Radiation Levels from Laboratory Wastes and Pharmacy Items at Four Hospitals in Harar and Dire Dawa Towns

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Abstract: Human beings are always exposed to radiation in one form or another. Though little could be done to minimize the background natural radiation, it is possible to minimize exposure to manmade radiation, to a certain extent. In this study radiation level measurements were conducted, at two private and two public hospitals in Harar and Dire Dawa towns. Radiation rate measurements were conducted on pharmacy items and laboratory wastes of each hospital using Universal survey meter (RDS-200) and Electronic Personal Dosimeter (mini-6100) for eight days. Radiation rate measurements using both instruments did not reveal significant radiation levels above the background in pharmacy items and laboratory wastes at the hospitals studied. This indicates that pharmacy workers and the public living close to lab wastes are not currently at the risk of exposure to dangerous levels of radiation in both towns.

Keywords: Background radiation; Man-made radiation; Radiation levels; radiation rate

1. Introduction

One of the potential environmental threats to human beings is radiation, especially when it is of ionizing type and exceeds a certain limit. Even if the level of tolerance varies from individual to individual, it is always important to keep radiation levels within a safe limit (IAEA, 1994; UNSCEAR, 2010).

Human beings are generally exposed to two types of radiation, namely, natural and manmade radiation. To know the contribution of manmade sources of radiation, it is necessary to know the natural background radiation, which accounts for over 80% of the total radiation (IAEA, 1997). Natural radiation can be seen as internal (inhalation and ingestion) and external. The internal, on average accounts for a radiation dose of 1.5mSv/y. The internal and the external together come to 2.4 mSv/y (IAEA, 2010).

Natural radiation is a combination of cosmic and terrestrial radiations. Cosmic radiations in turn are from two sources: galactic cosmic and solar cosmic radiations (IAEA, 2010). The former is from different sources within our galaxy. Solar cosmic radiation is created near the sun's surface due to magnetic disturbances. It has a dose range of 0.1-1.0 mSv/y (IAEA, 2010) and is considered to be of a lower level of energy compared to galactic cosmic radiation and hence, can be affected more with the earth's magnetic field. Cosmic ray interaction produces a number of radioactive nuclei also known as cosmogenic radionuclides, among which ^{14}C, with average effective individual dose of 0.012 mSv/y is predominant when it comes to public exposure (UNSCEAR, 2010). Even though cosmic and galactic radiations are assumed to be fairly constant, solar cosmic radiation may show increments during the sun's activity, which creates a variation of about 10% in solar wind (highly ionized plasma with associated magnetic field) and fluctuates with the solar activity cycle of about 11 years (UNSCEAR, 2010). On the other hand, cosmic radiations vary on the surface of the earth depending on where one is located in terms of latitude and altitude (UNSCEAR, 2010). Dependence of cosmic radiation on latitude is due to unevenness of the earth's magnetic field, which is responsible for weakening the radiation at the two van Allen belts; the internal, centered at 3,000 and the external, centered at 22,000 kilometers from the surface of the earth (UNSCEAR, 2010). In general, the effect of the earth's magnetic field on cosmic radiation increases from polar to equatorial regions (UNSCEAR, 2010). Cosmic radiation contributes 0.4 mSv/y to the background radiation (IAEA, 2010).

The Earth's atmosphere is another component that minimizes the amount of ionizing radiation reaching the earth's surface. High energy particles interact with atoms and molecules in the air and generate secondary charged and uncharged particles (UNSCEAR, 2010). Such an interaction is responsible for reducing the energies of the photons and that of secondary particles thereby diminishing the power of ionizing radiation reaching the earth's surface. Hence, areas of high altitude experience the effect of cosmic radiation more than arras of low altitude. Actually, dose rate increases exponentially with altitude (Federico *et al.,* 2010).

Terrestrial radiation is due to radionuclides within the earth, the dominant of which are: ^{40}K, ^{238}U and ^{232}Th (UNSCEAR, 2010). External terrestrial radiation accounts for 0.5 mSv/y (IAEA, 2010). Besides, there is inhalation (internal) of radon (Ra). Radon is the heaviest inert gas, which is radioactive and occurs in areas over granite and upon release joins other atmospheric gases (IAEA, 1978; USNRC, 2015). It is the dominant contributor to background radiation with a contribution of 1.2 mSv/y (IAEA, 2010).

