also captured by the third stage developed device; radiation exists, source is above the source pool water shown in Fig. 4.9.

Fig. 4.7: Fixed Image Captured by Third Stage Developed Device with no Radiation

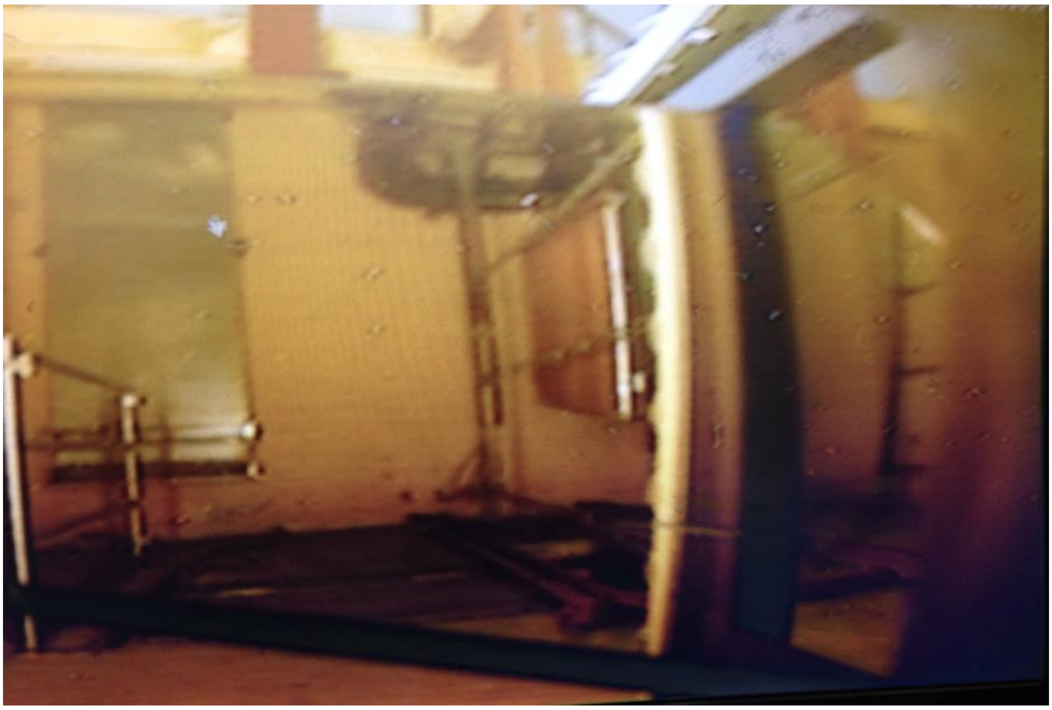


Fig. 4.8: Fixed Image Captured by Third Stage Developed Device with the Existence of Radiation

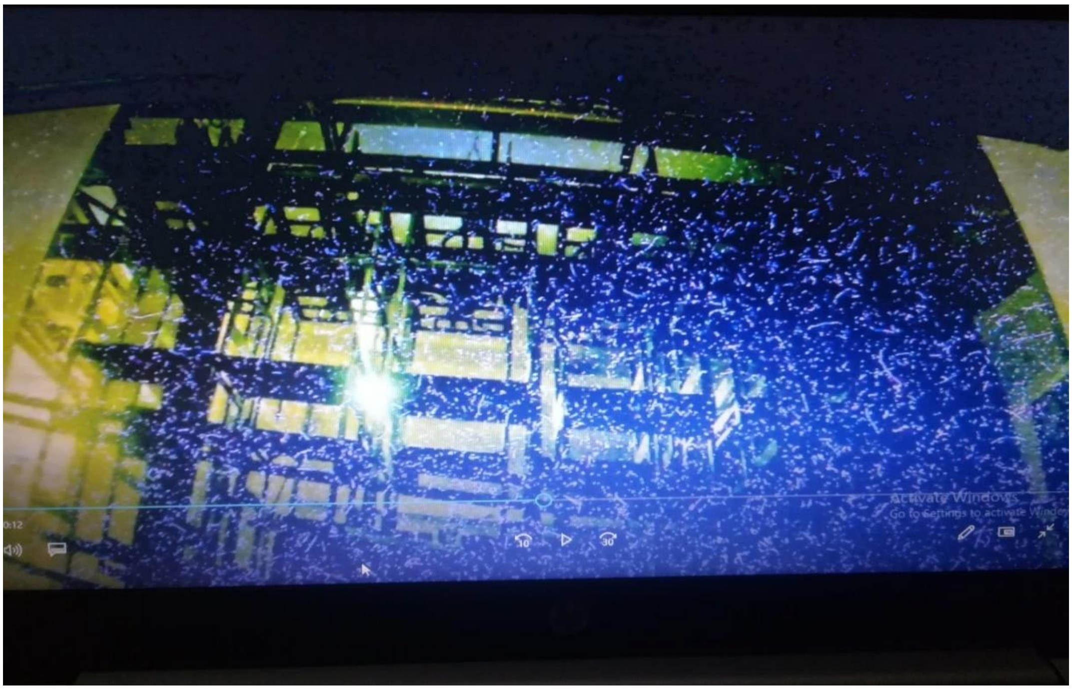


Fig. 4.9: Video Image Captured by Third Stage Developed Device with the Existence of Radiation

But due to the haziness of captured images by the first stage developed device it is difficult to understand the exact source position and the real situation of the source room though the existence of radiation is clearly understandable. The captured fixed and video images are more understandable in the Third stage which is more accurate and transparent. In order to investigate the effectiveness of the developed device the video and fixed images are closely observed with different angles, rotation and zooming.

4.3 Summary of Outcome from the Research

The outcomes from the research are as follows:

(i) Amber and red Perspex hold the radiation sensitive materials. The physical properties of amber and red Perspex have been changed after absorbing the radiation doses (energy); the color has been changed from lightest to darken which detected the radiation.

(ii) Measuring the absorbed doses by the amber and red Perspex with the help of ultra violet spectrophotometer and Harwell provided standard chart and the doses level has been analysed.

(iii) Position of highly radioactive source and the real situation of the source room (Gamma Irradiator, Co-60) have been identified through the circuit during its applications and visualized the radiation of highly radioactive source (Gamma Irradiator, Co-60) through computer monitor.

In order to investigate the effectiveness of the developed device the video and fixed images are closely observed with different angles, rotation and zooming. Hence, an effective detecting, measuring and monitoring device have been developed.

