MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Microbiology and Biological Sciences (ISSN: 2408-7076) Vol. 7(3) pp. 033-041, July, 2019
Available online http://www.meritresearchjournals.org/mbs/index.htm

DOI: 10.5281/zenodo.3354496

Original Research Article

Radiation Level Assessment of Construction Metals, Kitchen Utensils and Electronic Items

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Abstract

Radiation is what everyone encounters every day both from natural and from manmade sources. Though little could be done to limit radiation from natural sources, limit should be made on radiation levels from man-made sources. In this study, radiation level assessments were made on 19 construction metals, 9 kitchen items and three groups of electronic items using Universal Survey Meter. Radiation rates from each item were measured at four different distances (10, 20, 30 and 40 cm) from the source. Background radiations were measured once daily and the background radiations were subtracted from the daily measured radiation rates of the items to get net radiations, from which dose levels were evaluated. The result (in terms of radiation rate variability with distance) showed radiation levels in excess of the background radiation even though the values were not consistent. The result revealed 12 of the metals, 2 of the kitchen items and one group of electronic items to have doses above the recommended limit. Even though the survey meter did not have the required precision, its results indicated differences between background radiations and radiation rates from all the items. It is indicative of the presence of radionuclides in the metals even if they were in trace amounts. We recommend this study to be taken as a baseline study and more study be carried out using an instrument of better precision and by taking background radiation measurement at the same time radiation rate measurement is made on each item and at exactly the same location.

Keywords: Background radiation, Electronics items,Kitchen items, Metals, Radiation, Survey meter

INTRODUCTION

Human beings are constantly exposed to all sorts of radiations throughout their lifetimes. Some of these radiations known as non-ionizing are not as harmful as ionizing radiations that can mutate the gene pool and gradually weakens it, causes developmentaldeficiencies in the fetus, weakens the immune system and so on. When it breaks molecular bonds it can cause unpredictable chemical reactions (NIRS, 2005).

Radiation sources are divided into two major groups, namely, the background radiation and radiation from man-made sources. The background radiation with its average annual dose of 2.4 mSv accounts for approximately 80% of the total radiation (IAEA, 1997; Taskin *et al.,* 2008). It comes from two sources. The first source is cosmic source but most of this radiation is attenuated in the atmosphere and because of this, it accounts for about 10% of the background radiation at sea level (IAEA, 2010).The predominant part of the background radiation comes from terrestrial sources such as soil and rocks (Markkanen, 1999). Cosmic radiation varies with altitude and latitude but its overall variation is slightly less as compared to terrestrial radiation on day to day basis. The remaining 20% of radiation comes from man-made sources.

Materials extracted from earth can incorporate radionuclides even if it is in trace amounts. The concentration of radionuclide in any manufactured material depends on the quantity of the radionuclide in the raw material. For raw materials exploited from rock and soil, the amount of radionuclide in the two at a particular location determines how much gets into the produced item (EC, 1999). For manufacturers that use recyclable scrap metals as raw materials, the amount of radionuclide in the product depends on the purity of the recycled material.

For metal producers, cost and availability determine whether to use primary or recycled products as raw materials (Wilson, 1994). In metal works, material components are mixed and melted to produce new products. The use of metal scrap, which is radioactively contaminated, canintroduce additional radioactive substances into the molten metal. When the radioactive material is melted in a furnace, the radionuclides are not destroyed and the radioactivity remains. Most natural radionuclides pass either to the slag or to the gas in the combustion chamber. In other words, man-made radionuclides pass to the metal, to the slag or given off as gas dust depending on the type of radioisotope (IAEA, 2001).

Over the last century, metal scrap, as a secondary raw material, has become important for the production of metals. As an example, nearly half of all the steel that is produced world-wide is made from scrap and this percentage is increasing. This is a very positive contribution to sustainable development, with particular environmental benefits such as reduction of emissions during production and saving of natural resources (Nieves, 1995). Metal scrap also provides business opportunities from its collection, transport to metal works, rolling mills and foundries worldwide. There is an extended chain of supplier and customer interaction that reaches around the whole recycling loop back to the initial scrap and therefore,many economic operators may be involved throughout this process. But its negative contribution outweighs its positive contribution if it is accidentally or deliberately incorporated into the products that can expose consumers to radiations.