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Since radionuclides are not evenly distributed in earth, terrestrial radiations can show a spatial variability. In some regions of the world there can be elevated doses of natural radionuclides that can account for several mSv/y (Jwanbot *et al.,* 2014). Even country-wise, it is possible to encounter background radiation far greater than the regulatory limit (IAEA, 1994). In addition, terrestrial radiation can also show temporal variability, especially in terms of diurnal and seasonal variability. Diurnal variability can reach as high as 10% where radon emission is very high. Such temporal variability is caused by variation in the concentration of radon on the surface of the earth. For instance, at night when the atmosphere is not vertically mixing very well, more radon concentrates near the earth's surface on account of its heavy weight. This causes terrestrial concentration slightly higher at night close to the earth's surface. The situation changes when the atmosphere starts to mix up vertically as the earth warms up. Similarly, precipitation can scavenge radon progeny from the atmosphere and increase background radiation by up to two to three times until it is released back to the atmosphere. Seasonal variability can arise because of temperature (e.g. frozen soil) and precipitation (e.g. snow cover), both of which can be responsible for trapping radon in the soil. Terrestrial radiation has a range of 0.3-0.6 mSv/y (IAEA, 2010).

Contribution from manmade sources to the total radiation is on average 0.4 mSv/y and it elevates the total annual radiation to 2.8 mSv (IAEA, 2010). Manmade radiations are from sources such as health facilities (in the form of radiation test or radiation therapy), commercial and industrial activities. From among the three, medical facilities contribute over 90% of the manmade radiation (NCRP, 2009; USNRC, 2015) and deserve attention, in order to minimize manmade radiations.

Radiation in medical facilities poses threats to workers (especially the ones working in and around the radiation sources), patients (when they unnecessarily stay or loiter around the sources) and the general public (if radiation wastes are disposed with other wastes). Once present in the environment, radionuclides, whether natural or manmade, are available for uptake by plants and animals and can get into the food-chain (Kabir *et al.,* 2009). In pharmacies there can be drugs or other items that may contain radiation sources. For instance, chemicals containing Iodine-131, Xenon-133, Molybdenum-99 or Technetium- 99 can emit trace amounts of radiation (Ice and Hetzel, 1974). Because of limitation of resource, this study paid attention to health facilities (hospitals) and from the hospitals, pharmacies (to check drugs that contain radioactive materials) and laboratory waste sites. The study was conducted to elucidate radiation risks posed to humans from pharmacy items and laboratory wastes.

2. Materials and Methods

2.1. Study Sites

For this study, one public hospital (Hiwot Fana) and one private hospital (Yimaj) were selected at Harar town (latitude, 9°15'-9°27', longitude, 42°04'- 42°22'E, mean altitude of 1780 m above sea level and average temperature of 22.65°C). Similarly, Dil Chora (public) and Yemariamwork (private) hospitals were selected at Dire Dawa town (latitude, 9°27'-9°49'N, longitude, 41°38'-42°19'E, mean altitude, 950 m above sea level and average temperature of 24.55°C). The private hospital was included intentionally to see differences (if any) between the public and the private setups. All the four hospitals have facilities to carry out radiation therapies. There were no specific reasons for not selecting other hospitals, public or private, other than convenience.

2.2. Materials Used

For the actual radiation measurement, Electronic Personal Dosimeter (EPD, model Mini-6100) and Universal survey meter (model RDS 200) were used.

2.3. Data Collection

Background radiation and radiations from pharmacy items and background radiation and radiation from laboratory wastes of the four hospitals were measured using the two instruments for a period of eight days (a day for pharmacy items and another day for lab wastes of each hospital). Background radiation measurements were made at a height of 1 m from the ground surface five times (i.e., five replications) at intervals of three minutes every day before the other measurements. Radiation measurements from pharmacy items and laboratory wastes were made every three minutes for a total of one hour (19 replications) at distances not exceeding 5 cm from the source. All measurements were made before noon between 09:00 and 10:00 local times. For EPD measurements a three-minute waiting time was used. Survey meter measurements were conducted simultaneously with EPD measurements.