4.4 Observations

This research was critical to find out the way to develop an electronic device for Detecting, Measuring and Visual Monitoring of Radiation Doses for Highly Radioactive Sources. Some relevant research papers have been studied to enhance knowledge to carry the research. General ideas have been picked up from these relevant research papers to start this research works. The details are explained in Chapter -2 under literature review. The great success has been achieved after various stages of development and subsequent implementations. However, the research is successful with the following observations:

i) The absorbed doses are obtained by ultra violet spectrophotometer with the help of Harwell (UK) provided standard chart but some deviations are found in the absorbed doses as it is not real time measurement.

ii) The ordinary remote controlled car is not able to place in the source room near to the source by remote control. The developed device is placed manually which is not at all possible during operational condition of the source.

iii) The most of the fixed and video image are found hazy from different stages of developed device with the few exceptions.

iv) Finally developed device is able to place in the source room near to the source by microcontroller which is protected by IP address and password.

v) The effect of radiation on the camera sensor is beyond the scope of the research. So, durability of the camera lens is not analyzed.

vi) Durability and sustainability is not carried out in the research for continuous longer period of use the developed device.

vii) The calibrations of different equipment used in the experiment are not done due to non-availability of calibration facilities for such equipment in Institute of Radiation and Polymer Technology (IRPT), AERE, Savar, Dhaka, Bangladesh.

Chapter 5

Discussions on Results and Relevance

5.1 Discussion on Results

Earlier the research works on detecting and measuring of radiation had been done by the global scientists. Lots of International Journal and papers have been studied to find out the similarity of the research but few are found related to this topic. Most of the scientist worked on the robotic system, Internet of Things (IOT), identification and monitoring of toxic gas and decommissioning the radioactive establishments. Some of them worked on detecting and measuring the radiation doses but none of the researcher did carry out the research on visual monitoring of radiation doses and the real situation of highly radioactive source and source room to minimize the possibility of accident and preventive measures. Once the research has been stated lots of obstacles are found but it has been overcome by the technique, hardworking and tremendous support from every one. Finally success is found with subsequence development and experiments.

In the first stage, the research is started by using camera, amber and red Perspex, Lead mirror with a Lead block. Some fixed and video images have been captured but the developed device has been placed at the source room near to the source manually when source is under the source pool water. As the developed device has been placed manually so, it is not possible to place the developed device at source room near to the source when the source is above the source pool water. The captured images are little hazy and difficult to understand the exact position of the source at the source rack but it is cleared that the source is above the source pool water or the source is under the source pool water due to availability/non availability of camera glittering respectively.

Amber and red Perspex are used for measuring the absorbed doses. The absorbed doses are increased with increasing of time duration.

In the second stage, the research is started with an ordinary camera/CC camera, fabricated Lead box with steel frame, Lead mirror and an ordinary remote controlled carrier connected with computer for continuous monitoring of the source position and the real situation of the source room. Some fixed and video images have been captured when the developed device has been placed at the source room near to the source manually at the time of source is under the source pool water. But it is not possible to place the developed device at the source room near to the source by remote controller due to high turning radius of carrier. So, it is not possible to place the developed device at the source room near to the source when the source is above the source pool water. The images are also little hazy and it is difficult to identify the source position at the source rack. The ordinary car can be operated by anybody as it is not protected by password and separate IP address. So, finally two limitations had been identified with the developed device.

i) Unsafe operations and control

ii) Developed device cannot be placed by remote controller at the source room near to the source.

Amber and red Perspex are used for measuring the absorbed doses and the similar results are found.

In the third stage, the research is started with an ordinary camera/CC camera, fabricated Lead box with steel frame, Lead mirror, Wi-Fi device and micro controlled carrier connected with computer for continuous monitoring the source position and the source room. Some fixed and video images have been captured when the developed device has been place at the source room near to the source manually when the source is under the source pool water as well as by the microcontroller when the source is above the source pool water. This microcontroller carrier is having acute angle wheel and it can easily move in the narrow space, can take appropriate turning as well. In this stage the images are clear and the position of the source can be identified either the source is above the source pool water or it is under source pool water. Only authorized person can operate as it is protected by password and separate IP address. Finally, the developed device has got two tremendous advantages and overcome the limitations identified in the first and second stages:

i) Safe operations and control

ii) Developed device can be placed by remote control at the source room near to the source and continues monitoring is possible from the safe zone. Hence, the research is successful.

In all stages (1, 2 and 3) the physical properties (color) of amber and red Perspex has been changed during irradiation as it is made by the radiation sensitive materials. Hence, radiation has been clearly detected. Absorbed doses are measured from used amber and red Perspex with help of ultra violet spectrophotometer with the help of Harwell (UK) standard chart. The deviation of dose rates are sequentially 1.43%, 1.34%, 1.22%, 1.11%, 1.02% for 15 min, 30 min, 60 min, 120 min and 180 min respectively. The error found in the absorbed doses does not exceed the acceptable limit given by the manufacturer ($\leq\pm$2.00%). The fixed and video images have been analyzed during the experiments. Camera glittering indicates the presence of ionization radiation (Gamma) in the captured fixed and video images by the developed device in all stages (1, 2 and 3) which can be visually monitored continuously with the help of computer

/laptop. With the above statement, it is understood clearly that the developed device has been worked effectively for detecting, measuring and visual monitoring of radiation doses for highly radioactive sources, source position and real situation of source room.

5.2 Uncertainty Analysis of Experimental Results

There are two basic kinds of uncertainties, systematic and random uncertainties. Systematic uncertainties are those due to faults in the measuring instrument or in the techniques used in the experiment. In this research calibration accuracy of ultra violet spectrophotometer, old version of instrument, calibration of camera lens, time measurement by real time counter, Harwell standard measuring chart and measuring thickness of the amber and red Perspex are the systematic uncertainties in the experimental results.

Random uncertainties are associated with unpredictable variations in the experimental conditions under which the experiment is being performed, or are due to a deficiency in defining the quantity being measured. Radiation intensity, quality and chemical composition of amber and red Perspex, huge glittering due to irradiation, thermal effect and ambient temperature are the systematic uncertainties in the experimental results.

The above mentioned factors may affect the detecting, measuring and visual monitoring of experimental results. It is found from the uncertainty analysis that the deviation of the measuring absorbed doses of experimental results are from 1.02% to 1.44% which is within the acceptable limits (≤±2.00%) given by manufactures.

5.3 Relevance of Research

Relevance is the concept of one topic being connected to another topic in a way that makes it useful to consider the second topic when considering the first. The concept of relevance is studied in many different fields, including cognitive sciences, logic, and library and information science. In the global researches it is identified that same research works had not been done before by the global scientists but some relevance research activities had been done earlier. The verification of this research can be proven by comparing with reference [38], [42], [43], [62], [65].

