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Radioactivity Assessment Of Radiological Waste ^{131}I Applied To The Patients Of National Institute Of Nuclear Medicine & Allied Sciences(NINMAS) At BSMMU, Bangladesh

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Abstract:
All type of radiological substances is harmful for living objects, especially for human beings. Modern science is producing a number of radioisotopes and applying them for the diagnosis or treatment the patients in worldwide in nuclear medicine. In Bangladesh there are one National Institute of Nuclear Medicine and 16 Nuclear Medicine Centers. Thousands of patients are being given treatment and diagnosis every working day. The concern doctors and medical technologists are providing services using appropriate doses of isotopes like ^{131}I, ^{99m}Tc etc. Maximum people don't have enough knowledge on radionuclides/isotopes, radioactivity and their cell damaging capabilities. Even, the concern medical technologists and the patients are not given proper instructions & protections to save them from radiation hazards. Considering safety purposes, maintenance and keeping radio-isotopes within 'lead shielding' is another essential task. This study is for the assessment of used isotopes and their activity disintegration process. The experiments and obtained spectrum data would provide the real scenario of the environment around NINMAS, Dhaka.

Background:
Artificially produced radioisotopes ^{131}I and ^{99m}Tc are mostly used in nuclear medicine for therapy treatment and thyroid diagnosis. The radioactivity of these two isotopes is high enough. Half-life of these two are eight days & six hours respectively. Radiation may spread out to other patients or peoples if the protection is not taken accordingly. Contamination of any type of radiological substances is harmful for human beings if the activity is high enough and long half-life. The waste samples (isotopes) may be taken under experiments using 'Gamma Spectrometry' data acquisition setup to make a baseline data that may provide primary situation of the environment.

Materials and Methods:
The primary objective of this study is to characterize the radiological waste of isotopes ^{131}I and ^{99m}Tc used in National Institute of Nuclear Medicine & Allied Science at BBMU. ^{137}Cs and ^{60}Co point sources were used for the energy calibration of 'Gamma Spectroscopy' data acquisition setup. The gamma energy lines 661.7 keV from ^{137}Cs and 1173.5 keV & 1332.7 keV energy line from ^{60}Co were applied for energy calibration. Detector counting efficiency calibration was also done using the gamma energy lines emitted from ^{131}I radioisotopes.

Results:
The main unit of the 'Gamma spectroscopy' data acquisition setup is HPGe detector. For better results, detector efficiency calibration has been done using known gamma energy lines. This counting efficiency is essential for the calculation of radioactive concentration.

Conclusion:
'Gamma data acquisition setup' used for this research works was checked the efficiency calibration curve explained the efficiency of the detector. From the spectrum of different energy lines emitted from Iodine-131 (^{131}I) were characterized.

Key Word*: HPGe, MCA, NINMAS, Radiation, Shielding, Gamma, Efficiency, Calibration.*

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I. Introduction

This research work reported that radiological assessment of medical waste which is disposed in the environment. The wastes have foretold the uplift of human and other living beings, as well as all natural resources that are necessary to human existence. Iodine-131 radio-isotope is widely used in therapy to treat thyroid cancer (Mrozik, Rajaeifar et al. 2021). The patient would be awarded and quarantined for a few days, until the activity of ^{131}I becomes less than 30 mCi in patient's body. Patient is being orally ingested ^{131}I and warded within 4 to 5 days for RAI therapy. Earlier concept was to have delay tank to store urine and feces excreted from patients. According to IAEA, dated 2010-02-23, the policy on delay tank and criteria for releasing patients, treatment may to cautions and costly to implement (Amaral 2010). There is no evidence that storing urine in delay tanks produce any health benefits. In regards to delay tanks, the IAEA recommends that waste activity should be diluted and dispersed in continuous sewage system rather than stored in delay tanks. But it's essential to study the radiological effect of medical waste in nuclear medicine on environment specially contaminated waste syringe of ^{131}I and ^{99m}Tc which carry radionuclides (Almahi 2016).

Gamma radiation is harmful to human body that could not be protected without appropriate shielding. The nucleus is occasionally created in an excited condition when an unstable nucleus decays into a more stable nucleus. A gamma-ray photon is released as a consequence of the daughter nucleus's subsequent relaxation to a lower energy state. Uncharged electrons are gamma-ray photons(Dendy and Heaton 2011). A photoelectron is released when a gamma ray combines with an electron in an atom's inner shell, which causes the photoelectric effect. This is the most significant impact for gamma ray detection using semiconductor detectors.

