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Calibration of Radiation Detectors for Monitoring and Decontamination of Radioactive Surface Contamination

Haniya Saleh Alhoweij *
Department of Physics, Faculty of Science, Bani Waleed University, Libya
***Email (for reference researcher):** haniyaalhaj@gmail.com

معايرة كواشف الإشعاع لمراقبة وإزالة التلوث الإشعاعي عن الأسطح

هنية صالح الحويج *
قسم الفيزياء، كلية العلوم، جامعة بني وليد، ليبيا

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Abstract:
This study presents a systematic approach for managing radioactive surface contamination and evaluating the effectiveness of decontamination procedures. The methodology involves the calibration of three distinct radiation detectors: Monitor E, Monitor S, and NE BP1/4, followed by the identification of the contamination source. Instrumental monitoring was integrated with smear testing to assess the efficacy of surface decontamination. This was performed by wiping the contaminated areas with specialized filter papers and measuring the residual radioactivity. The results demonstrated successful surface decontamination; subsequently, the generated radioactive waste was collected and disposed of in compliance with established radiological safety guidelines. Waste disposal procedures were initiated once the total accumulated activity reached the regulatory limit of 370 kBq, as determined by the filter paper measurements.

Keywords: Surface Radioactive Contamination, Decontamination, Radiation Monitoring, Smear Test, Radioactive Waste, Detector Calibration.

الملخص
تهدف هذه الدراسة إلى تقديم منهجية متكاملة للتعامل مع حالات التلوث الإشعاعي السطحي وتقييم فعالية عمليات إزالة التلوث. تضمنت الخطوات العلمية معايرة ثلاثة أنواع من كواشف الإشعاع هي: Monitor S و Monitor E (كواشف غازية) و NE BP1/4 (كاشف وميضي)، تليها عملية تحديد مصدر التلوث الإشعاعي. اعتمد البحث على الجمع بين القياسات المباشرة باستخدام أجهزة الرصد واختبارات المسح السطحي (Smear Testing) للتحقق من كفاءة إزالة التلوث. وقد نُفذت هذه العملية بمسح الأسطح الملوثة باستخدام أوراق ترشيح خاصة، ثم قياس النشاط الإشعاعي المتبقي لتقدير مستوى التلوث بعد المعالجة. أظهرت النتائج النهائية نجاح عملية إزالة التلوث السطحي؛ حيث جُمعت النفايات المشعة الناتجة وتم التخلص منها وفقاً للوائح ومعايير السلامة الإشعاعية المعتمدة. كما تم تنفيذ إجراءات التخلص من النفايات عند بلوغ إجمالي النشاط الإشعاعي الحد التنظيمي البالغ 370 كيلو بيكريل (kBq)، والذي حُدد استناداً إلى القياسات المأخوذة من أوراق الترشيح.

الكلمات المفتاحية: التلوث الإشعاعي السطحي، إزالة التلوث، المراقبة الإشعاعية، اختبار المسح السطحي، النفايات المشعة، معايرة الكواشف.

Introduction

Radioactive contamination material can be found within a solid, liquid and gas that include the human body where the present is unintended [1,2]. They can be released in a laboratory or in another suitable environment. This can occur due to an accidental leakage as a result of damage the radiation apparatus. However, in general, radioactive contamination is the result of an accidental spillage during the production of radionuclide due to its instability nucleus that has excessive energy[2,6]. The contamination is categorized according to the physical states of material. The danger associated with radioactive depends on the type of radioactive marital emitted (α, β, γ)[5]. Radioactive contamination of person, animals, equipment, etc adds to the unnecessary dose being received by an individual. The exposed could be through direct irradiation or by a contaminant within the body by ingestion, inhalation or absorption through the skin[5].

Theory

International Commission on Radiological Protection (ICRP) has recommended the usage of maximum permissible doses of individuals[7]. The area designation of these doses has been derived, and then the permissible

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level of radioactive contamination surface has been estimated. The method of waste disposal was also discussed in these recommendations. The requirement data for decontaminate of 32P radioactive contamination has been calculated as follows:

1. The Derived working limit (DWL) is 30Bq/cm^2 for the surfaces of active area of plant, equipment, material and articles within active areas. Surface of the body is 3 Bq/cm2 and other surface including areas is also 3 Bq/cm2
2. DWl rely on the type of radiation such as β emission, averaging over large areas is permitted when calculating DWL, which are floors and ceiling 1000cm^2,other surfaces for example bench tops 300cm^2, hands is 300cm^2, parts of the body is 100cm^2.