Quality assurance standards want producersto comply with the required specifications fortheir products. One of these product specifications is the type and activity of radionuclides in the metal (IAEA, 2005). But on the other hand, however small, the continuous release of radiation waste into the environment thickens the radiation environment and has bioaccumulation effect since its effects are additive, cumulative and synergetic (D'Arrigo, 2004)

In practice, consumers of goods do not wish to have any radiation emission from what they purchase. In spite of that, there is still a possibility that radioactive wastes could be recycled into everyday household items like toys, cookware, cars, furniture and medical equipment, besides buildings and roadways (NIRS, 2005). Metal, plastic and other recyclers could probably unknowingly mix and melt radioactive materials with clean ones to make new products (NIRS, 2005). For metal products to be acceptable to consumers, all producers downstream of the metal works look to the metal works to provide materials complying with the standards. The metal works, in turn, look to their suppliers of secondary raw materials to ensure that the scrap does not contain radioactivity additional to the typical natural background radioactivity content in the metal. However, incidents of companies finding themselves in possession of contaminated scrap continue to be reported despite the vested interest of the scrap recyclers not to come into possession of radioactively contaminated metal scrap (IAEA, 2000).

Some countries have the will and capability in terms of manpower, technology and resource to control radioactive substances including monitoring recyclable materials. In such countries the possibility of radioactive material accidentally getting into the production process is low. But in countries which lack the manpower, the technology or the resource to monitor products that get into the market, there is a possibility that materials that contain radionuclides above the recommended limit can get into the hands of consumers.

The Ethiopian Standard Agency does not have the capability to monitor the radiation levels of all metals and other items getting into the country at this time. Hence, there may be items that get into the country, which may contain radioactive elements above the limit allowed by IAEA. In this research, tests were made by selecting different types of metals (construction metals, metal used for kitchen items and electronic equipments) to check whether they were within the limit set by IAEA standards.

MATERIALS AND METHODS

This section presents description of the location,the instruments used to collect data and the methods of data analysis.

Sources of metals used in the study

The materials used for testing were obtained from Haramaya University (HU)campus workshop and from Harar and Dire-Dawa markets, Eastern Hararghe zone, Ethiopia. Latitude, longitude and altitude of the three locations are summarized in Table 1. The items tested include,various types of construction metals, metallic kitchen itemsand electronic equipments. Radiation emissions from these items weremeasured and compared with background radiations.

Table 1. Latitude, longitude and altitude of the three locations

Location	Latitude	Longitude	Altitude*
HU*	9°15'N	42°0'E	1950 m
Harar	9°15'-9°27'N	42°04'- 42°22'E	1780 m
Dire Dawa	9°27'-9°49'N	41°38'- 42°19'E	950 m

Altitude* isaverage value above sea level

Instrument of data collection

In this research,Universal survey meter (model RDS-200) was used to measure radiation levels emitted from the different items.

Materials acquisition and data collection

For data collection, building materials shops, small kitchen items shops, large kitchen appliances shops, and electronics shops were selected, based on the willingness of the shop owners.From the three locations, a total of 19 construction metal types, 9 different kinds of kitchen items and 3 electronics items were selected. Background radiations were always measured prior to other measurements, outside, at locations far from any other radiation sources at 1 m above ground. All other radiation measurements were taken at horizontal distances of 0.1, 0.2, 0.3 and 0.4m, for each metal type.

Radiation measurements were made on the ground at time intervalsof 5minutes. Data were recorded after waiting time of 5 minutes. The survey meter measured radiation rate in µSv/h.

Data analysis

For every item, background radiation was subtracted from the radiation rate measured from the item to get net radiation. The net radiations were computed and the values obtained were compared for different measurement distances. The distance at which maximum net radiation occurred and the corresponding net radiation were selected and used to calculate the annual dose.