II. Material and Methods

'Gamma Spectroscopy' data acquisition setup developed in the Accelerator Facility Laboratory of Atomic Energy Centre, Dhaka. The newly developed setup with other facilities needed was applied for all of the experiments. The energy calibration of this counting system was conducted using point sources ^{137}Cs & ^{60}Co which provided by IAEA.

Figure 1: Gamma radioactive point sources^{137}Cs & ^{60}Co along-with others.

Figure 2: Used Iodine-131(^{131}I) syringe as waste with Lead Shielded holder.

Gamma-ray Spectroscopy System

The newly developed 'Gamma Spectroscopy' system at accelerator laboratory of Atomic Energy Centre, Dhaka may be applied for the detection & analysis of different radionuclides accumulated in substances. Any type of samples may be placed in the lead shielded chamber for experiment. The basic block diagram with main units of gamma data acquisition setup is given below; (Abedin, Akter et al. 2013).

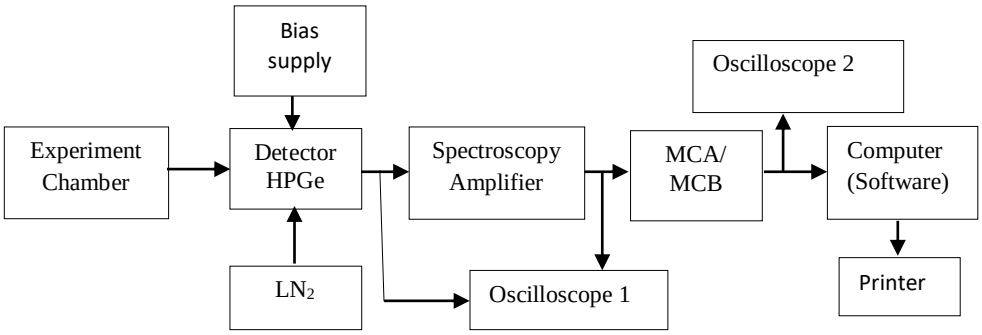

Figure 3: Block diagram of 'Gamma Spectroscopy' data acquisition setup

Lead Shielded Chamber

The experiment chamber is fabricated in such a way that no background radiation can get a way for entrance into chamber. The head of the HPGe gamma detector is being positioned and fixed inside the lead-shielded chamber. The wall thickness of the round shaped experiment chamber is 76 mm, the upper cover thickness is also same and is being operated by thread mechanism. LN_2 pouring facility is also incorporated within the chamber-base shown in the figure given below.

