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Comparison of Calibration Factors of the Radiation Survey Meters

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Abstract. The purpose of this experiment was to compare the calibration factors for Cs-137 and Co-60 of six radiation measuring instruments in fast five years to evaluate the accuracy of radiation measurements of different instruments. For this comparison, we used survey meters with different type of gaseous ionization detectors mainly GM tube, Proportional counters and ionization chambers.

This research shows that, response of the survey meter for Co-60 radiation is higher than the Cs-137. Hence Calibration Factor for Co-60 radiation is much lower than the Cs-137. Calibration Factor of instrument remaining nearly stable within the regions of 0.1 to 10 mSv/h for the duration of five years while other two regions, 0-0.1 mSv/h and 10-30 mSv/h show some variation. Survey meters with GM counters and proportional counters have nearly same response to the gamma radiation. But it is much different for the survey meter with pressurized ion chamber as the detector.

Key words: Calibration factor, radiation monitoring instrument, detector, Cs-137, Co-60

1. Introduction

There are lots of radiation detectors and radiation monitoring instrument. But, they have different technologies and, also use to different purposes. Mainly Radiation detectors can classified into three groups such as gas detectors, scintillation detectors and solid state radiation detectors.

Gaseous ionization detectors are radiation detection instruments used in radiation protection applications to measure ionizing radiation. They use the ionizing effect of radiation upon a gas-filled sensor. If a particle has enough energy to ionize a gas atom or molecule, the resulting electrons and ions cause a current flow which can be measured.

The three basic types of gaseous ionization detectors are ionization chambers, proportional counters and Geiger-Müller tubes (GM tubes). All of these have the same basic design of two electrodes separated by air or a special fill gas, but each uses a different method to measure the total number of ion-pairs that are collected. The strength of the electric field between the electrodes and the type and pressure of the fill gas determines the detector's response to ionizing radiation.

Operational regions of various types of detectors are illustrated in figure 1. It shows how the pulse amplitude varies with voltage.

Ionization chambers operate at low electric field strength, preferred such that no gas multiplication takes place. The ion current is generated by the formation of "ion pairs". The +ve ions drift to the cathode whilst free electrons drift to the anode under the influence of the electric field. This current is independent of the applied voltage if the device is being operated in the "ion chamber region". Energy dependence of ion chamber are not significant.

Proportional counters operate at a considerably higher voltage, selected such that discrete avalanches are created. Each ion pair produces a single avalanche so that an output current pulse is generated which is proportional to the energy deposited by the radiation. This is in the "proportional counting" region.

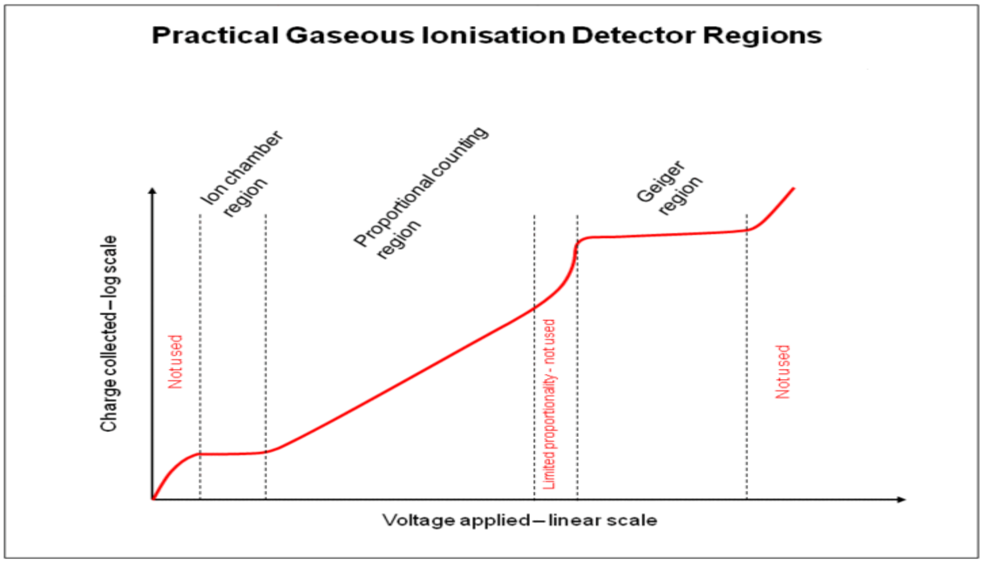


Figure 1. Plot of variation of ion pair current against applied voltage for a wire cylinder gaseous radiation detector.