The method of data analysis included finding annual dose (D), whichwas obtained from the product of dose rate ($\dot{D}$) and time (t) as shown in Eq.2.1a.

$$D = \dot{D}t \qquad (2.1a)$$

Since radiation rate measurements were made in$\mu Sv/h$by the survey meter,$D$was obtained by making proper unit conversions. For $\dot{D}$ measured in $\mu Sv/h$, to obtain D in mSv/y conversionwas made as shown in Eq. 2.1b.

$$D\left(\frac{mSv}{y}\right) = \frac{\dot{D}(\mu Sv/h)\left(\frac{24hrs}{d}\right)\left(\frac{365d}{y}\right)}{10^3\left(\frac{\mu Sv}{mSv}\right)} = 8.76(\dot{D})(mSv/y) \qquad (2.1b)$$

The annual dose calculated using Eq. 2.1b was finally compared with the limit of 1 mSv/y set for public (USNRC, 2015).

Many radiation sources can be considered as point sources especially if the size of the source is small compared to the distance at which radiation rate measurement is made. For such sources radiation rate decreases with inverse of distance (d) squared (Voss, 2000) as;

$$\dot{D}d^2 = k \qquad (2.2a)$$

The result$k$ is a constant.For two distances d_1 and d_2,

$$\dot{D}_1 d_1^2 = \dot{D}_2 d_2^2 . \qquad (2.2b)$$

When the sources are approximated to line sources, the dependence of the dose on distance is shown (Voss, 2000)as;

$$\dot{D} = \frac{\delta}{h}(\theta_L + \theta_R) \qquad (2.3a)$$

where, δ is emission rate from a unit length of the line source (constant for isotropic source),h is the perpendicular distance from the line source to the point of measurement and $\theta_L \text{and } \theta_R$ are the angles (measured in radians) that the lines joining the left and the right ends of the line source make with respect to h at the point of measurement, respectively. Hence for different$h$ values (perpendicular distances from the source), Ḋ is dictated by the ratio $\frac{(\theta_L+\theta_R)}{h}$.

For a very long line source (L » h), $\theta_L + \theta_R$ approach π (measured in radians) such that,

$$\dot{D} = \frac{\pi\delta}{h} . \qquad (2.3b)$$

Area sources are generally approximated with a circular source of area, πR^2 where R is the radius of the circle. Therefore, for a circular area the dose rate is given as:

$$\dot{D} = \frac{\delta_a}{R^2} ln \frac{R^2 + h^2}{h^2} . \qquad (2.4)$$

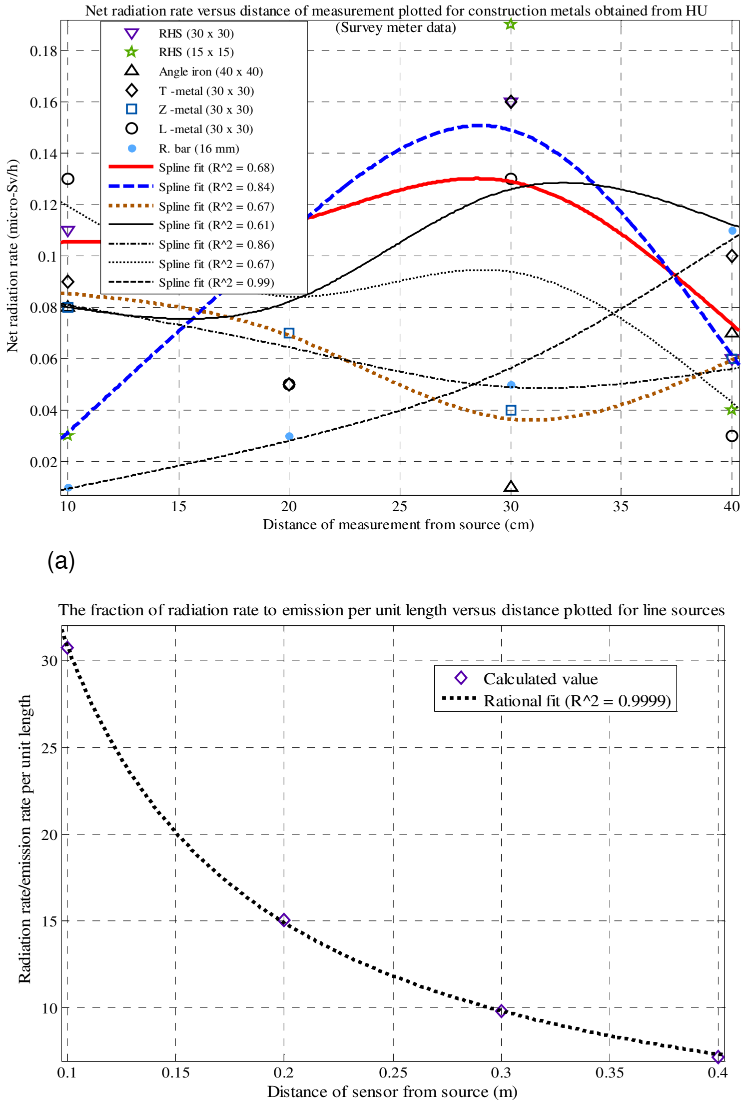
Where δ_a is rate of emission perunit areaof the circular source. In order to find radiation rate from a source other than a circular source, area of equivalent circle is sought. For instance, for a rectangular source with sides a and b, the circular area is approximated to the rectangular areaas shown next.