2.4. Data Analysis

Net radiation of pharmacy items and laboratory wastes (radiation in excess of background radiations) were important in this study. But in the case of EPD measurement the background and the other radiation rate measurements showed a declining tendency over time and it was necessary to find correction factor for EPD data. In order to obtain the two correction factors for the two locations, first, the mean values of the daily background radiations were plotted against the days of measurement of each location. Plotting was necessary to find the trend in the decreasing pattern of the measured values. Then, the plots were curve-fitted, to get appropriate correction parameters, on daily, hourly and finally, for every minute.

After obtaining the correction factors, measured rates of pharmacy items and laboratory wastes of each hospital were adjusted using the correction factors. The adjusted values were then compared with their respective background radiation. The study laid out as completely randomized design and hence one-way ANOVA was used for comparison. Besides, net radiation and percent errors were calculated as shown in Eqns. 1 and 3. Net radiation rate (R_n) was obtained by subtracting the respective background radiation (R_b) from the measured (R_m) pharmacy items or laboratory waste radiation rates as:

$$R_n = R_m - R_b \quad (1)$$

Generally, the unit of dose rate is Sievert per hour (Sv/h). Net radiation dose (D_n) in Sievert per year (Sv/y) was obtained from the net radiation rate multiplied by the time interval, t the system is exposed to the radiation as:

$$D_n = R_n t$$

The radiation dose calculated over a year is:

$$D_n = R_n\left(\frac{\text{Sv}}{\text{h}}\right)\left(24\frac{\text{h}}{\text{d}}\right)\left(365\frac{\text{d}}{\text{y}}\right) = R_n \times \frac{(8.76\times10^3)\ \text{Sv}}{\text{y}}. \quad (2)$$

Since the magnitude of the radiation dose rate is in the order of two hundred Nano-scales $(\sim 2\times10^{-7})$ Sv/h in this case, the radiation annual dose is in the order of $(\sim 2\times10^{-3})$ Sv/y $\simeq 2$ mSv/y from relation (2) above.

Percent differences (P_d) were calculated as;

$$P_d = \frac{R_m - R_b}{R_b}(100\%). \quad (3)$$

3. Results and Discussion

3.1. Obtaining Correction Factors from Background Radiations

Since Harar and Dire Dawa are at two different altitudes (their latitudes are nearly the same), their background radiations showed differences accordingly. The fact that a linear decreasing pattern was observed over each of the two locations in EPD measurement indicates that the changes were not due to atmospheric phenomena or random error. Izewska and Rajan (2005), mention about energy dependence of the beam quality and readings of dosimeters. They also mention about storage traps and recombination centers due to lattice imperfections or impurities. The storage traps can capture charges, which may recombine with charges of opposite sign in recombination center. Such recombination can reduce the sensitivity of the instrument especially when power gets weaker. Hence, the daily decline of the readings may be due to reduction in the sensitivity of the EPD as power gets weaker. Since the reduction in radiation rate was observed after some readings were taken, we preferred to go for correction factor rather than tampering with the instrument.

Hence, two correction factors were required for the two locations. In order to see the decreasing pattern of the background radiation, the daily averaged background radiations of each location were plotted against the days over which the measurements were carried out. Figures 1 and 2 reveal the plots of background radiations of Harar and Dire Dawa towns, respectively.