A. Kannapan *et al* [38], in this research detecting radiation detection monitoring in hazardous and chemical industries giving more emphasize on those of developing countries where safety and environment are not given priority. IOT or Internet of Things is a system of connecting physical device or sensors and everyday objects with computer using internet. This study intended to identify the poisonous gas and radiation leakage by using gas and radiation sensors and connecting them to IOT. Arduino UNO r3 board is used as central microcontroller which is connected with sensor, temperature, gas sensor, radiation sensor to get data from environment. This device used for as multi gases and multi radiation detection as possible. Also in this research an intelligent system was programmed to detect and monitor poisonous gas and radiation integrating Arduino controller and IOT. However, no visual monitoring during incident was not possible from the developed system. Also the radiation absorbed dose measurement could not be possible from the developed system.

U. Sarker *et al* [42], in this research a mobile robot had been developed to use for remote radiation measurement, however due to exposure of high level of absorbed dose, robot’s component’s durability was doubtful. In the radiation sensor and the telescopic mechanism, radiation sensor GM sensor, mounting at the end of the telescopic assembly has been used as radiation sensor. The developed robot is controlled by a robot controlled by robot control software, a joystick and button in a desktop computer. This device was successful in radiation measurement without risking unwanted personnel radiation exposure. However, it cannot monitor the highly radioactive source and the real situation of the source room.

J. B. Mohamed *et al* [43], in this study a multi arm crane with robotic facilities are developed for nuclear decommissioning. There is a risk of exposure of radiation to workers and wider range of environment. Currently the robotic cranes are used in decommissioning of radiation facilities, like a large power plant. Using Proportional integral derivative and proportional integral plus control algorithms real time control method was examined. The mobile platform is contained 40 decommissioning robot which can be operated in small and confined space consisting moving vehicle with single five degree of freedom manipulator, hydraulic tank, controller and remote-control device. Using this robot tasks like pipe manipulation, complex pipe cutting has been performed successfully using single and both arms. This system uses graphical simulations which enables the correctness of the robot. Although, this study focused mainly on complex activity in the decommissioning task using multi arm robot. However, radiation detection, measurement and monitoring were not in the scope of this research. Related to these research activities, a lot of research works had been done before by the global famous scientists other than the above mentioned research works. But in this research there are some advantages comparing to the other similar researches and equipment by which the similar purposed can be fulfilled.

B. P. Gloria *et al* [62], in this research the functionality, radiation characteristics, and clinical implementation of an implantable MOSFET radiation detector (dosimeter) had been successfully done. The dosimeter is powered by radio frequency telemetry eliminating the need for a power source inside the dosimeter. The implantable dosimeter can be used, together with the current radiation delivery and planning techniques, to optimize radiation treatment on an individual basis. This dosimeter can be used for the individual purpose only.

A. Budiman *et al* [65], researcher carried out research on Government. Regulation of Safety and Health of Ionizing Radiation Utilization for Indonesia. The Regulations stated that it is necessary to take preventive measure of radiation exposure for X-ray machine to protect officers, patients and the public from radiation. At present in Indonesia there are few devices that can measure the dose of radiation. Indonesia holds very less radiation dose measurement which is great problem in the country. So, it is difficult to take the measure to protect the professional radiation workers. The researcher designed a radiation measurement device using Geiger Muller detector, microcontroller and smartphone to display the result of radiation measurement. The study consisted of one intervention group and one control group. The designed device is a digital radiation measurement device that could be connected with android-based smartphone via Bluetooth connectivity but the researcher did not mentioned about operational protection of the developed device.

Chapter 6

Conclusion and Recommendation for Future Studies

6.1 Conclusion

Radiation detection, measuring and monitoring is a very important in nuclear facilities. The present available devices are very expensive and can be operated only with trained personnel. This study is intended to easily detect, measure and monitor of radiation doses for highly radioactive source. Finally, placing the detection device at the source room near to the source with the help of remote controller is successful by the fabrication and design of microcontroller carrier with acute angle fixing in the front wheel of the carrier. Radiation detection is successful by observing physical properties (color) changed in the amber and red Perspex, fabricated by radiation sensitive materials, camera glittering and huge scattered narrow lights from the various captured video and fixed images.

The absorbed dosed are measured from Amber and red Perspex by ultra violet spectrophotometer with the help of Harwell standard chart. The similar doses are found for the same duration in different stages of experiments in amber and red Perspex. The minimum absorbed doses are measured 2.08 kGy and maximum 22.80 kGy for 15 and 180 minutes respectively. The minimum and maximum deviations with experimental absorbed doses for amber and red Perspex are found 1.02% and 1.44% with the time duration for 15 minutes and 180 minutes respectively. After analysing the dose level it is found that the absorbed doses are almost linearly increasing with increasing of time duration and deviations are found in experimental results within the recommended limit ($\leq \pm$2.00%) given by the manufacturer.

Monitoring of real time incidents of source and the source room is experimentally successful, observing the fixed and video images captured by the developed device connected to the computer. In order to investigate the effectiveness of experimental visual monitoring of radiation doses by the developed device the captured video and fixed images are closely observed with different angles, rotation and zooming.

The device is simple and does not have sophisticated robotic technology. This device is secured due to its individual specific IP address and password. Hence, the developed device can be used as a simple alternative effective device instead of sophisticated costly robot.

6.2 Recommendation for Future Studies

It will be possible by using the developed device with few further successful studies to easily detect; measure and visual monitor the radiation facilities like power plants, research reactors, medical radiation facilities, nuclear establishment and decommissioning. However, the researcher recommends the following future studies:

- ✓ Amber and red Perspex has been used in this study to measure the absorbed doses. It is obtained with the help of ultra violet spectrophotometer which cannot give real time measurement of absorbed doses after being irradiated. Real time radiation measurement sensor and display can be integrated with the developed device in the future study.

- ✓ Sustainability and reliability of the developed device for using continuous longer period in the similar radioactive source and investigate the effect of radiation on the materials and equipment of developed device may be considered for another further study.

- ✓ Effect of radiation on camera sensors and lens can be investigated further for continuous longer used of the developed device and the developed device needs to be tested for repeated number of radiation exposure to know the durability of sensors and lens which can be scope of further study.

The developed device is found suitable experimentally to detect, measure and monitor the radiation facilities like power plant, research reactor, medical facilities as well as nuclear establishment and decommissioning. However, it can be used for such type of nuclear facilities with further recommended successful studies. In near future, further above mentioned research and development works are required to make the developed device commercially available in the global markets.

References

[1] Canada, *"Introduction to Radiation".* Canadian Nuclear Safety Commission, Dec 2012.

[2] H. Cember and T. E. Johnson, 4th Eds., *Introduction to Health Physics,* New York, Mc Graw Hill Medical, 2008.

[3] H. J. Anikar, 4th Eds., *Essentials of nuclear chemistry,* New Age International Ltd., publishers, 2004.

[4] S. Glasstone and A. Sesonske, 3rd ed., *Nuclear Reactor Engineering,* CBS Publishers & Distributors, Delhi, 1986.