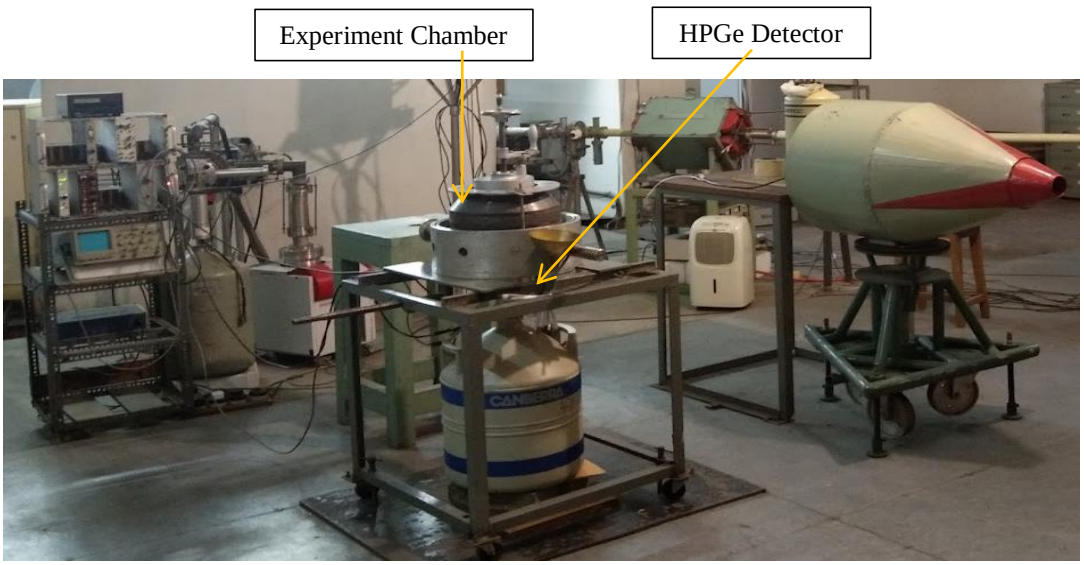

Figure 4: Photograph of Gamma Experiment Chamber with major units

HPGe Detector

Photon radiation detectors with semiconductors as their main component have been developing for more than 50 years. High Purity Germanium analyzers are being designed for a variety of programs and a wide range of energies. The smallest part of the container base has an HPGe (vertical) strong state detector (Wallbrink, Walling et al. 2003) with a 30 liter Dewar positioned perpendicular to the pattern-holder, the detector is a GC-12175 model from Canberra. LN2 is used in order to minimize noise/eddy current to the absolute minimum level. 3.5KV regulated bias supply (positive) is provided to activate the detector. An oscilloscope is connected with the setup to check the output of preamplifier, spectroscopy amplifier and other units.

Spectroscopy Amplifier

The detected gamma photons were converted into voltage pulses by charge sensitive preamplifier and output is fed to the input gate of the spectroscopy amplifier (Model: 671, ORTEC). All units of the setup are NIM BIN based standard. Many functions are being done within the spectroscopy amplifier and the refined output is connected to the input gate of the Multi-Channel Analyzer.

Multi-Channel Analyzer

The MCA is the most important component of the Gamma Spectroscopy System. This unit, along with all others, is compatible with a well-regulated NIM BIN power module with ±6, ±12, and ±24 volts d.c power options. The outputs of amplifier are connected to the input gate of MCA. The microprocessor memory based MCA incorporates the input data, shapes & signal converts them into binary form and so many functions are done by different circuitry within a fraction of second. ADC also measures and sorts the pulses based on their amplitudes. Digital signals propagate more efficiently than analog signals, owing to the fact that digital impulses are easier for electronic circuits to distinguish from noise. Output of MCA is connected to the computer in which the software Genie-2000 is installed previously. All the functions of data acquisition is controlled by the Genie-2000 software.

Sampling

Through the permission of the concern authority of NINMAS at BSMMU, the wastage syringes of Iodine-131 were taken to Accelerator Laboratory within lead shielded box. The syringes of Iodine-131 were taken under experiment carefully and the gamma photons were detected, the spectrums were analyzed and output data were printed. Half-life of this isotope is eight days and up to ten half-lives, the measurements were repeated for its disintegration assessment.

Figure 5: Lead Shielded holder of ^{131}I

Figure 6: Solid Non Sharp Lead Container for Preservation^{131}I

Figure 7: Lead Container for Preservation wastages

The concern medical technologists, most of the time, don't take care to preserve the radiological wastages in proper ways. So, radiation hazards may spread out anywhere (Murphy, Balter et al. 2007). Some radionuclides having long half-lives which contaminate in environment and constantly exposed of ionizing radiation.

III. Result (Energy Calibration)

The standardization of experiment setup is a necessary prerequisite for research projects. The energy calibration of the 'Gamma Spectroscopy' data acquisition setup is done using a point source ^{137}Cs (1.109 µCi, #214-17-103, dated: 04-01-88), and ^{60}Co (0.958 µCi, #214-17-153, dated: 04-01-88) (Gouda, Badawi et al. 2015). The experiment shows; 661.7 keV, 1173.5 keV and 1332.7 keV energy lines. Figure 8 shows the predicted gamma energy lines emitted from these two isotopes for ^{137}Cs and ^{60}Co.