$$\pi R^2 = ab \qquad (2.5a)$$

Now the radius, R can be approximated from a and b as:

$$R = \left(\frac{ab}{\pi}\right)^{0.5} \qquad (2.5b)$$

In this case the$R$ value is first evaluated as shown in Eq. 2.5band inserted in Eq.2.4 to find the dose rate.



(a)

(b)

Figure 1. (a) Plots showing the effect of distance of measurement from the metal on the net radiation rate as measured by the survey meter and (b) the pattern that is supposed to be followed by line source with distance based on calculated value using Eq. 2.3a. All the metals were line sources and were obtained from HU campus.

For volume sources a drum is taken as representative source. Evaluation of dose rate using the drum, with slight approximation (Chabot, undated) gives;

$$\dot{D} = \frac{\delta_v}{R^2} ln \frac{R^2 + h^2}{h^2}. \qquad (2.6)$$

The δ_v is emission rate per unit volume. Equations2.4 and 2.6 are almost identical except the two multiplicative factors, δ_a and δ_v.

RESULTS AND DISCUSSION

In this section, measured results of radiation rates of construction metals, kitchen items and bulk electronic equipment are given. Since rate measurements were done at four different distances from the source, rate dependences on the distanceswere also investigated.

Radiation rates of construction metals

In this part, a total of 14 line type and 6 area type construction metals of the three locations (HU, Harar and Dire Dawa) were investigated. For radiation rate dependence on distance, only line type metal groups of HU workshop and Harar market were considered for illustration as shown in Figure 1 and Figure 2.

Except for the reinforcement metal which showed

Table 2. Decrease in radiation rate with increasing distance from the source, calculated for line sources.

h (m)	$(\theta_L+\theta_R)/h$	Fraction
0.1	30.75	1.00
0.2	15.04	0.49
0.3	9.81	0.32
0.4	7.19	0.23