[5] R. P. Chhetri, "Background Radiation: Detection, Measurement and Hazards," Journal of *the Himalayan Physics,* vol. 6 & 7, pp. 119-122, 2017.

[6] J. R. Lamarsh and A. J. Baratta, 3rd Eds., *Introduction to Nuclear Engineering,* Prentice Hall, New Jersey, 2001.

[7] A. Beiser, *Concepts of Modern Physics,* 6th Eds., Mc Graw Hill, 2002.

[8] A. Charlesby and A. J. Swallow, "Radiation Chemistry:" *Annual Reviews in Physical Chemistry*, vol. 10, pp. 289-330, 1959.

[9] IAEA, "*Advanced Radiation Chemistry Re-search: Curing Status"*, IAEA-TECDOC-834, pp. 7-11, International Atomic Energy Agency, Vienna, Austria, 1995.

[10] M. Joseph and G. Jean, *Radioactivity, Radionuclides, Radiation,* Springer, 2005.

[11] IAEA, *"Nuclear Fuel Cycle Information system: A directory of Nuclear Fuel cycle facilities,"* IAEA TECDOC 1613, pp. 7-31, International Atomic Energy Agency, Vienna, Austria, 2009.

[12] UNEP- 2016, *"Radiation effects and sources"* pp. 1-5, United Nations Environment Program, New York, U.S.A., 2016.

[13] IAEA-CN-86-60, *"Regulatory Control and Safety of Radiation and Radioactive Sources in Bangladesh", pp. 108-109,* Nuclear Safety and Radiation Control Division, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh, 2002.

[14] A. E. Walter, *The medical, Agricultural and Industrial Applications & Nuclear Technology,* New Orleans LA, 2003.

[15] IAEA," *Nuclear Security Series: Identification of Radioactive sources and devices 2007"*, no-5, pp.30-32, International Atomic Energy Agency, Vienna, Austria.

[16] O. Holmberg, J. Malone, M. Rehania, D. McLean, and R. Czarwinsk "Current issues and actions in radiation protection of patients," *European Journal of Radiology,* vol. 76, pp. 15-19, 2010.

[17] Kwan-Hoong Ng, "Non-Ionizing Radiations – Sources, Biological Effects, Emissions and Exposures," *The Proceeding of the International Conference on Non-Ionizing Radiation,* UNITEN, 2003, pp. 1-16.

[18] A. C. Upton, "The biological effects of low-level ionizing radiation*," Scientific American,* vol. 246, no. 2, pp. 41-49, 1982.

[19] European Commission, *"Understanding the effects of radiation on health"*. Community Research, Office for Official Publications of the European Communities, 2002.

[20] K. K. Anil, "Gamma Irradiation Technology: Challenges and Future prospects" *Universal Journal of physics and Application,* vol. 12, no 3, pp. 47-51, 2018.

[21] H. P. Schatzler, "Basic aspects on the use of elastic and inelastic scattered gamma radiation for the determination of binary systems with effective atomic numbers of less than 10," *The International Journal of Applied Radiation and Isotopes,* vol. 30, no. 2, pp. 115-121, 1979.

[22] IAEA, "*Safety standards for protecting people and the environment: Radiation safety of Gamma, Electron and X ray irradiation facilities".* no. SSG-8, pp. 1-5, International Atomic Energy Agency, Vienna, Austria, 2010.

[23] IAEA, "*Directory of Gamma processing facilities in member states".* pp. 35-40, International Atomic Energy Agency, Vienna, Austria, 2004.

[24] Germany, *"Personal Dosimeter Requirements".* German Commission on Radiological Protection, Feb 2011.

[25] Pamela A. Y., "The Influence of Long-Term Gamma-Radiation and Initially Dissolved Chemicals on Aqueous Kinetics and Interfacial Processes," *PhD The*sis, The School of Graduate and Postdoctoral Studies, The University of Western, Ontario, London, Ontario, Canada, pp. 1-7, 2014.

[26] D. R. McAlister, Ph.D., “Gamma Ray Attenuation Properties of Common Shielding Materials” *PG Research Foundation, Inc.,* University Lane Lisle, USA, pp. 1-15, 1955.

[27] BAEC, “*Annual report July 2017 to June 2018”*. Bangladesh Atomic Energy Commission, Dhaka, Bangladesh, 2018.

[28] P. Zanzonico, and S. Heller, “The intraoperative gamma probe: basic principles and choices available,” *In Seminars in Nuclear Medicine,* vol. 30, no. 1, pp. 33-48, 2000.

[29] Thomas G., “Properties of Terrestrial Gamma ray Flashes.” *PhD Thesis*, Department of Physics and Technology, University of Bergen, Norway, pp. 1-7, 2012.

[30] Ragnhild S. N.,” Constraining the initial properties of Terrestrial Gamma-ray Flashes” *PhD Thesis*, Department of Physics and Technology, University of Bergen, pp. 1-5, 2014.

[31] P. Olivier and P. F. Michel, *“Cobalt”* Springer International Publishing, Switzerland, 2016.

[32] Dr H. K. James, Dr J. G. Herman and Mr H. D. Paul, “Cobalt and Inorganic Cobalt Compounds,” World Health Organization, *Concise International Chemical Assessment Document,* vol. 69, pp.4-7. 2006.

[33] IAEA, *“Beneficial uses and production of Isotopes: Organization for Economic cooperation and development”*. pp. 10-14, International Atomic Energy Agency, Vienna, Austria, 1998.

[34] IAEA, *"Measurement of Radionuclides in Food and the Environment".* no. 295, International Atomic Energy Agency, Vienna, Austria, 1989.

[35] Aamir I. and Kamran M. C., "Core Neutronic and source strength analysis of Co-60 Production in Local power Reactors", *Proceeding of the International conference on Applications of Radiation Science & Technology,* Vienna, Austria, 2017, pp. 24-27.

[36] Paulo de S. S., Pablo A.S Vasquez and Pable A. S., "C-188 Co-60 Sources installation and source Rack loading optimization Process in gamma irradiation facilities", *Proceeding of the International Nuclear Atlantic conference-INAC 2017*, Vangvez, 2017.

[37] F. A. Soad, S. Y. Eman, H. E. Amira, K. M. Reta and E. A. Kasar ,"Experimental study on the use of Co-60 irradiation in the inactivation of Giardia Lamblia cyst" *Medical Journal,* vol. 19, no. 2, Apr., pp. 25-34, 2013.

[38] A. Kannapan, and P. K. Hari "Toxic Gas and Radiation detection monitoring using IOT" *International Journal of Engineering and Development and Research,* vol. 5, no. 2, Jun., pp. 1762-1768, 2017.

[39] J. Fagerstrom, *Ionizing Radiation effects on radiation sensors: method on evaluation from an image quality perspective,* Lund University, ISEC Industrial Security AB, 2016.