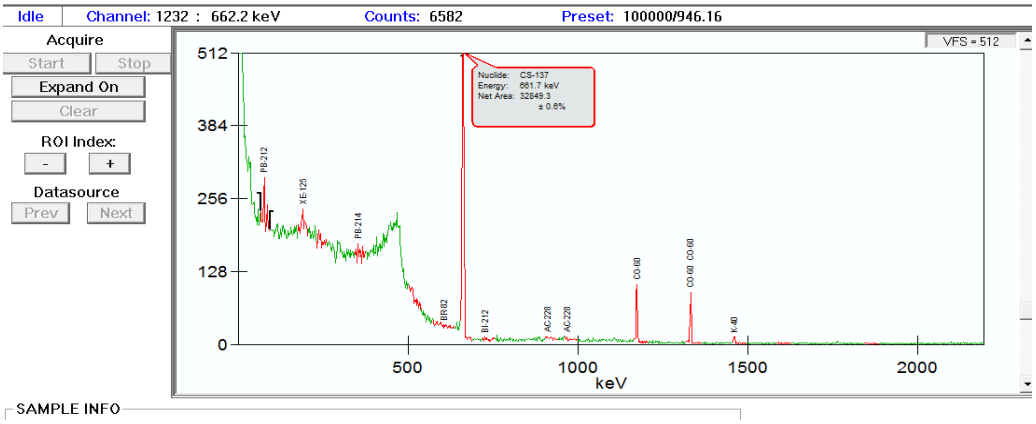

Figure 8: Analyzed energy lines from 'Gamma Spectrometry' system.

Activity calculations for the ^{137}Cs & ^{60}Co point sources at the moment of the experiment are as follows: Activity calculation for ^{137}Cs; $A = A_0\, e^{-\lambda t}$;where, A_0 = Initial activity of ^{137}Cs is 41.033kBq. t = Time passed from manufactured =33.9 years, A = Present activity = ? Half-life ($T_{½}$) of ^{137}Cs = 30.5 years, $T_{½} = \frac{0.693}{\lambda}$ 0r, $\lambda = \frac{0.693}{T_{½}} = \frac{0.693}{30.5} = 0.02272131148\ y^{-1}$ or, $A = 41.033\text{kBq} \times e^{-.02272131148\times 33.9} = 18.99401941$ kBq. More than one half-life passed and total activity decreased = (41.033 −18.99401941) kBq = 22.03898059 kBq current activity of ^{137}Cs is 18.99401941 kBq, near about half of the initial activity. Activity Calculation for ^{60}Co; $A = A_0\, e^{-\lambda t}$;where, A_0 = Initial activity of ^{60}Co is 35.446 kBq , t = time passed from manufactured=32.9 years, A = Present activity = ? Half-life ($T_{½}$) of ^{60}Co = 5.24 years, $T_{½} = 0.693/\lambda$ So, $\lambda = 0.693/T_{½} = 0.693/5.24 = 0.1322519084\ y^{-1}$ or, $A = 35.446\text{ kBq} \times e^{-0.1322519084\times 33.9} = 35.446\text{ kBq} \times e^{-4.483339695} = 35.446\text{ kBq} \times 0.01129562615 = 0.4003847645$ kBq. More than six half-lives passed and total activity decreased = $(35.446 - 0.4003847645)$ kBq = 35.04561524 kBq is near about initial activity. Therefore, ^{60}Co's current activity of 0.4003847645 kBq is insufficient for setup calibration.

The calculation projected that half-life of ^{137}Cs has gone through one half-life and the ^{60}Co source has gone through more than six half-lives. As a result, the ^{60}Co point source is insufficiently strong; however, ^{137}Cs is still being used for the energy calibration of 'gamma data acquisition setup. The gamma energy line from

^{137}Cs 661.7 keV and from ^{60}Co 1173.5 keV & 1332.7 keV has been applied for energy calibration. (Abt, Caldwell et al. 2007).

Efficiency Calibration

Counting efficiency is one of the essential parts for radiological assessment of any sample. So, efficiency calibration of the gamma data acquisition is most important factor. The gamma energy lines from an used syringe of ^{131}I isotope has been applied for efficiency calibration. Accordingly, using the certified efficiency data file, the comparison of experiment & certified data is also shown (Abedin, Zamil et al. 2021). The analyzed and calculated efficiency curves are projected as below (Figure 10).