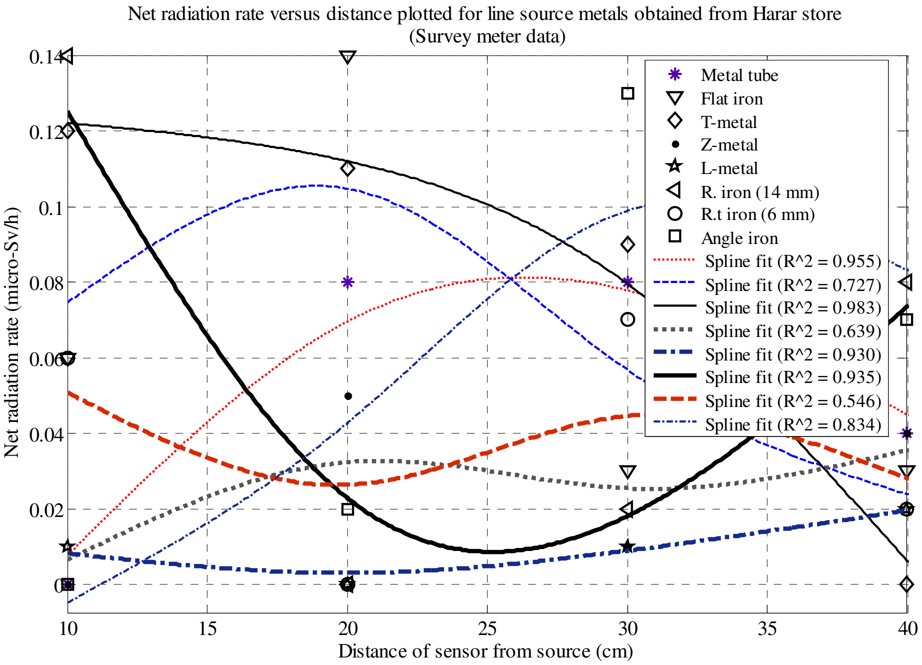


Figure 2. Plots showing the effect of distance of measurement from the metal on the radiation rate as measured by the survey meter (Metals obtained from Harar store). Figure 3.1b is common for both.

smooth increasing trend with distance, for most metals thetrends were not uniform. Even though radiation from line source is supposed to show a decrease with distance as shown in Figure 1b, in this particular case we found mixed results. Three of the metals (the two RHS metals and the T-metal) showed maxima at a distance of 30 cm. The three metals, showed maximum dose equivalents of 1.4, 1.66, and 1.4 mSv/y, respectively, as indicated in Table 1a. These dosesare higher than the recommended limit of 1 mSv/y (IAEA, 2010). The other three metals (Angle iron, Z- metal and L-metal) slightly showed decreasing trends but failed to show decreasing trend all the way. They showed small peaks either at 30 or 40 cm distances. All of the metals showed fairly good spline fits with R^2 (shown in the same figure) ranging from 0.61for the T-metal to 0.99 for the reinforcement metal.

Ideal changes with distance were computed using Eq. 2.3a with *h* values changing from 10 to 40 cm and the two angles were calculated from the two end points at the line passing through the middle of the line sources. The δ in the equation is a constant value, for isotropic sources. Considering the center of the metal and evaluating the parameters given in the equation, the reduction in radiation rates are summarized in Table 2.

The last column shows the ratio of $(\theta_L+\theta_R)/h$ of a given h to that of h = 0.1 m. The angles were measured in radians. Since the fractional value at h=0.1 m is one, all the other values were compared with this value. At h=0.2 m the rate reduced to about 50% of the value at h=0.1. At h = 0.3 m and h = 0.4 m the rates reduced to about one third and one fourth of the value at h= 0.1 m, respectively. The best fit (R^2 = 0.9999) obtained in Fig. 3.1b was a rational function as it is supposed to be since $(\theta_L+\theta_R)/h$ is also a rational function. The values obtained in column 2 of Table 1 could then be approximated from:

$$\frac{\theta_L+\theta_R}{h} == \frac{2.892}{d-0.006} \qquad (3.1)$$

Where d represents h are in meters and the right hand side of the equation is the rational function obtained by curve fitting.

Table 3. Maximum net radiations of different construction metals (linear sources) shown with the corresponding doses and distances from the survey meter at which the maxima occurred.

		Construction metals (Line sources)													
Source	**Dimension (mm x mm)**	**RHS (30 x 30)**	**RHS (15 x 15)**	**A-iron* (40 x 40)**	**L-metal (30 x 30)**	**T-metal (30 x 30)**	**Z-metal (30 x 30)**	**R-iron (16)**	**M. tube (30 x 30)**	**F- metal (40 x 40)**	**F- metal (30 x 30)**	**R-iron (14 mm)**	**R-iron (6 mm)**	**D-metal (30 x 30)**	**C-pipe (25 mm)**
HU workshop	Net rate (µSv/h)	0.16	0.19	0.09	0.13	0.16	0.08	0.11							
	Distance (cm)	30	30	20	10 & 30	30	10	40							
	Dose (mSv/y)	**1.40**	**1.66**	0.79	**1.14**	**1.40**	0.70	0.96							
Harar store	Net rate (µSv/h)			0.13	0.02	0.12	0.05		0.08	0.14		0.14	0.07		
	Distance (cm)			30	40	10	20		20	20		10	30		
	Dose (mSv/y)			**1.14**	0.18	**1.05**	0.44		0.70	**1.23**		**1.23**	0.61		
Dire Dawa store	Net rate (µSv/h)			0.05	0.08	0.13	0.07				0.07			0.03	0.09
	Distance (cm)			10	20	30	30				20			30	40
	Dose (mSv/y)			0.44	0.70	**1.14**	0.61				0.61			0.26	0.79