[40] O. Koichi, T. Takahiro, U. Yuichiro, N. Jun, I. Takafumi, T. Isao, F. Yasutake, K. Hayashic and N. Kenichi, "Development of a gamma camera to image

radiation fields," *Progress in Nuclear Science and Technology,* vol. 4, pp. 14-17, 2014.

[41] Bauca, P., "Development of Gamma Camera for Medical and Nuclear Physics Application" *Doctoral Thesis,* Department of Electronics and Information, Politechnico Di Milano, Italy, pp. 1-5, 2013.

[42] U. Sarker, T. Swaroop and R. Kumar "Development of Mobile Robot for Remote radiation measurement*";adfa P.I, Research Gate,* pp.2-7, 2011.

[43] M. J. Bakari, K. M. Zied and D. W. Seward "Development of a Multi-Arm Mobile Robot for Nuclear Decommissioning Tasks", *International Journal of Advanced Robotic Systems,* vol. 4, no. 4, pp. 387-406, 2007.

[44] Y. Qiang, G. Quanjie, and L. Haoming,"Research on a kind of nuclear and chemical reconnaissance robot", *Communications in Computer and Information Science*, vol.152, Jan., pp.165-170, 2011.

[45] S. S. Saini, U. U. Sarkar, T. T.Swaroop, D. D. Ray and N. D. Badodkar, "Development of Technologies for Remote Surveillance and Radiation Measurement", *BARC Newsletter Founder's Day Special Issue,* paper 20, pp. 172-174, 2015.

[46] R. Meghdari and M. Salehi, "General Impact of Robotics and Automation in Radiation Environments", *ICHLNR, Nov.,* pp. 237-247, 1990.

[47] R. Maheswaran, S. Muruganand and K.B. Dinesh, "Nuclear Power Plant Robots Monitoring and Control Using Lab View," *International Journal of Advanced*

Research in Computer and Communication Engineering, vol. 5, no. 7, Jul., pp. 30-39, 2016.

[48] L. F. Michael and E. Annuziata, "Radioactivity: Introduction and History", *Oxford*, UK, 2007.

[49] B. R. Amy, "The history of radiation use in medicine" *Journal of Vascular Surgery*, Jan., pp. 3-5, 2011.

[50] M.N. Paulo, "A Brief History about Radiotherapy," *International Journal of Latest Research in Engineering and Technology*, vol. 4, no. 2, Feb., pp. 8-11, Feb 2018.

[51] Dr. Ch. Desaintes, Dr. G. N. Kelly and Ms. K. Coifrard, "Understanding the effects of radiation on health", *European Commission community research*, 2002.

[52] F. N. Flakus, "Detecting and measuring ionization radiation- short history," *IAEA Bulletin*, vol. 23, no.4. pp. 31-36, 2004. A. L. Edward, Radiation Biophysics, *Academic Press 1998*, pp. 222-272, 1998.

[53] World Nuclear Association, "*World Nuclear Performance Report 2018". pp. 7-10, 2018.*

[54] IAEA, "*Safety standards for protecting people and the People: Fundamental safety Principal".* no. SF-1, pp. 1-4, Internal Atomic Energy Agency, Vienna, Austria, 2006.

[55] IAEA, *"International safeguards in nuclear facility design and construction"*. no. NP-T-2.8, pp. 5-8, Internal Atomic Energy Agency, Vienna, Austria, 2013.

[56] IAEA, *"Nuclear Security Recommendations on Radioactive Material and Associated Facilities"*. no. 14, pp. 5-10, Vienna, Austria, 2011.

[57] P. Maria and C. U. Alexandra, "Gamma Radiation for Improvements in Food Industry, Environmental Quality and Healthcare," *Romanian J. Biphys*, vol. 25, no. 2, Bucharest, pp. 143-162, 2015.

[58] G. S. J. Antonio, G. A. A. Enrique, R.M.A. Pedro, B.S. Alfredo and R. A. David, "Ionizing Radiation Measurement Solution in A Hospital Environment," *Sensors*, vol. 18, no. 2, pp. 2-4, 2018.

[59] IAEA, "*Symposium on International Safeguards*" no. CN267-131, pp.20-25, International Atomic Energy Agency, Vienna, Austria, 2018.

[60] Almgren, S., "Studies on the Gamma radiation Environment in Sweden with special Reference to137_{Cs}" *Doctoral Thesis*, Department of Radiation, GÖteborg University, Sweden, 2008, pp. 1-4.

[61] S. Alexander, "Use of concrete as a biological shield from ionizing Radiation: Energy and Environmental Engineering," *Harison Research publication,* 2013, pp. 90-97.

[62] B. P. Gloria, G. M. Greg, J. A. Pursley, T. E. Espenhahn, C. Fraisse, D. J. Godfrey, M. Oldham, T. B. Carrea, N. Bolick, and C. W. Scarantino,"An Implantable MOSFET Dosimeter for the Measurement of Radiation Dose in

Tissue During Cancer Therapy” *EEE Sensors Journal*, vol. 8, No. 1, Jan., pp. 38-51, 2008.

[63] C. Adam, J. Garnier–Laplace and S. Roussel-Debet, “Radionuclide fact sheet cobalt-60 and the environment*”, IRSN,* pp. 1-10, 2001.

[64] O. Makiko, H. Naomi, T. Yasuyuki, F. J. Yoshiko, E. Yuuko, K. Takashi, Y. Shunichi and T. Noboru, “Measurement of Individual Doses of Radiation by Personal Dosimeter is Important for the Return of Residents from Evacuation Order Areas after Nuclear Disaster”, *Plos One*, Mar., pp. 3-11, 2016.

[65] A. Budiman, G. Santoso, F. Amri, S. Hadisaputro, M. C. Anwar, and R. Indrati, “The design of digital instrument connected to android based smartphone to measure radiation,” *International Journal of Allied Medical Science and Clinical Research*, vol. 6, no.1, Jan., pp. 1-5, 2018.

List of Publications:

[1] Conference Processing

Rokonuzzaman, M. and Dr. Khan, R. A., "Cost Effective Electronic Device for Detecting, Measuring and Visual Monitoring of Radiation Doses," *The Proceeding of the International Conference on Mechanical Engineering and Design 2018,* Lankawi, Malaysia, 2018, pp. 38.

[2] Journal Paper

M. Rokonuzzaman and Dr R. A. Khan, "Cost Effective Electronic Device for Detecting, Measuring and Visual Monitoring of Radiation Doses," *International Journal of Smart Grid and Clean Energy*, vol. 7, no. 4, Oct., pp. 271-275, 2018.