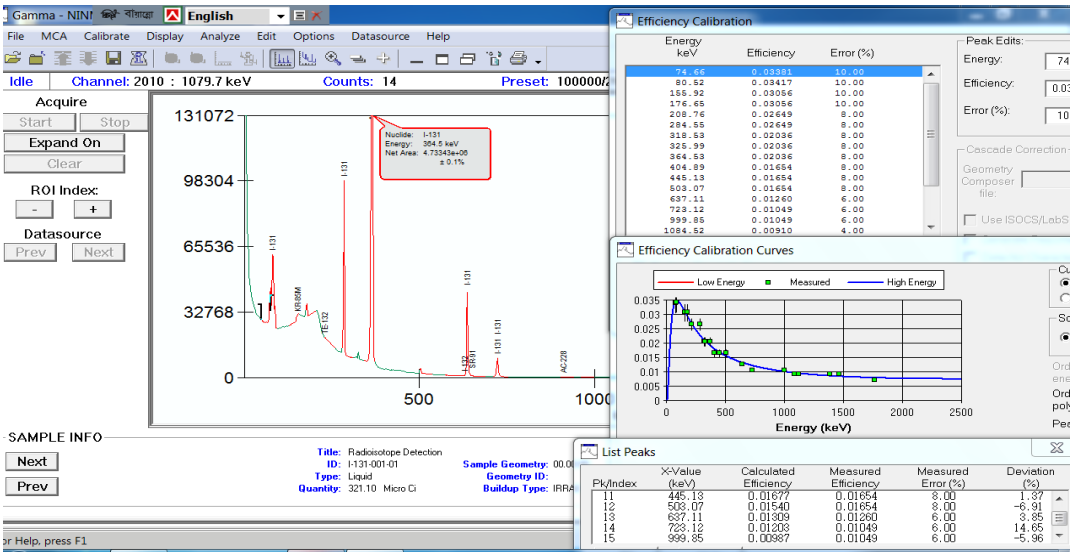

Figure 9: Detector Efficiency Calibration curve using energy lines of Iodine-131.

Table 1: Comparison of calculated & certified counting efficiency.

Energy (KeV)	Calculated efficiency	Certified /Measured efficiency	Measured error (%)	Deviation
74.66	0.03423	0.03381	10.00	1.24
80.52	0.03456	0.03417	10.00	1.14
155.92	0.03101	0.03056	10.00	1.47
176.65	0.02943	0.03056	10.00	-3.69
208.76	0.02712	0.02649	8.00	2.38
284.55	0.02264	0.02649	8.00	-14.52
318.53	0.02106	0.02036	8.00	3.42
325.99	0.02074	0.02036	8.00	1.86
364.53	0.01924	0.02036	8.00	-5.50
404.89	0.01791	0.01654	8.00	8.25
445.13	0.01677	0.01654	8.00	1.37
503.07	0.01540	0.01654	8.00	-6.91
637.11	0.01309	0.01260	6.00	3.83
723.12	0.01203	0.01049	6.00	14.65
999.85	0.00987	0.01049	6.00	-5.96
1084.52	0.00944	0.00910	4.00	3.71
1121.32	0.00927	0.00910	4.00	1.92
1378.59	0.00842	0.00910	4.00	-7.45
1460.33	0.00823	0.00910	4.00	-9.56
1762.93	0.00774	0.00699	4.00	10.66

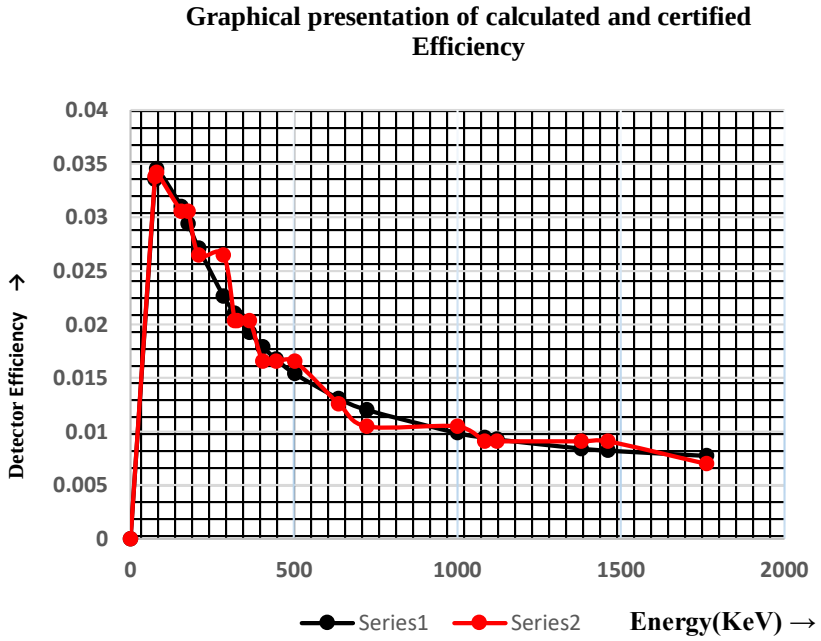

Figure 10: Graphical Comparison of calculated and certified efficiency.