Distance is distance of sensor from the metal; R = reinforcement; M. tube is metal square tube; F- metal= flat metal; C pipe = circular pipe; A-iron* = angle iron (for Harar its dimension is 30 x 30).

Based on Figure 2, three of the metals, namely, R (reinforcement) iron of 14 mm, the T-metal and R-iron of 6 mm showed maxima at 10 cm with the first curving up, the next curving down and the third oscillating. Hence none of the three followed the pattern shown in Fig. 3.1b. The flat iron showed maximum at 20 cm and declined thereafter. The metal tube showed maximum between 20 and 40 cm but started with low value at 10 cm. The angle iron showed maximum at 30 cm similar tosome metals obtained from HU workshop.

Possible explanations could be given as to why the radiation from the metals failed to uniformly decreasewith distance as shown in Fig.3.1b. One possibility is change in background radiation over time. Since background radiation was measured only once before any other measurement, changes that occur thereaftermight haveaffectedthe radiation rate measurements of the metals. The effectcould either increase or decrease the measured radiation rate of ametal and hence could create fluctuation in the net radiation. Klemic (undated) mentions about diurnal variability of background radiation that can reach as high as 10% when radiation emission ratio is very high. The second possibility is unisotropicity of the metal. If a metal is anisotropic, the contributions of the sections far from where the measurements were taken can increase,with distance. Consequently,the measured value increases especially if the concentration of radionuclides from distant sections is higher. The third possibility is the influences of other nearby materials with significant amounts of radionuclides.The contribution of the other materialsbecomes stronger as the distance of the detector from the source increasessince the distance between the other materials and the source decreases.The other possibility is the inherent problem with the survey meter in reproducing identical or nearly identical values every time measurements were made. Under such circumstances, even small deviations can bring observable fluctuations in the net radiations.

Radiation risks associated with construction metals

In this part, the measurements conducted using survey meter is presented. Table 2 depicts the results of the line source metals as obtained from the survey meter data. Three things were shown in the table. Thefirst row is the maximum net radiation and the second row is the distance where it occurred. The last row is the annual dose obtained from the net radiation.

The first items tested were construction metals considered as line sources. They were considered as line sources since they had lengths of 6 m (all metals except reinforcement metal whose length is 12 m) and their lengths were much larger than their other sides. Based on Table 3 four of the metals of HU workshop (the two RHSs, the L-metal and the T-metals) revealed doses in excess of 1 mSv/y, which is the recommended limit for public (IAEA, 2010). From among the metals obtained from Harar and Dire Dawa stores, the T-metals revealed net radiation doses (in excess of background radiation) of 1.05 and 1.14 mSv/y, respectively. The flat metal (40 x 40) and the reinforcement iron obtained from Harar store had net radiation doses of 1.23 mSv/y each. One sheet metal of HU workshop and one of Dire Dawa store showed net radiation doses above the recommended value.

The survey meter lacked consistency since it sometimes showed relatively high results and sometimes low results. The instrument needs periodic calibration (CNSC, 2011). But such periodic calibration may not be

Table 4. Maximum net radiations of different construction items (area sources) shown with the corresponding doses and distances at which the maximum occurred.