The Geiger counter consists of two main components; the Geiger-Müller tube which detects the radiation, and the processing and display electronics. They operate at an even higher voltage, selected such that each ion pair creates an avalanche, but by the emission of UV photons, multiple avalanches are created which spread along the anode wire, and the adjacent gas volume ionizes from as little as a single ion pair. This is the "Geiger region" of operation. The current pulses produced by the ionizing events are passed to processing electronics which can derive a visual display of count rate or radiation dose.

There are different type of radiation measuring instrument based on the above technologies such as area monitors, survey meters and contamination monitors. These instruments should calibrate to ensure that an instrument is working properly and hence will be suitable for its intended monitoring purpose.

Calibration is define as the quantitative determination, under a controlled set of standard conditions, of the indication given by a radiation measuring instrument as a function of the value of the quantity the instrument is intend to measure.

In this research, calibration factors of six survey meters, done in the Secondary Standard Dosimetry Laboratory (SSDL) are compared to ensure the accuracy of the each instrument and to check the variation of the calibration factor within 5 years.

2. Experiment

Gamma calibrations are performed by using standardized gamma radiation field (OB85 gamma irradiator). The Instrument is exposed to known dose rates to verify or calibrate in required dose rates obtained by using previously measured dose rates. Dose rates are measure annually and graph is prepared between dose rates and the distance as shown bellow. It helps to find the distance to required dose rate where the instrument has to be place in the field.

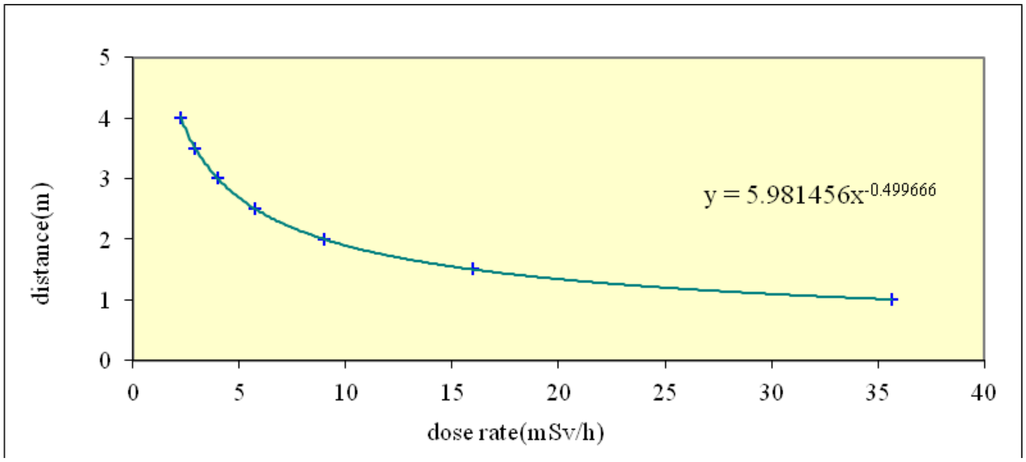


Figure 2. The graph of distance Vs Dose rates

The reference point of the detector / instrument is position to the center of the radiation field as shown in figure 3. Timer of the OB85 is set for suitable time duration and the instrument is irradiated using the Cs- 137 or Co-60 gamma radiation source. After obtain 10 consecutive readings at time interval of 15 seconds and the mean value of them is taken. Then, calibration factors for each range ware calculated.

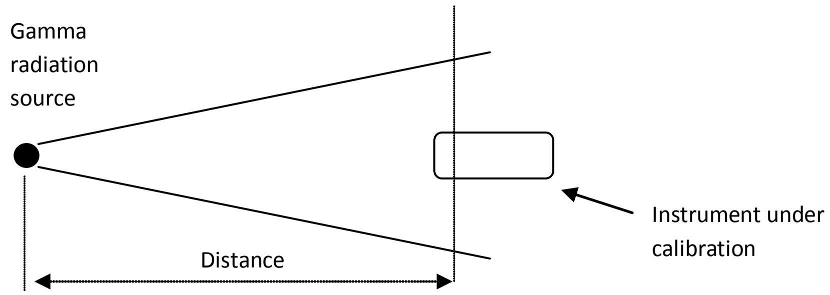


Figure 3. How to place the Instrument for Gamma Radiation

There are several methods to calibrate radiation measuring instrument. Here, we used above procedure to calibrate a survey meter for gamma radiation (Cs-137 and Co-60).