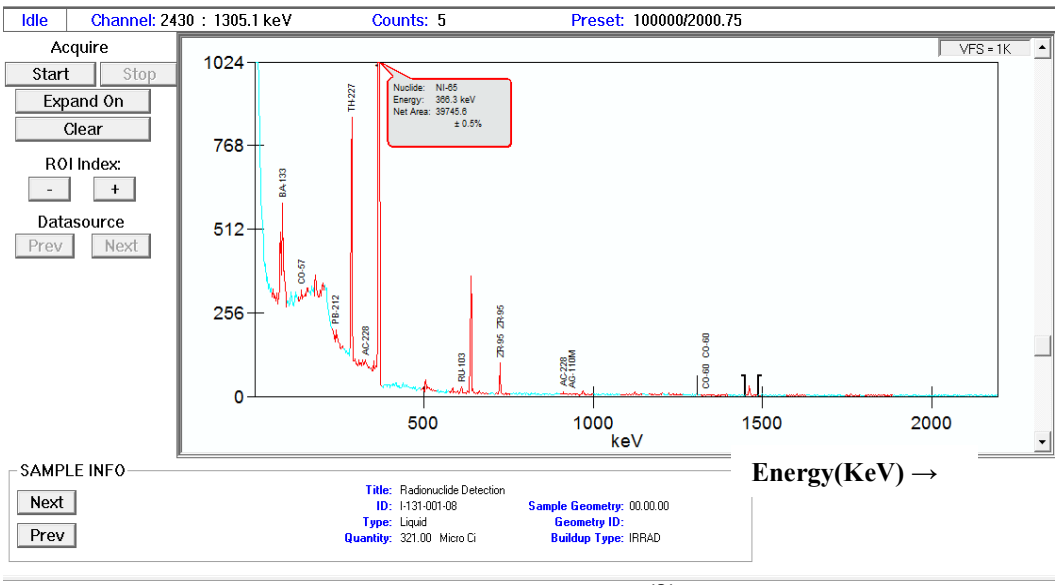

Figure 11: Spectrum of sample ^{131}I-001-08

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** P E A K A N A L Y S I S R E P O R T **

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Sample Title : Detection of energy line of ^{131}I
Sample Description : Wastages syringe (^{131}I)from NINMAS
Sample Identification : ^{131}I-001-08
Sample Type : Radioactive liquid
Initial Activity : 321.1 µCi
Live Time : 2000.8 seconds
Real Time : 2030.4 seconds
Dead Time : 1.46 %

Peak No.	ROI start	ROI end	Peak Centroid	Energy (keV)	FWHM (keV)	Net Peak Area	Net Area Uncert.	Continuum Counts
1	**126**	**170**	**148.58**	**80.83**	**3.12**	**1.646E+03**	**70.27**	**5.098E+03**
2	319	343	329.38	177.85	2.30	4.217E+02	176.58	7.445E+03
3	**519**	**542**	**529.29**	**285.13**	**2.46**	**3.791E+03**	**119.41**	**2.608E+03**
4	594	619	606.13	326.37	1.17	3.032E+01	98.90	2.293E+03
5	**660**	**697**	**678.80**	**365.37**	**2.47**	**3.908E+04**	**223.12**	**1.876E+03**
6	927	948	937.52	504.20	1.71	1.146E+01	40.02	4.195E+02
7	**1075**	**1201**	**1187.25**	**638.22**	**2.70**	**2.091E+03**	**49.31**	**1.073E+02**
8	**1336**	**1360**	**1347.60**	**724.27**	**2.01**	**4.130E+02**	**30.51**	**1.250E+02**
9	2709	2736	2722.22	1461.95	2.90	1.780E+02	16.52	2.100E+01