Experimental Method

This study is divided into four methods: the Instrument calibration, Monitoring Surface Contamination, Smear Testing and Decontamination and Disposal.

Figure 1 A typical surface contamination meter.

Instrument Calibration

The type of detectors is used calibration which contains Monitor-E, Monitor-S. These types of detectors have a G-H tube probe type. Whereas the third one is Monitor NE BP1/4 with scintillator probe.

Each probe is calibrated by using 4.85kBq, each detector was calibrated using a Known reference source which is ^{90}Sr. It has a half-life of 28.64 years. ^{90}Sr is a β- emitter with end point energy of 0.54MeV which produces a daughter ^{90}Y with end point energy of 2.25MeV. Calculate the activity per unit area of the reference sources by using this date in order to obtain a calibration factor for each instrument that is used from background subtracted count rate to true source activity (Bq/cm^2). this was the first part of this experiment. The second part used a high efficiency G-M tube (Distron Tube) to detect and contaminated surface. The G-M tube was first calibrated by using different activities of ^{32}P unsealed sources to get a precise calibration curve.

Monitoring Surface Contamination

In this part of this experiment, a region of the bench is contaminated with ^{32}p. monitor E is used to obtain the level of the contamination and its estimated, contamination level are quoted in units of Bq/cm^2.

Smear testing

This method is used in area where the contamination is removable. A filter paper was saturated with a solvent and then rubbed over the contamination area. This process continues until the whole suspected are smeared. The filter paper has been placed on a Petri dish facing upwards and then has been measured with G-M counter. It is assuming that 10% of the total contaminated activity is transferred to the filter for each single smear.

Decontamination and Disposal

This procedure is connected with smear testing by using filter paper. Decontamination solutions are used to moisten filter papers that could be used to wipe clean the affected areas. Residual activity on the contamination surface recorded every time. This process continued until the level of contamination is decreased to become less than the background level. A smear is taken place until electron probe records the counts within the limit of 370kBq. This number is estimated by the regulation contained in the Radioactive Substances Act (1993).

Results

Instrument calibration

The reference sources used in this experiment was ^{90}Sr , with initial activity of 4.85kbq , half-life is calculated from the same day of the experiment. Activity was calculated by using this equation

A= $A_0\, e^{-\lambda t}$

Where A_0= initial activity
λ = decay constant, t is the half-life and here is the time elapsed since the initial activity A_0
A= 4.17kBq, activity per unit is 4.17/150=0.0278 kBqcm^{-2} =27.8Bq/cm

Table 1 shows results of background count rates.

SN.	Detector	Background Count Rate (s^{-1})	Count Rate (s^{-1})			Average Count Rate(S^{-1})
1	**Monitor E**	**0.5**	**70**	**65**	**55**	**62**±7.8
2	**Monitor S**	**0.5**	**17**	**16**	**12**	**15±3.8**
3	NE BP1/4	4	**220**	**250**	**180**	**212.67±14.5**

Table 2 presents the calibration factors for each monitor, which are calculated.

SN.	Detector	Count rate (background subtracted) S^{-1}	Activity, surface area for ^{90}SrBq/cm	Calibration factor
1	**Monitor E**	**62±7.8**	**27.8±5.19**	**0.44**
2	**Monitor S**	**15±3.8**	**27.8±5.19**	**1.9**
3	NE BP 1/4	**212.67±14.5**	**27.8±5.19**	**0.13**

The manufacture's value for Monitor E calibration factor and Monitor S are 1Bq/cm for detector E and 1.6 Bq/cm for Monitor S, comparing with the result above in the table is almost convergent.

Distort probe Calibration

Table 3 shows the various activities for ^{32}P sources by time 300s to estimate the calibration factor.