3. Results and Discussion

In this research, we used six radiation survey meters with different type of detectors (3 GM counters, 1 pressurized ionization chamber and 2 proportional counters) which were calibrated every year, in Secondary Standard Dosimetry Laboratory at Sri Lanka Atomic Energy Board, for last 5 years.

The prime function of Secondary Standard Dosimetry Laboratory is to provide calibration services. As a holder of secondary standards it provides an essential link to the international measurement system which is itself based on the inter-comparison of standards held by primary standards laboratories under the aegis of the BIPM.

Calibration is define as the quantitative determination, under a controlled set of standard conditions, of the indication given by a radiation measuring instrument as a function of the value of the quantity the instrument is intend to measure. After calibrating the instrument, calibration factor are provided for radiation detectors to correct the response to true value. Calibration and irradiation are performed in terms of the physical quantities of air kerma and exposure. Calibration factor is a quotient of the conventional true value and the indicated value corrected to the reference condition.

The conventional true value of a quantity is the best estimate of the value, determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard. Indicated value is the value of the quantity derived from the scale reading of an instrument by application of any scale factors indicated of the instrument panel.

Calibration Factor (CF) = Conventional true value / Indicated value corrected to the reference condition

Radiation measuring instruments should calibrate to ensure that an instrument is working properly and hence will be suitable for its intended monitoring purpose. CF is important to convert the indicated radiation measurement to actual radiation value.

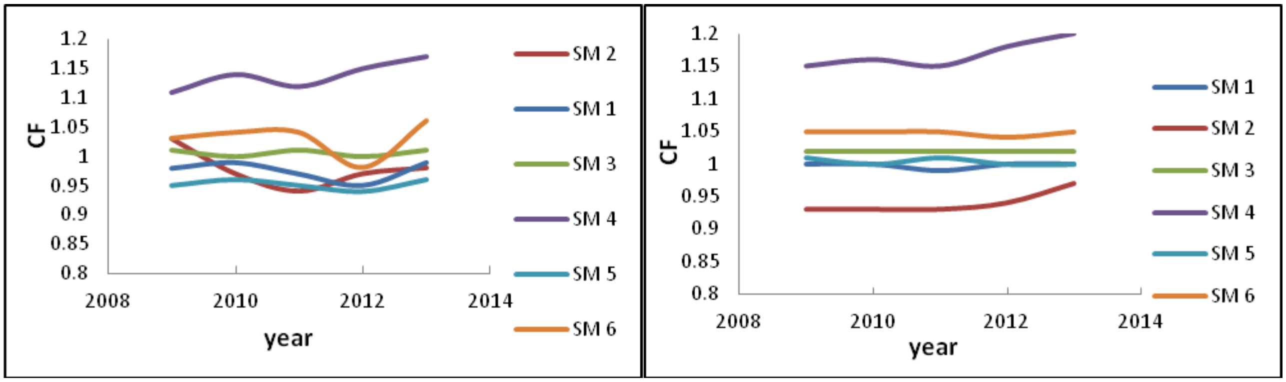
In this research, we compare the calibration factors of survey meters calibrated in every year within the period of 2009 to 2013, to check whether the calibration factor of the instrument defend on the detector type or not and the accuracy of the instrument.

Table no 01, shows the calibration factors for Cs-137 with uncertainty of six radiation survey meters. According to this experimental data, calibration factor of the survey meter with the pressurized ion chamber has high value compare to the other two types of detectors. Reason for that is, the response of pressurized ion chamber is lower than the reference reading.