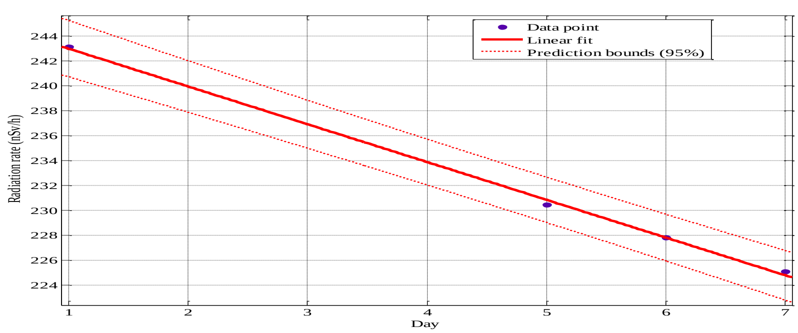

Figure 1. Change in Harar background radiation during the measurement days

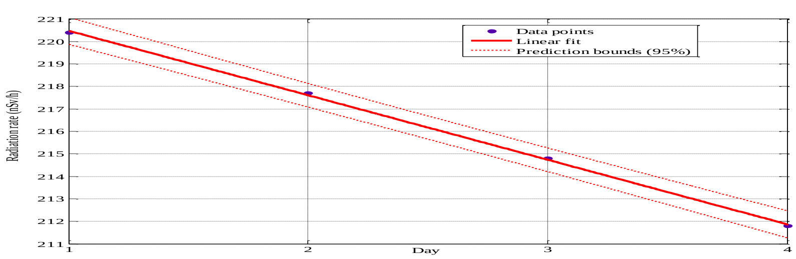

Figure 2. Change in Dire Dawa background radiation during the measurement days

In the case of Harar, there were three days during which measurements were not taken after the first day and those days were left blank. The two figures showed perfect linear fit as observed from their R^2 values (>0.99) and prediction bounds. The summary of regression statistics of the two plots is given in Table 1.

Table 1. Summary of regression statistics and time change of background radiation rates at the two locations.

Location	Slope	Intercept	R^2	SSE	RMSE	Hourly chang	Δ/min.
Harar	-3.03	246.0	0.9985	0.2869	0.3787	-0.1263	-0.0021
Dire Dawa	-2.87	223.3	0.9994	0.0230	0.1072	-0.1196	-0.0020

Note: SSE = Sum squared error; RMSE = Root mean square error; Δ/min. = change in radiation rate per minute (correction factor)
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As observed from Table 1, the slopes and intercepts obtained from the plots of the two locations were close to each other. They also revealed low SSE and RMSE, which clearly revealed the close correlation between the predictor (day) and the predicted (radiation rate). The slopes represented daily rate change (inherent reduction in the rate measurement by the instrument) in nSv/h, at the two locations. Since time differences between measurements were in hours or minutes, the daily values were converted to hourly values dividing by 24 h/d and the hourly values were converted to minute values dividing by 60 min/h. The last two columns can thus be looked at as hourly and minute correction factors.

As observed in the figure, variation in location did not cause significant difference in the correction factors. Even though each location was treated with its own correction factor, the average of the two values could have been used for both locations.

Daily variation at Harar town showed a linear declining trend rate of 3.03 nSv/hd. At Dire Dawa town, the daily decline revealed a linear trend with a slope of -2.87 indicating that daily background radiation rate declined at 2.87 nSv/hd. Since there is nothing that shows daily variability of cosmic radiation except for the changes that occur following sun's activity, the diurnal variability must be associated with terrestrial radiation (UNSCEAR, 2010) or inherent pattern in the instrument.

The time variability observed in the two figures is better explained in relation to terrestrial radiation than cosmic radiation. During morning hours (until the atmosphere mixes very well vertically) there are more radon particles near the earth's surface and this tends to increase values measured during morning hours. As the earth's surface gradually warms, the radon particles move up with other atmospheric particles and that brings in gradual reduction in near surface radiation measurement. Hence, it shows decreasing tendency as the day hour progresses. However, we cannot confidently say what happened, say around noon or in the afternoon since our measurements were limited to between 09:00 and 10:00 local times.

Based on the correction factors given in Table 1, the pharmacy and laboratory waste values were corrected and the mean values and the standard deviations were calculated. Summary for the two locations for the EPD data are given in Table 2a.