From where the metals were obtained	**Dimension (m x m)**	**Construction metals (area sources)** **Sheet -metal 2.0 x 1.2**	**Sheet metal 2.0 x 1.0**	**Sheet metal 2.0 x 0.85**	**Scrap metal**	**Metal grill (2.0 x 1.0)**
HU workshop	Net rate (µSv/h)	0.14	0.10	0.10	0.05	
	Distance (cm)	40	20	20	10	
	Dose (mSv/y)	**1.23**	0.88	0.88	0.44	
Harar town	Net rate (µSv/h)		0.07			
	Distance (cm)		10			
	Dose (mSv/y)		0.64			
Dire Dawa town	Net rate (µSv/h)		0.18			0.12
	Distance (cm)		40			10
	Dose (mSv/y)		**1.58**			**1.05**

possible under field conditions. Perhaps the reason why such doses above the recommended values were obtained for substantial type of metals could be because the high values significantly exceed the measured background radiations to give high net radiation rates. It could also be due to oversensitivity of the instrument such that changes in the surrounding environment (including changes in background radiations) could trigger appreciable changes in the measured values. For instance, Döse *et al.* (2014) mention how hand-held instruments show variations due to humidity and background radiations. In general, the survey meter lacked precision.

Generally metals (especially iron) are recycled from scrap metals. Recyclers can unknowingly mix and melt metal with relatively high radioactive contents with clean ones while making new recycled products (NIRS, 2005; CNSC, 2011). Sources that are considered orphan because they were abandoned, lost, misplaced, stolen or transferred without authorization are dangerous to public since they can get into recycling facilities, for instance, with scrap metals (CNSC, 2011). Purposeful plan to sell some of the radioactive wastes to scrap dealers and recyclers is also one of the methods makers and regulators of nuclear wastes use to spread it around as a dilution method such that they can save the money spent for cleanup (NIRS, 2005).

Since metals are used in multiple numbers during construction, the doses could even be higher when their quantities increase. Even for those metals that have shown doses less but close to one, there are possibilities that their dose could exceed 1 mSv/y when their quantities increase.

When considering radiation risks of metals it is important to differentiate metals that remain exposed to the environment from the metals that will ultimately be enclosed. For instance, for the same dose, the risk from reinforcement metal is lower since it is ultimately covered with concrete and the concrete screens most if not all of the radiation. On the other hand, metals that remain exposed all the time continue to pose threat all the time. Metals used for framing of doors and windows, metals used as support structures or as part of decorative items or materials used indoor must be carefully selected such that they contain none or very small radioactive materials. For such metals even doses lower than the limit could be risky particularly for young and new born since no amount of radiation could be considered as risk free (NIRS, 2005).

Sheet metals are considered area sources. They have more areal coverage and materials than line sources and are mostly used as outer covers, which means, they are mostly exposed. In countries where wood products are scarce because of cost and availability,sheet metals are used as partial cover of doors of different types or as shelf cover. The use of sheet metals for any purpose indoors is risky especially if it contains radiation levels above the recommended value. Summaries of results of area sources are given in Table 4

Out of the five area source metals tested, the survey meter data depicted three of them to be risky (above the recommended limit). Variability were observed because of the sources of the metals, which means for the same type of metal some may exhibit high doses while others do not.

Radiations from electronics items

In this case three tests were made. The first was to check the level of radiation from bulk (a number of small electronic items) in lumpsum. The second test was to check radiation levels from computers, laptops, printers and television sets together. Such test was necessary since these items are found around offices where people have frequent encounter with them. The third was to check radiation risks of people working in electronics equipment stores. Out of the three,the survey meter data showed elevated doses (1.52 mSv/y shown in bold face in Table 5) from computers, laptops, printers and television sets that slightly exceeded the recommended limit. The result is not surprising because electronic items

Table 5. Maximum net radiations of electronics items shown with the corresponding doses and distances at which the maximums occurred

		Electronics items		
Location		**Bulk electronics**	**C +**	**E. shop**
HU workshop	Net rate (µSv/h)	0.08	0.19	
	Distance (cm)	10	20	
	Dose (mSv/y)	0.70	**1.67**	
Dire Dawa store	Net rate (µSv/h)			0.04
	Distance (cm)			10
	Dose (mSv/y)			0.35

C+ = computers, laptops, printersand television sets; E-shop = electronic shop

Table 6. Maximum net radiations of different kitchen items shown with the corresponding doses and distances at which the maximum occurred