Appendix:

A-1: International Conference Proceeding (ICMED 2018)

Langkawi Mar.23-25, 2018

ICMED2018

2018 International Conference on Mechanical Engineering and Design

Notification of Acceptance of ICMED 2018

Langkawi; March 23-25, 2018.
http://www.icmed.org/

Paper ID : E-ED019	
Paper Title : Cost effective electronic device for Detecting, Measuring and Visual Monitoring of Radiation Doses	

Dear Engr Md Rokonuzzaman Peng, Dr Ruhul Amin Khan,

Congratulations! The review processes for 2018 International Conference on Mechanical Engineering and Design (ICMED 2018) has been completed. The conference committee received submissions from nearly 10 different countries and regions. Based on the recommendations of the reviewers and the Technical Program Committees, we are pleased to inform you that your paper identified above has been accepted for publication and oral presentation. You are cordially invited to present the paper orally at ICMED 2018 to be held during March 23-25, 2018, Langkawi.

Your paper will be published on SGCE. (International Journal of Smart Grid and Clean Energy)

ISSN: 2315-4462 (Print); ISSN: 2373-3594 (Online); Indexed by: Scopus, EI (INSPEC, IET), DOAJ, Ulrich's Periodicals Directory, Google Scholar, Crossref, etc.

(Important) So in order to register the conference and have your paper included in the proceedings successfully, you must finish the following steps.

1. Revise your paper according to the Review Comments in the attachment carefully.

2. Format your paper according to the Template carefully.

http://www.ijsgce.com/uploadfile/2013/0330/20130330071050491.doc (DOC Format)

3. Download and complete the Registration Form.
http://www.icmed.org/author-reg.docx (English)

4. Finish the payment of registration fee by Credit Card. (The detailed information can be found in the registration form.)

5. Send your final papers (both .doc and .pdf format) and filled registration form (.doc format) to us at **icmed@iact.net** . (February 15, 2018.)

6. Download and Scan the copyright form

http://www.ijsgce.com/uploadfile/2016/0318/20160318044731908.pdf

Please strictly adhere to the format specified in the conference template while preparing your final paper. If you have any problem in preparing the final paper, please feel free to contact us via **icmed@iact.net**. For the most updated information about the conference, please check the conference website at http://www.icmed.org/. The Conference Program will be available at the website in Feb. 2018.

Finally, we would like to further extend our congratulations to you and we are looking forward to meeting you in Langkawi!

Yours sincerely,

Organizing Committee of ICMED 2018
http://www.icmed.org/
Langkawi Malaysia

Conference Abstract

The 6th International Conference on Nanomaterials and Materials Engineering

(ICNME 2018)

2018 International Conference on Mechanical Engineering and Design

(ICMED 2018)

March 23-25, 2018

Langkawi, Malaysia

Supported by:

Published by:

dimensions. A sinusoidal wave vibration was applied to the model as the seismic excitation. The positive half of the wave cycle resulted in a an adverse pressure gradient, which led to a reversed flow of the fluids in the domain. Consequently, we started the excitation at the negative half of the wave cycle, which applies a favorable pressure gradient. The favorable pressure gradient resulted in a viscous pressure that overcame the capillary pressure holding the oil globule. Consequently, the oil globule was squeezed out of pore 2 and mobilized. The trapped oil globule was successfully mobilized by the effect of the seismic wave excitation.

E-ED019

Time: 17:30-17:45

Cost effective electronic device for Detecting, Measuring and Visual Monitoring of Radiation Doses

Engr Md Rokonuzzaman Peng,Dr Ruhul Amin Khan
Military Institute of Science and Technology (MIST), Dhaka, Bangladesh, BAEC.Bangladesh

Abstract:
Ionization Radiation is one of the major concerns for using nuclear energy. It carries more than 10eV energy which is enough to ionize atoms and molecules and break chemical bonds. Radioactive materials emit alpha, beta, or gamma radiation, positrons, and photons, respectively. The use of ionization radiation offers several advantages like the sterilization of foods, medical devices, laboratory, research, agricultural fields and many other industrial applications.
A Cobalt-60 source having present capacity of 140kCi has been used in this investigation. Survey meter can measure the level of radioactive contamination, radiation dose rate in a certain place. Few devices which can visualize the distribution of radiation intensity were already developed. However, the above mentioned devices cannot identify the locations of the radiation sources.
At present, Robots are being used for highly radioactive sources to measure its intensity at its close position where radiation workers cannot safely enter but it is very expensive, not user friendly and difficult to handle due to its heavy weight and modern technology. Gamma ray protective cameras are also very costly. In the research, the information of complete dose levels of source room have been obtained with the help of Amber Dosimeter during the application of source and developed cost effective electronic device for detecting, measuring and visual, monitoring of radiation doses. Through the developed device, the position of highly radioactive sources (Cobalt-60) is visualized and detected during its applications with the help of a Closed Circuit (CC) camera shielded by a Lead (Pb) box in a way that the lenses of the camera are placed toward mirror to take fix and video images of source and its room. CC Camera is connected with the computer in a safe zone of control room to visual monitoring the real situation inside the source room.

B-1: Publication in Internal Journal (IJSGCE)

Review Form of ICMED 2018

Langkawi, Malaysia, March 23-25, 2018.

http://www.icmed.org/

Paper Title: Cost effective electronic device for Detecting, Measuring and Visual Monitoring of Radiation Doses

Evaluation(● where appropriate)

	Exceptional	Very Good	Good	Fair	Poor
Relevance			●		
Originality			●		
Significance			●		
Technical soundness			●		
Clarity of presentation/ language			●		

Final Evaluation

☐Excellent ☐Very Good ■Good ☐Fair ☐Poor

Recommendation

☐Strongly Accept ■Accept ☐Marginally Accept ☐Reject ☐Strongly Reject

Comments and Instructions:

The paper accords to the reality, discussing about Cost effective electronic device for Detecting, Measuring and Visual Monitoring of Radiation Doses. The originality, innovation and applicability of this paper are done well. For every point, the author gives a detail explanation to help easily understanding. However, a small point need to be improved is that the abstract can be shortened for people know the theme directly. Please make some improvements.

Modify your format according to the template.