Based on Table 2a, location differences in background radiations have clearly shown that the average for Harar was greater than 239 nSv/h over the four days while that of Dire Dawa was 219 nSv/h. The corresponding annual doses were between 2.10 and 2.13 mSv for Harar and 1.93 nSv for Dire Dawa. The difference between the two could account for 0.2 mSv/y. IAEA (1996) generally indicates the level of background radiation in any country to range between 100 and 200 nSv/h, even though the value can be much higher in some sites. In this study, the values measured by EPD are slightly higher whereas the values measured by the survey meter are within this range. Compared to the background radiation values of other countries such as 3.1 mSv/y for US (USNRC, 2015), 2.7 mSv/y for UK (Watson *et al.,* 2005) and 2.09 mSv/y for Japan (Harada *et al.,* 2014), the values obtained at Harar were closer to the latter two whereas that of Dire Dawa were lower as it is supposed to be since the town is located at a lower altitude. Consistent with this result, earlier showed that radiation levels are usually lower at lower altitudes Compared with the global average of about 2.4 mSv/y (IAEA, 2010), background radiations of the two towns are well within limit. The difference between Harar and Dire Dawa is attributable to difference in atmospheric air masses at the two locations. More of the background cosmic radiation over Dire Dawa is attenuated by the thicker atmospheric mass compared to that of Harar. According to Federico et al. (2010), dose rate changes exponentially with altitude.

Radiation rates from pharmacy items of the two Harar hospitals were 242 nSv/h (2.12 mSv/y) each. For Dire Dawa hospitals the rates were between 219 and 220 nSv/h (1.92 and 1.93 mSv/y). Similarly, for laboratory wastes the values were between 241 and 242 nSv/h (2.11 and 2.12 mSv/y) for Harar on average 219.5 nSv/h (1.92 mSv/y) for Dire Dawa, Looking at these values, one can see that there is no significant difference between the background values and the values obtained from pharmacy items and laboratory wastes at all hospitals. The ANOVA results shown in Table 3a and 3b also reveal the same outcome.

Anything above background radiation (radiation from manmade sources) has to be limited to 1 mSv/y (USNRC, 2015; Harada *et al.,* 2014) for the general public and to less than 50 mSv/y for those working with radiative materials (USNRC, 2015). But based on the EPD data, in this particular case there was no significant difference between the background and the other values and hence there is no radiation risk from the two sources.

The result from the survey meter data was seen independently to check whether or not the two instruments gave the same results. A summary of the survey meter result is shown in Table 2b.

While working with the survey meter, there were two problems encountered. The first problem was the very large standard deviations, which in most cases were more than half of the measured values. This meant that the instrument lacked consistency or repeatability. The second problem was in the values measured. Even if five replications were made for background measurements and 19 replications each for radiation rates of pharmacy items and laboratory wastes, the average values gave about half of what were measured by EPD. Both the inconsistency and the low values measured by this instrument compelled us to rely more on the EPD data even though comparisons were made using both data.

Table 2a. Mean and standard deviation of radiation rates obtained from pharmacy items and laboratory wastes shown with the background radiation for EPD data.

Location	Hospital	Average rate (nSv/h)		Dose (mSv/y)		Average rate (nSv/h)		Dose (mSv/y)	
		Pharmacy	Background	Pharmacy	Background	L.waste	Background	L.waste	Background
Harar	HF	241.9 ± 0.46	243.1 ± 0.27	2.12 ± 0.004	2.13 ± 0.001	241.3 ± 0.37	242.4 ± 0.06	2.11 ± 0.003	2.12 ± 0.0005
	Yimaj	242.1 ± 0.34	239.8 ± 0.27	2.12 ± 0.003	2.10 ± 0.002	242.4 ± 0.33	240.1± 0.06	2.12 ± 0.003	2.10 ± 0.0005
Dire Dawa	YW	219.3 ± 0.42	220.4 ± 0.08	1.92 ± 0.004	1.93 ± 0.001	219.4 ± 0.30	220.7 ± 0.27	1.92 ± 0.003	1.93 ± 0.002
	DC	219.9 ± 0.33	220.8 ± 0.27	1.93 ± 0.003	1.93 ± 0.002	219.6 ± 0.33	220.8 ± 0.27	1.92 ± 0.003	1.93 ± 0.002

Note: L..= laboratory; HF=Hiwot Fana; YW = Yemariamwork; DC = Dil Chora

Table 2b. Mean and standard deviation of radiation rates obtained from pharmacy items and laboratory wastes shown with the background. (Survey meter data).