Duration of half-life (8 days)	Activity in (µCi)	Activity in (Bq)	Net Area				
			Spectra line-01	Spectra line-02	Spectra line-03	Spectra line-04	Spectra line-05
Initial	321.1	11.88E+06	1.992E+05	3.64E+05	8.17E+08	2.47E+05	6.29E+04
1st	160.55	5.94E+06	1.08E+05	2.26E+05	6.29E+04	1.18E+05	2.91E+04
2nd	80.275	2.97E+06	5.62E+04	1.29E+05	1.30E+06	7.17E+04	1.49E+04
3rd	40.1375	1.845E+06	2.58E+04	6.31E+04	6.39E+05	3.22E+04	7.22E+03
4th	20.0687	7.425E+05	1.18E+04	3.10E+04	3.90E+05	1.65E+04	3.30E+03
5th	10.0343	3.71E+05	7.96E+03	1.76E+04	1.76E+05	8.92E+03	2.03E+03
6th	5.01718	1.856E+05	2.30E+03	5.85E+03	5.84E+04	3.13E+03	7.32E+02
7th	2.50859	9.28E+04	1.646E+03	3.791E+03	3.908E+04	2.091E+03	4.130E+02
8th	1.25429	4.64E+04	6.916E+02	2.020E+03	1.921E+04	1.240E+03	2.452E+02

Table 2: Decay of the net area and activity of the sample for different half-life (Sample ^{131}I-001-08)
Activity of the sample is shown in below graphically:

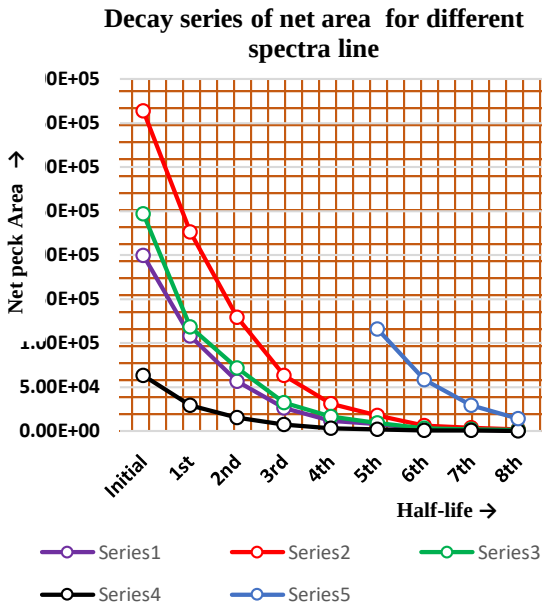

Fig12: Graphical presentation of Net area

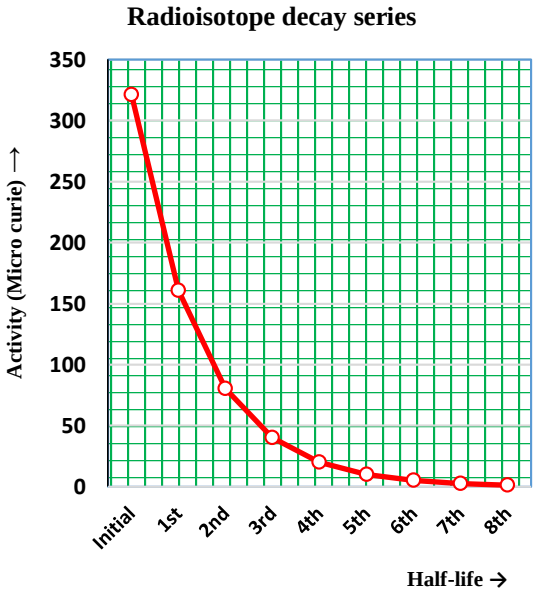

Fig13: Graphical presentation of Radioactivity of sample

IV. Discussion

Initially rate of disintegrations of the sample (^{131}I) is very high which is very much harmful for living body. During first half life number of unaffected atoms decreasing so rapidly after then the rate of disintegration is decreased gradually with increase the time. The radioactivity will be continued through a very long time. During 8th half-life the rate of disintegration falls down very low. In this stage radioactivity of the sample is less harmful for the environment and living body.

V. Conclusion

The research experiments show that the wastage syringe of Iodine-131 emitted five gamma energy lines shown in spectrum as figure-11. Activity disintegration according to its half-life is projected graphically in figure-12. The experiment chamber wall is enough protective for background radiation. Management and handling of radio-isotopes is the important factors due to overall health issue of employees, patients, the visitors and around the environment of any hospital. The authority may take proper steps to minimize the radiation spreading within & around the hospital and the people. Regular & concern data-base may be helpful to take proper action. So, a research program may be undertaken with a view to create an elaborate data-base in order to take appropriate precautions.

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