Cost effective electronic device for detecting, measuring and visual monitoring of radiation doses

Md Rokonuzzaman[a] , Ruhul A. Khan[b] *

[a] *Department of Nuclear Science and Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh*
[b] *Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh*

Abstract

Ionization Radiation is one of the major concerns for using nuclear energy. It carries more than 10eV energy which is enough to ionize atoms and molecules and break chemical bonds. Radioactive materials emit alpha, beta, or gamma radiation, positrons, and photons, respectively. The use of ionization radiation offers several advantages like the sterilization of foods, medical devices, laboratory, research, agricultural fields and many other industrial applications. A Cobalt-60 source having present capacity of 140kCi has been used in this investigation. Survey meter can measure the level of radioactive contamination, radiation dose rate in a certain place. Few devices which can visualize the distribution of radiation intensity were already developed. However, the above mentioned devices cannot identify the locations of the radiation sources.
At present, Robots are being used for highly radioactive sources to measure its intensity at its close position where radiation workers cannot safely enter but it is very expensive, not user friendly and difficult to handle due to its heavy weight and modern technology. Gamma ray protective cameras are also very costly. In the research, the information of complete dose levels of source room have been obtained with the help of Amber Dosimeter during the application of source and developed cost effective electronic device for detecting, measuring and visual, monitoring of radiation doses. Through the developed device, the position of highly radioactive sources (Cobalt-60) is visualized and detected during its applications with the help of a Closed Circuit (CC) camera shielded by a Lead (Pb) box in a way that the lenses of the camera are placed toward mirror to take fix and video images of source and its room. CC Camera is connected with the computer in a safe zone of control room to visual monitoring the real situation inside the source room.

Keywords: Ionizing radiation monitoring, Cobalt-60 source, CC camera, cost effective, radioactive contamination, amber dosimeter

1. Introduction

Radiation is defined as the emission or transmission of energy in the form of waves or particles through space or through a material medium. Radiation is categorized as (i) Ionizing (ii) Non-ionizing depending on the energy of the radiated particles. Ionizing radiation carries more than 10eV which is enough to ionize atoms and molecules and break chemical bonds. This is an important distinction due to the large difference in harmfulness to living organisms. A common source of ionizing radiation is radioactive materials that emit alpha, beta, or gamma radiation, consisting of helium nuclei, electrons or positrons, and photons, respectively

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive material may also be of artificial origin and they have many beneficial applications, including uses in power generation, medicine, industry, agriculture, and research. Exposure

* Manuscript received May 29 , 2018; revised August 10, 2018.
Corresponding author. ; E-mail address: dr.ruhul_khan@yahoo.com
doi: 10.12720/sgce.7.4.271-275

of human tissues or organs by radiation can induce the death of cells on a scale that can be extensive enough to impair the function of the exposed tissue or organ. Effects of this type are called 'deterministic effects' are clinically observable in an individual only if the radiation dose exceeds a certain threshold level. Above this threshold level of dose, a deterministic effect is more severe for a higher dose.

There are several devices to measure radioactivity. One popular device is Survey Meter which can measure the level of radioactive contamination, radiation dose rate in a certain place. However, it cannot identify the locations of the radiation sources. Few devices which visualize radiation intensity distribution have already been developed. Laboratory counters which is used to identify and quantity of radioactive material, and Personnel Dosimeter is used to measure the accumulated dose to individuals working the radiation environment.

At present, robots are using for highly radioactive sources to measure its intensity at its close position where a radiation worker cannot safely enter. But Robots are very expensive and very difficult to handle due to its heavy weight. In Bangladesh, few highly radioactive sources are using for research and commercial irradiation of food and medical products. Gamma ray protective cameras are also very costly.

The application of gamma radiation is becoming more widespread every year. Over the past four decades, there has been a continuous and significant growth in the development and application of radiation techniques. The use of gamma radiation offers several advantages, such as continuous operation, minimum time requirement, less atmospheric pollution, curing at ambient temperatures and increased design flexibility through process control. Gamma Radiation can also be used for the sterilization of food and medical devices.

In this investigation, an electronic device has been developed and connected with the computer which is placed in control room (safe zone) for visual monitoring of highly radioactive source. In our study, a gamma irradiation facility of Bangladesh Atomic Energy Commission (BAEC) has been used which is situated at the Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh. The source was established in 2010. The initial activity of the source was 350 kCi but the present capacity is 140 kCi. Amber Dosimeters have also been used to find out the radiation level in the source room during its application with time duration.

2. Method and Materials

The dose levels of Cobalt-60 source (350 kCi Gamma irradiation plant) at IRPT, AERE are measured from different points of source room by using Amber Dosimeter and Ultra-Violet Spectroscopy. Amber dosimeters have been kept in five groups (Five Amber dosimeter in each group) at the five places of source room at a time as group identity 1 to 5 for 15, 30, 60, 120, and 180 minutes respectively. After all necessary protective measures, the source has been pulled up from the source pool (water) and put in the proper place for 15 minutes. After 15 minutes the source has been pulled down to put inside the source pool (water) and Amber dosimeter of group identity-1 is collected safely. The repeated works are done for group identity 2, 3, 4 and 5 after the time duration of 30, 60, 120 and 180 minutes respectively. The dose levels were then calculated in the laboratory of IRPT with the help of Ultra-Violet Spectroscopy and standard charts. The obtained dose levels of different points of Gamma irradiation source room have been analyzed.

The investigation for visual monitoring of source and source room has been carried out by developing the electronic device with the help of computer, closed circuit (CC) camera, stainless steel frame with bolts, Lead box, Lead mirror, electrical cable, cable connector and Amber Dosimeters. Some basic tools were also used to develop the device and measure dose levels which are basic electrical tools and devices, survey meter, dosimeter. A lead box is fabricated from the lead sheet measuring 180 x 135 x 175 mm with the thickness of 25 mm (Fig.2).

The objective to place CC camera is to monitor the source visually to observe the real situation inside the source room. The CC camera of electronic device is shielded by fabricated Lead (Pb) box so that the lens of the camera can visualise Lead glass. It is kept in mind to place the CC camera that the radiation cannot fall directly on lens; hence it cannot be damaged due to high radiation effect. During the application of the source, the source is pulled out from the source pool (water) and CC camera is able to take the fix and video images which can be monitor visually and detecting the source position for the times of operation and the real situation of the source room. In order to investigate the effectiveness of the developed device the video and fixed images are closely observed with different angles, rotation and zooming. A block diagram of the developed device is shown Fig.1.

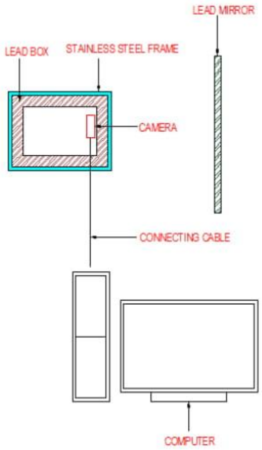


Fig.1. Block diagram of the developed device

Fig.2. Lead Box with Stainless steel frame

3. Cost Analysis

Cost analysis of the developed system has been carried out and detailed are shown in Table 1. It is evident that within 550 USD the device has been developed, which is more economic than the existing devices. The materials are very common and available in the local market of Dhaka, Bangladesh. The required materials are economic and fabrication of required frame and box is not so complicated. The developed device is not that much sophisticated than the existing devices.