Location	Hospital	Average rate (nSv/h)		Dose (mSv/y)		Average rate (nSv/h)		Dose (mSv/y)	
		Pharmacy	Background	Pharmacy	Background	L.waste	Background	L.waste	Background
Harar	HF	150 ± 114	72 ± 37	1.31 ± 1.00	0.63 ± 0.32	117 ± 94	126 ± 79	1.02 ± 0.82	1.10 ± 0.69
	Yimaj	114 ± 90	72 ± 37	1.00 ± 0.75	0.6 3 ± 0.32	143 ± 110	70 ± 34	1.25 ± 0.96	0.61 ± 0.30
Dire	YW	107± 66	72 ± 54	0.94 ± 0.58	0.63 ± 0.47	144 ± 142	80 ± 35	1.26 ± 1.24	0.70 ± 0.31
Dawa	DC	106 ± 72	68 ± 41	0.93 ± 0.63	0.61 ± 0.36	125 ± 61	94 ± 39	1.09 ± 0.54	0.82 ± 0.34

Note: L= laboratory; HF = Hiwot Fana; YW = Yemariamwork; DC = Dil Chora

3.2. Comparison of Rates from Pharmacy Items and Laboratory Wastes with Background Radiations

The main objective of this work was to check if there were differences between radiation rates of pharmacy items and the respective background radiations and those of laboratory wastes with their background radiations. For comparison a one-way ANOVA was used at alpha of 0.01. Besides, ANOVA, net radiations and percent differences were also calculated. The results are shown in Table 3 (3a for EPD data and 3b for survey meter data).

In Table 3a, all the differences between radiation rates of pharmacy items and the background were found out to be negative. Likewise, the same result was observed with laboratory wastes. Besides, the differences in all were very small (percent differences of less than 0.7). In other words, background radiation rates slightly exceeded the values measured from pharmacy items and laboratory wastes. However, as far as radiation risks were concerned, they were the same with the background radiation (no significant radiations were coming from the two sources). ANOVA result at alpha of 0.01 also reflected the same outcome. Based on this result, both do not pose a threat to any one as far radiation risks are concerned.

The negative difference may be due to site differences. Major contributor to background radiation is terrestrial radiation, especially the soil. Since laboratory wastes are mostly outside with small hole or pit dug for this purpose, the pit creates additional distance between the sensor and the soil. Because radiation intensity decreases as the distance from the source increases (Voss, 2001). This can be the cause for smaller values recorded from laboratory wastes. Such small difference could also be due to instrumental errors.

Pharmacy items are measured within the pharmacy (i.e., in a room). In rooms with floors paved with cement or any other material the possibility of radon gas escaping from the soil underneath is slim (EC, 1999). If on top of that the materials from which the walls and the floors were constructed do have low concentrations of radionuclides, emission from both would be very low. But to the contrary, the walls can also shield some of the external radiation (EC, 1999). With no emission from pharmacy items and low emission within the room, it is possible to get radiation rates lower than the background (negative net radiation). From EPD data there was also no difference between radiation rates from pharmacy items and laboratory wastes.

Comparison using a survey meter data gave a different result not in terms of ANOVA but in terms of percent differences (Table 3b). In this case, except for one incidence (laboratory waste of HF hospital), all the rest gave positive differences. The highest percent difference was between pharmacy items' radiation rate and the background (52%) at HF hospital and the lowest, between laboratory wastes and the background (-8%) of the same hospital. Had it not been for the large standard deviations (large variability among data values) it could have been possible to find significant statistical differences using these data.

Table 3a. Comparison of pharmacy and laboratory wastes with location background radiations (EPD data).