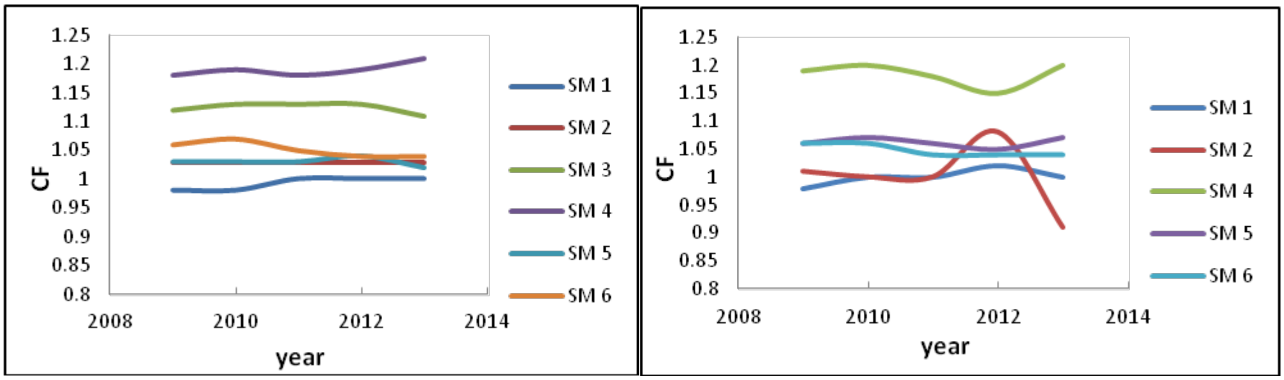
Table no.01. Calibration factors with uncertainties for Cs-137 of each instrument within last five years

Instrument	Detector type	Energy Range (mSv/h)	Calibration Factors for Cs-137				
			2009	2010	2011	2012	2013
Survey meter 1	GM	0-0.1	0.98±0.03	0.99±0.03	0.97±0.04	0.95±0.04	0.99±0.04
		0.1-1	1.00±0.02	1.00±0.02	0.99±0.04	1.00±0.04	1.00±0.04
		1-10	0.98±0.02	0.98±0.02	1.00±0.04	1.00±0.04	1.00±0.04
		10-30	0.98±0.01	1.00±0.02	1.00±0.04	1.02±0.04	1.00±0.04
Survey meter 2	GM	0-0.1	1.03±0.04	0.97±0.05	0.94±0.05	0.97±0.06	0.98±0.05
		0.1-1	0.93±0.03	0.93±0.02	0.93±0.03	0.94±0.04	0.97±0.04
		1-10	1.03±0.02	1.03±0.02	1.03±0.02	1.03±0.04	1.03±0.04
		10-30	1.01±0.02	1.00±0.02	1.00±0.00	1.08±0.04	0.91±0.04
Survey meter 3	GM	0-0.1	1.01±0.04	1.00±0.04	1.01±0.06	1.00±0.05	1.01±0.05
		0.1-1	1.02±0.03	1.02±0.03	1.02±0.04	1.02±0.05	1.02±0.05
		1-10	1.12±0.02	1.13±0.02	1.13±0.05	1.13±0.05	1.11±0.05
Survey meter 4	Pressurized ionization chamber	0-0.1	1.11±0.04	1.14±0.05	1.12±0.05	1.15±0.05	1.17±0.05
		0.1-1	1.15±0.03	1.16±0.01	1.15±0.05	1.18±0.05	1.20±0.05
		1-10	1.18±0.04	1.19±0.03	1.18±0.07	1.19±0.05	1.21±0.05
		10-30	1.19±0.03	1.20±0.01	1.18±0.05	1.15±0.05	1.20±0.06
Survey meter 5	Proportional counter	0-0.1	0.95±0.02	0.96±0.03	0.95±0.05	0.94±0.04	0.96±0.05
		0.1-1	1.01±0.02	1.00±0.03	1.01±0.05	1.00±0.04	1.00±0.04
		1-10	1.03±0.03	1.03±0.03	1.03±0.05	1.04±0.04	1.02±0.04
		10-30	1.06±0.02	1.07±0.02	1.06±0.05	1.05±0.04	1.07±0.04
Survey meter 6	Proportional counter	0-0.1	1.03±0.03	1.04±0.02	1.04±0.05	0.98±0.04	1.06±0.05
		0.1-1	1.05±0.02	1.05±0.03	1.05±0.05	1.04±0.04	1.05±0.04
		1-10	1.06±0.02	1.07±0.02	1.05±0.05	1.04±0.04	1.04±0.04
		10-30	1.06±0.02	1.06±0.02	1.04±0.04	1.04±0.04	1.04±0.04

Figure 4 shows the variation of calibration factors of each instrument (without the uncertainty) within last five years. According to these graphs, CF of instrument remaining nearly stable within the region of 0.1 to 10 mSv/h for the duration of five years while other two region, 0-0.1 mSv/h and 10-30 mSv/h show some variation.



(a) (b)



(c) (d)

Figure 4. Calibration factors (for Cs-137) of each instrument (a) for 0- 0.1 mSv/h range (b) for 0.1-1 mSv/h range (c) for 1-10 mSv/h range (d) for 10-30 mSv/h range without the uncertainty.