Table 1. Cost analysis of the device

Sl.	Item	Cost (USD)
1	CC Camera	60.00
2	Lead Box	100.00
3	Computer	325.00
4	Cable with connector	25.00
5	Stainless steel Frame	15.00
6	Fabrication	25.00
Total		550.00

4. Result

The dose rates obtained from the amber dosimeter with the help of standard chart and Ultra-Violet Spectroscopy of laboratory of IRPT. The results are plotted in the graph and found linear along with time duration. The doses are found 2.09 KGy, 4.49 KGy, 8.23 KGy, 16.23KGy and 22.52 KGy with respect to time duration of 15, 30, 60,120, and 180 minutes respectively.

During visual monitoring, when the source was pulled out the screen was slightly pinkish blurred with some noise in the screen, but no permanent damage was noticed. This noise also can be considered an indication of presence of Gamma irradiation of Co-60 source.

In this investigation maximum duration of use of device was three hours and we did not found any abnormalities with the devices and no damage was found at all in the system.

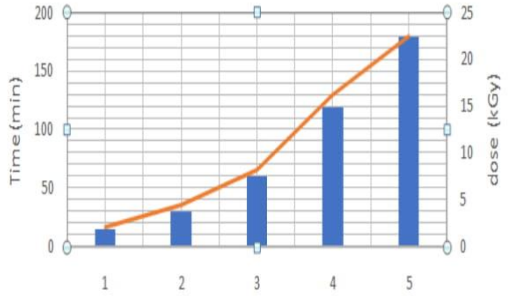


Fig.3. Time VS Dose Graph

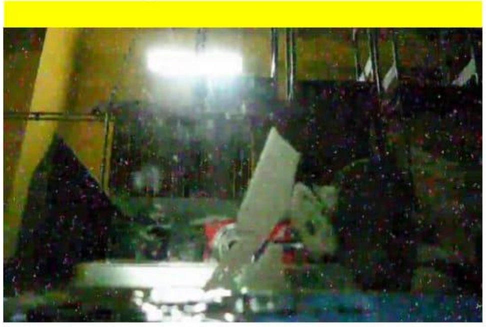


Fig.4. Footage captured from the device

5. Discussion

The study is performed for maximum duration of three hours. For practical uses, further study may be carried out to use the device for longer period of time in similar range of radiation doses.

It has been found that the developed device is less expensive than the existing devices and easy to manufacture even in the developing countries of the world.

In our study, the device is placed manually but it can be possible to place the device by incorporation of remote control programming system which may be further scope of research connected to this study.

As the signal of the camera did not disappear completely during the test so it is not considered as complete failure, however, picture quality degraded. The radiation effect on camera sensors is beyond the scope of this study. The objective of the study is to make the device as economic as possible, so "radiation hardened" Charged Coupled Device (CCD) sensors are also not taken into consideration.

However, for the use of regular basis the effect of radiation on the camera sensors should be investigated further. Hence the camera can be used for general viewing for the period of three hours but device may get or may not get any problem to perform continuous visual monitoring the source for a longer period of time.

Acknowledgment

First of all I would like to show my sincere gratitude to the management of 2018 ICME, Dr Ruhul Amin Khan, Director, IRPT, my supervisor and the second author of the paper, Head of NSE deptt, Col Abu Zafor Md Salauddin, Program Coordinator, Major Altab Hossain, PhD and Management of EGCB for highest level of cooperation to complete the study. I would also like to give special thanks to Ms Dana D. Chen, Conference Secretary and Organizing and Technical Committee of 2018 ICMED for excellent support. I am also gratified to all staffs of Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment (AERE) and laboratory technicians of IRPT, Savar, Dhaka, Bangladesh. Without their help and assistance it was not possible to complete my study. I would also like to thanks to my classmates Ashikur Rahman and Md Muminul Haque who assist me in the laboratory to complete my study. This works was supported in part by grant from IRPT, AERE, Savar, Dhaka, Bangladesh.

References

[1] Kataoka J, et al., "Nucl. Instrum. Methods" *A 732 (2013) 403.*
[2] Kataoka J, et al., "Nucl. Instrum. Methods" *A 784 (2015) 248.*
[3] Haefner A, et al., "Nucl. Instrum. Methods" *A 857 (2017) 42.*
[4] Ueno Y, et al., "Nucl. Instrum. Methods" *A 822 (2016) 48.*
[5] Adam A, Rivlin E, Shimshoni I. Robust fragments-based tracking using the integral histogram. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR),* June 17-22, 2006. In;1:798–805.

[6] Benfold B, Reid I. Stable multi-target tracking in real-time surveillance video. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR). 2011: 3457–3464.*
[7] Charlesby A, Swallow, A. J. Radiation Chemistry. Annual Reviews in Physical Chemistry. *1959 10:289.*
[8] International Atomic Energy Agency, "Advanced Radiation Chemistry Research: Curing Status", *IAEA-TECDOC-834, 1995, Vienna, Austria.*
[9] Chappas WJ, Grossman N, Pourdeyhini EB. Manufacturing of polymer fiber composites vehicle structures. *Proceedings of the 10th Annual Advanced Composites Conference, Dearborn, Michigan, USA, 1994, 7–10 November.*
[10] Khan RA, Salmieri S, Dussault D, Calderon J, Kamal MR, Safrany A, Lacroix M. Production and properties of nano-cellulose reinforced methylcellulose-based biodegradable films. *Journal of Agricultural and Food Chemistry, 2010; 58:7878–7885.*
[11] Khan MA, Khan RA, Zaman HU, Hossain MA, Khan AH, Effect of gamma radiation on the physico-mechanical and electrical properties of jute fibre reinforced polypropylene composites. *Journal of Reinforced Plastics and Composites, 2009; 28(13):1651–1660.*
[12] Lee W, Cho G, Kim HD, A radiation monitoring system with capability of gamma imaging and estimation of exposure dose rate, *IEEE Transactions On Nuclear Science, 49(3); 1547-1551, June 2002.*
[13] Ghoshal S, Khan MA, Noor FG, Khan RA. Gamma radiation induced biodegradable shellac films treated by acrylic monomer and ethylene glycol. *Journal of Macromolecular Science, Part A, Pure and Applied Chemistry, Vol. 46, 2009, pp. 975–982.*
[14] Zaman, HU, Khan RA, Khan MA, Khan AH, Hossain MA, Effect of γ radiation on the performance of jute fabrics reinforced polypropylene composites. *Radiation Physics and Chemistry, Vol. 78, 2009, pp. 986–993.*
[15] Koichi O, Takahiro T, Yuichiro U, Jun N, Takafumi I, Isao T, Yasutake F, Katsumi H, Kenichi, N. Development of a gamma camera to image radiation fields. *Progress in Nuclear Science and Technology, Vol. 4, 2014, pp. 14-17.*
[16] Kalal Z, Mikolajczyk K, Matas J. Tracking-learning-detection" IEEE Trans. Pattern Analysis Mach. Intell. 34 (7), 2012, pp. 199–206.