Location	Hospital	Average rate (nSv/h)		Δ bkgnd	% diff.	ANOVA	Average rate (nSv/h)		Δ bkgnd	% diff.	ANOVA
		Pharmacy	Background	Pharmacy	Pharmacy	(at 1%)	L. Waste	Background	L.Waste	L. Waste	(at 1%)
Harar	HF	241.93	242.9	-0.97	-0.40	NS**	241.3	242.9	-1.6	-0.66	NS**
	Yimaj	242.05	242.9	-0.85	-0.35	NS**	242.4	242.9	-0.5	-0.21	NS**
Dire Dawa	YW	219.30	220.7	-1.4	-0.63	NS**	219.42	220.7	-1.28	-0.58	NS**
	DC	219.94	220.7	-0.76	-0.34	NS**	219.61	220.7	-1.09	-0.49	NS**

*Note: HF=Hiwot Fana; YW = Yemariamwork; DC = Dil Chora; Δbkgnd = Pharmacy or L. waste rate – background rate; % diff = [(Δbkgnd)/background rate](100%); L. = laboratory; NS** = not significant at 1%.*

Table 3b. Comparison of pharmacy and laboratory wastes with location background radiations (Survey meter data).

Location	Hospital	Average rate (nSv/h)		Δ bkgnd	% diff.	ANOVA	Average rate (nSv/h)		Δ bkgnd	% diff.	ANOVA
		Pharmacy	Background	Pharmacy	Pharmacy	(at 1%)	L.Waste	Background	L.Waste	L. Waste	(at 1%)
Harar	HF	150	72	78	52	NS**	117	126	-9	-8	NS**
	Yimaj	114	72	42	37	NS**	143	70	73	51	NS**
Dire Dawa	YW	107	72	35	33	NS**	144	80	64	44	NS**
	DC	106	68	38	36	NS**	125	94	31	25	NS**

*Note: HF=Hiwot Fana; YW = Yemariamwork; DC = Dil Chora; Δ bkgnd = Pharmacy or L. waste rate – background rate; % diff = [(Δbkgnd)/background rate] (100%); L. = laboratory; NS** = not significant at 1%.*

Table 4 includes the dose exceeding the background, based on the survey meter data. The maximum dose above the background observed in the Table is 0.68 mSv/y, which is still below the 1 mSv/y set as the highest limit for the general public (Harada *et al.,* 2014). But if the reading is twice as much or higher than this value, it may exceed the recommended limit. However, as the reading in this experiment is assumed to have been done fairly accurately, the amount of radiation measured is supposed to pose no threat to the public.

Table 4. Equivalent dose of the difference between radiation rates from pharmacy items and the background and laboratory wastes and the background (Survey meter data).

Location	Hospital	Average rate (nSv/h)		Δ bkgnd Pharmacy	Dose (mSv/y)	Average rate (nSv/h)		Δ bkgnd L. Waste	Dose (mSv/y)
		Pharmacy	Background			L. Waste	Background		
Harar	HF	150	72	78	0.68	117	126	-9	-0.08
	Yimaj	114	72	42	0.37	143	70	73	0.64
Dire Dawa	YW	107	72	35	0.31	144	80	64	0.56
	DC	106	68	38	0.33	125	94	31	0.27

Note: HF=Hiwot Fana; YW = Yemariamwork; DC = Dil Chora; Δ bkgnd = Pharmacy or L. waste rate – background rate; [(Δbkgnd)/background rate](100%); L. = laboratory.

4. Conclusion

Radiation rate measurement studies were conducted at two public and two private hospitals, two each in Harar and Dire Dawa towns. In the study, radiation rate measurements were conducted on pharmacy items and laboratory wastes for each hospital along with their respective background radiations, for a period of eight days. Both EPD and Survey meters were used for radiation rate measurements.

Radiation rate measurements of items of four pharmacies and four laboratory wastes did not show significant differences from the background based on the data of both instruments. EPD data revealed small negative percent differences, which means the background radiation rate slightly exceeded those of pharmacy items and laboratory wastes. The survey meter data gave the opposite result (except in the case of HF laboratory wastes), with large differences. However, ANOVA result did not reflect significant differences because of large variability in the data. Based on the result of EPD there is no eminent threat of radiation risk either to the workers and the public. The result of the Survey meter data is inconclusive because the instrument did not show good accuracy and precision.

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