Table no 02, shows the calibration factors for Co-60 with uncertainty of radiation survey meters. According to this data, CF of the survey meter with the pressurized ion chamber has high value compare to the other two types of detectors. This condition is same as the response for Cs-137.

Survey meter with pressurized ion chamber shows uniform response for Co-60 radiation than Cs-137. Ion chambers have a good uniform response to radiation over a wide range of energies and are the preferred means of measuring high levels of gamma radiation.

Gamma radiation emit from the Co-60 source have high energy (1.33 MeV) than the Cs-137 (662 keV). Therefore, response of the survey meter for Co-60 radiation is higher than the Cs-137. CF is inversely proportional to the instrument indicated value corrected to the reference condition. Hence, CF for Co-60 radiation is much lower than the Cs-137.

Table no.02. Calibration factors with uncertainties for Co-60 of each instrument within last five years

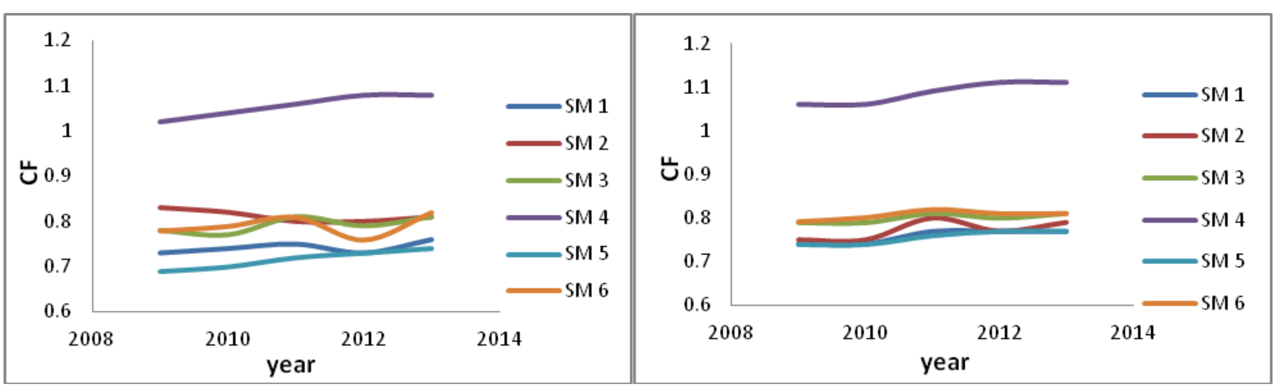
Instrument	Detector type	Energy Range (mSv/h)	Calibration Factors for Co-60				
			2009	2010	2011	2012	2013
Survey meter 1	GM	0-0.1	0.73±0.03	0.74±0.03	0.75±0.05	0.73±0.05	0.76±0.06
		0.1-1	0.74±0.03	0.74±0.03	0.77±0.05	0.77±0.04	0.77±0.03
		1-10	0.73±0.03	0.73±0.03	0.77±0.05	0.77±0.05	0.77±0.05
		10-30	-	-	0.78±0.05	0.79±0.06	0.77±0.05
Survey meter 2	GM	0-0.1	0.83±0.05	0.82±0.06	0.80±0.06	0.80±0.07	0.81±0.06

		0.1-1	0.75±0.04	0.75±0.02	0.80±0.04	0.77±0.05	0.79±0.03
		1-10	0.83±0.03	0.84±0.02	0.88±0.03	0.84±0.06	0.84±0.06
		10-30	0.81±0.03	0.81±0.02	0.85±0.02	0.89±0.07	0.75±0.06
Survey meter 3	GM	0-0.1	0.78±0.05	0.77±0.05	0.81±0.07	0.79±0.06	0.81±0.06
		0.1-1	0.79±0.04	0.79±0.04	0.81±0.06	0.80±0.05	0.81±0.04
		1-10	0.87±0.04	0.87±0.04	0.90±0.06	0.89±0.07	0.89±0.07
Survey meter 4	Pressurized ionization chamber	0-0.1	1.02±0.04	1.04±0.06	1.06±0.07	1.08±0.08	1.08±0.08
		0.1-1	1.06±0.03	1.06±0.02	1.09±0.07	1.11±0.06	1.11±0.04
		1-10	1.09±0.04	1.08±0.04	1.12±0.08	1.12±0.08	1.12±0.08
		10-30	1.09±0.04	1.10±0.02	1.11±0.07	1.09±0.08	1.11±0.08
Survey meter 5	Proportional counter	0-0.1	0.69±0.03	0.70±0.03	0.72±0.06	0.73±0.05	0.74±0.06
		0.1-1	0.74±0.03	0.74±0.03	0.76±0.06	0.77±0.05	0.77±0.03
		1-10	0.76±0.03	0.75±0.03	0.78±0.06	0.80±0.06	0.78±0.05
		10-30	0.78±0.03	0.79±0.03	0.81±0.05	0.81±0.06	0.82±0.05
Survey meter 6	Proportional counter	0-0.1	0.78±0.03	0.79±0.03	0.81±0.06	0.76±0.06	0.82±0.06
		0.1-1	0.79±0.03	0.80±0.03	0.82±0.06	0.81±0.05	0.81±0.03
		1-10	0.80±0.03	0.81±0.03	0.82±0.06	0.81±0.06	0.81±0.06
		10-30	0.80±0.03	0.81±0.03	0.81±0.05	0.81±0.06	0.80±0.06