SN.	Activity Bq	Counts rate S^1(background subtracted	Counts/300s	cps	Calibration factor (Bq/cps
1	3.2	79381	256.82	264.6	0.012
2	6.4	87899	294.21	264.6	0.024
3	12.8	109510	366.25	292.9	0.04
4	25.8	134871	450.79	365	0.07
5	516.2	195450	652.72	651.9	0.79

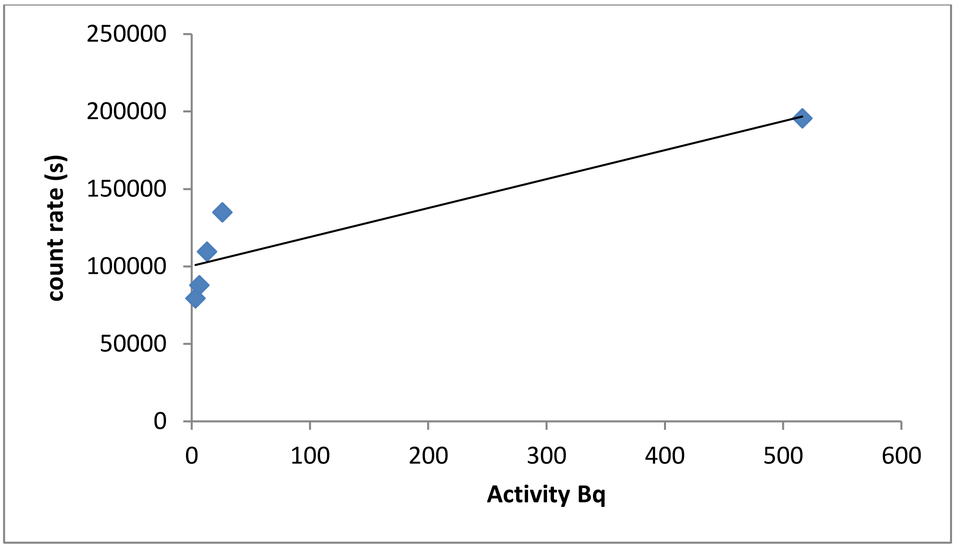

Figure 2 Activity against count rate(s^{-1})

Surface Contamination Monitoring

During the survey of contamination with the bench surface, the area was 900 cm^2, and an area of 49 cm^2 was recorded in the region that had the highest contamination.

1	2	3
4	z 5	6
7	x1	9

Figure 3 illustrates the spatial distribution of the surface over the surveyed bench area.

The X and Z axes represent the measurement coordinates on the surface, while the numbered points indicate the surveyed locations. The highest contamination level was observed at position (X1, Z5).

Smear Testing

In this part, the Reference activity =435.9
Background =162, count rate =4352s

Table 4 shows high surface contamination before and after wiping.

SN.		Before wipe	After 1st wipe	After 2^{nd} wipe	After 3^{rd} wipe	After 4th
	Contaminated area	Counts per second on the filter paper				
1	85	18109	782	232	241	191
2	60	491	547	415	256	218
3	50	1160				

A significant reduction in count rate after the first wipe indicates effective removal of removable contamination. Lower initial counts resulted in minor changes after wiping. Smear testing proved reliable for evaluating surface contamination and decontamination efficiency.

Decontamination and Disposal

The contaminated area has been wiped and smear tested until the contamination level on the surface reach the background. Filter paper has been collected in a glass baker.

Discussion

Significant variations in radiation count rates were observed throughout the experiment using the three detectors. Both Monitor S and the NE BP1/4 scintillation probe yielded the highest count rate readings. A strong linear relationship was established between source activity and the recorded count rate, confirming the detectors' capability to respond accurately to varying levels of activity reaching the detector window.
The results indicated that the majority of the contamination was concentrated within a localized region, which was effectively remediated using the smear test method. The efficiency of this decontamination process was found to be dependent on several factors, including the surface texture, the type of absorbent material used for smearing,

and the physical state of the radioactive contaminant. To prevent the cross-contamination of adjacent clean areas, it is recommended to perform the smear test using a spiraling inward motion within each designated survey grid.

Conclusion

Radioactive contamination remains a significant concern in various environments due to its hazardous effects on the human body, particularly if internalized through ingestion, inhalation, or skin absorption. To mitigate these risks, strict adherence to radiological protection measures is essential, including the consistent use of Personal Protective Equipment (PPE) when handling unsealed radioactive sources.

This study evaluated three surface contamination monitors—Monitor E, Monitor S, and NE BP1/4—all of which were successfully calibrated to determine their specific calibration factors. The application of smear testing using filter papers proved to be an effective technique for quantifying and removing surface contamination from laboratory benches, ensuring compliance with safety limits.

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