Source		Kitchen items								
		Local frying pan*	**Charcoal stove**	**Laketch Stove****	**Senegal pot**	**Frying pan**	**Kettle**	**Al. pot**	**Electric stove**	**Others*****
Harar town	Net rate (µSv/h)	0.08	0.07	0.07	0.05	0.07	0.12	0.11	0.14	0.05
	Distance (cm)	10	40	40	20	30	30	30	20	30
	Dose (mSv/y)	0.07	0.61	0.61	0.44	0.61	**1.05**	0.96	**1.23**	0.44

Local frying pan*is locally made skillet known as'biret mitad'; Laketch stove** is locally made stove; Al. pot = aluminum pot; others***= collection of small kitchen items.

such as computers are alsoareas of target for recycling. It could also be because of high radioactive material content of the raw materials from which the materials were processed.

Compared to risks from other sources, the risk from computers should be taken seriously because of two reasons. First, nowadays substantial number of people generally spends more time in front of computers, which means the time spent with such radiation source is high. The higher the level of radiation from the source the lower should be the stay time (time a person could spend with the item without exceeding the limit = *limit/dose rate* both in the same units). The limit is generally 1 mSv/y or 114 nSv/h and the dose rate is the rate measured from the item. Secondly, the separation distance from these sources to the radiation receptor (the user) is also very small (only tens of centimeters). Hence, with these items it is difficult to minimize the risk either by decreasing the stay time or by increasing the distance between the source and the recipient. In such cases, the only precaution is to make radiation level testing before purchasing the items.

Radiation from kitchen items

Only one location (Harar) was used to obtainunused kitchen items. Most of these kitchen items were either imported illegally or manufactured in the country from locally available scrap materials. Maximum net radiations and the corresponding doses of the kitchen items are shown in Table 6

Based on survey meter data, two items (kettle and electric stove) revealed radiation levels slightly exceeding the recommended limit. The values for others, though not insignificant, do not pose threats.

Kitchen items are considered to be volume sources. The radiation rate from such sources is supposed to obey Eq. 2.6, which with slight approximation comes close to area sources.

From the equation the rates show declining trends with distance.Rearranging the equation gives

$$\frac{\dot{D}}{\delta^*} = \frac{1}{R^2} ln \frac{R^2 + h^2}{h^2} \qquad (3.1).$$

The dominant role player in Eq. 3.1 is the logarithmic function. With this approximation, the fractions of radiation rates observed for *h*increments of 10 cm are shown in Table 6.

Table 7 shows that at h = 20 cm its value reduces to one third of the value at 10 cm. The value at 30 cm is half of the value at 20 cm and so on. For a volume source, the rate decreases to about 10% after increasing the distance by 30 cm. Hence for such sources, the 40 cm could be considered as a safe distance unless the source is emitting exceptionally high amount of radiation.

Table 7. Fraction of radiation rate for every increment of sensor distance from the source for volume sources calculated using R = 10 cm.

h	$\ln [(R^2+h^2)/h^2](1/R^2)$	Fraction
10	0.0069	1.000
20	0.0022	0.322
30	0.0011	0.152
40	0.0006	0.087

CONCLUSION

In this study assessment of radiation levels of fourteen different line-source and five area-source metals, nine different kitchen items and three electronic bulk items; all obtained from three locations were made using Universal Survey Meter. From the study made, the survey meter data revealed nine of the line-source and three of the area-source metals that have doses that exceeded the recommended limit. Only two of the kitchen items showed doses above the limit. A set of computers, printers and television sets measured in lumpsum showed above the limit radiation from electronics items. The results of the survey meter had high standard deviation, which means the error could be high but nevertheless the results make sense. The study shows the importance of periodically testing radiation levels of items which can get into possession of the public.

ACKNOWLEDGEMENTS

The authors would like to thank Haramaya University and the shop owners of Harar and Dire Dawa towns (whose names the authors would like to keep anonymous) for allowing them take the measurements. They also thank the Ethiopian Radiation Authority for the survey meter used in this study. This research was performed through the research grant provided by HU.

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