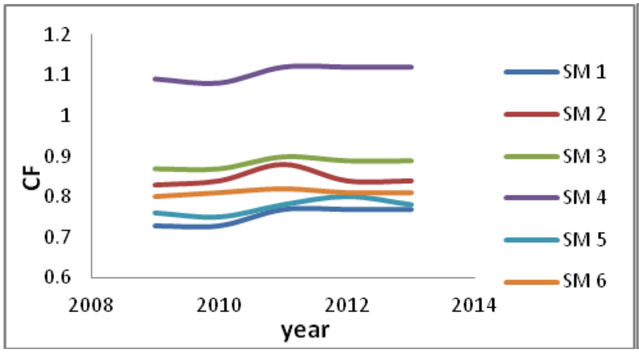
According to the figure 4 and figure 5, survey meters with GM counters and proportional counters have nearly same response to the gamma radiation. But it is much different for the survey meter with pressurized ion chamber as the detector.

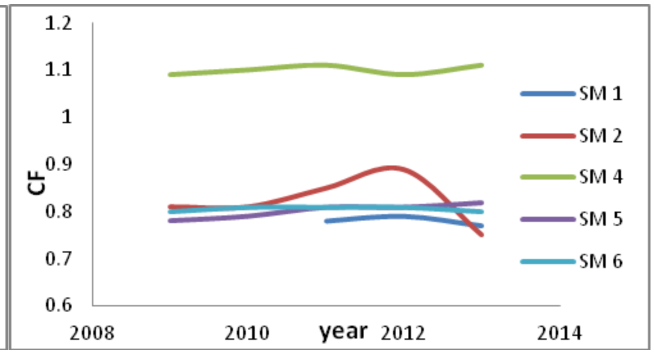
There are four concept govern the operation of gas detectors, ionization of gases, charge movement and collection in gas, charge multiplication and quenching. Even though pressurized ion chamber has good uniform response to gamma radiation, it has disadvantage of very low electronic output which requiring sophisticated electrometer circuit and operation and accuracy easily affected by moisture. It only uses the discrete charges created by each interaction between the incident radiation and the gas, and does not involve the gas multiplication mechanisms used by other radiation instruments, such as the Geiger-Muller counter or the proportional counter. Further, energy dependence of ion chamber is not significant. Because of these reasons ionization chambers shows low response than other detectors.

If we considering the uncertainty of the calibration factor, there is no significant difference of CF within last five years for each instruments.



(a) (b)





(c) (d)

Figure 5. Calibration factors (for Co-60) of each instrument (a) for 0- 0.1 mSv/h range (b) for 0.1-1 mSv/h range (c) for 1-10 mSv/h range (d) for 10-30 mSv/h range without the uncertainty.

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Conclusions:

In this work, we have reported that, response of the survey meter for Co-60 radiation is higher than the Cs-137. Hence Calibration Factor for Co-60 radiation is much lower than the Cs-137. Calibration Factor of instrument remaining nearly stable within the regions of 0.1 to 10 mSv/h while other two regions, 0-0.1 mSv/h and 10-30 mSv/h show some variation. Survey meters with GM counters and proportional counters have nearly same response to the gamma radiation while it is much different for the survey meter with pressurized ion chamber as the detector.

Acknowledgement:

The authors thank to Sri Lanka Atomic Energy Board for facilitating to make this work success.

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