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Measurement of Background Radiation at Oracle Plastics and Sacks Company in Makurdi, Benue State

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ABSTRACT

The background radiation level of Oracle Plastics and Sacs were investigated and measured using the Radiation Alert Inspector. A total of seven (7) units/departments within the company were considered: marketing, clinic waiting room, entrance, sack section, leather/shopping bag, polyvinyl chloride (PVC), and injection mould units, and data were obtained from those units. The investigation revealed that the mean exposure dose rate of the background radiation within the company was 0.019±0.0062 µSv/hr, and the mean annual exposure dose equivalence was 0.17±0.0028 mSv/yr. The global average natural dose of background ionizing radiation for exposure dose rate as recommended by UNSCEAR (2008) was 0.274 µSv/hr. The ICRP and UNSCEAR values of the annual effective dose equivalence were 1.00 mSv/yr and 20.00 mSv/yr for individual in general public and occupational workers respectively as recommended by the organization. The average activity concentration measured from different section ranged from 9.017 Bq/Kg (Marketing and Injection Mould) to 21.322 Bq/Kg (Polyvinyl Chloride) with mean value of 13.413±4.742 while the estimated result of excess lifetime cancer risk ranged from 0.069 (Polyvinyl Chloride) to 0.161 (Marketing, sack section and the injection mould) with a mean value of 0.118±0.040. The ELCR mean value was also found to be lower than the world average safe limit of 0.29. The ELCR mean value was also found to be lower than the world average safe limit of 0.29. The Company has low level activity of background radiation compared to other such company around the world.

KEYWORDS: Background radiation, Plastics, Sacks, Dose and Health risk.

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Introduction

The word radiation arises from the phenomenon of waves emanating (i.e., traveling outward in all directions) from a source. Radiation is energy in motion. It is the energy that comes from a source and travels through space at the speed of light. This energy has an electric field and a magnetic field associated with it, and has wave-like properties (Weisstein 2007).The different forms of radiation include:

1. Electromagnetic radiation such as radio waves, microwaves, infrared, visible light, ultraviolet, x-rays and gamma radiation.
2. Particle radiation, such as alpha radiation, beta radiation, proton radiation and neutron radiation (particles of non-zero rest energy).
3. Acoustic radiation, such as ultrasound, sound, and seismic waves (dependent on a physical transmission medium).
4. Gravitational radiation, that takes the form of gravitational waves, or ripples in the curvature of spacetime.

Radiation is often categorized as either ionizing or non-ionizing depending on the energy of the radiated particles. A common source of ionizing radiation is radioactive materials that emit alpha, beta, or gamma radiation, consisting of helium nuclei, electrons or positrons, and photons, respectively. The non-ionizing radiation lower the energies of the lower ultraviolet spectrum which cannot ionize atoms, but can disrupt the inter-atomic bonds which form molecules, thereby breaking down molecules rather than atoms; a good example of this is sunburn caused by long-wavelength solar ultraviolet radiation (Eisenbud, et al. 1997).

Radiation and its interaction with living organisms (human) is a reality of life because we live in a world in which radiation is naturally presents everywhere from different sources, light and heat are good examples. Light and heat from nuclear reactions in the sun are imperative to our existence (Ode et al, 2017). Humans are always exposed to different sources of radiation which can either be artificial or natural radiation and this occurs as a result of vibration or unstable state of an atom of any element. The radiation emanating from different sources contributes to what is known as background radiation. This radiation can be harmful depending on the energy of the radiating particle(s). An unstable atom changes into a more stable atom of a different element by giving off radiation and producing energy. This process is called radioactive decay.

Background radiation is present on earth at all times. The majority of background radiation occurs naturally from minerals and a small fraction comes from man-made elements. Naturally occurring radioactive minerals (e.g Uranium, and Radon) in the ground, soil, and water produces background radiation. The human body even contains some of these naturally-occurring radioactive minerals like carbon-14, Polonium-210, and Potassium-40 (Ode et al, 2017). Potassium-40 is found in the food, soil, and water we ingest. Our body contain small amount of radiation because the body breakdown/dissolve the non-radioactive and radioactive forms of Potassium and other elements in the same way Cosmic rays from space also contribute to the background radiation around us. The main components of natural background radiations are extraterrestrial cosmic rays and radiation due to radioactivity of some primordial elements in the earth. Cosmic rays consist of 87% protons, 12% α-particles and 1% heavy nuclei with energies ranging between 10^9eV to 10^{17}eV. When these high energy particles react with the particles of the atmosphere, many products such as mesons, electrons, photons, protons, and neutrons are emitted and in turn produce other secondary particles as they travel down to the earth's surface (Farai and Vincent 2006). There can be large variances in natural background radiation levels from place to place, as well as changes in the same location over time. The knowledge of background radiation levels in the environment is also important to enable estimation of the effects of radiation exposure to humans, predicting the level of natural radioactivity without laboratory measurement and also forms the baseline for assessment of future radioactive contamination or pollution in the environment (Olagbaju, et al. 2021).

To measure the background radiation level in any environment or factory, one has to know the major element(s) emitting radiation.

The terrestrial component of natural background radiation is therefore strongly influenced by local geology. That is, rocks that contain radioactive substances such as radon emit high amount of radiation which affect the people living around her. In addition to the inevitable natural background radiation sources, man can be exposed to various man-made radiations sources that are enhanced by human activities such as mining activities, or production of chemicals which has to do with many elemental chemical/nuclear reactions. Because of the deleterious health effects of radiation exposure, the practice has been to keep exposure to man-made sources to as low as reasonably achievable, usually term the ALARA principle. However, the risks of accidents, which can result in environmental pollution of radioactive substances, are always finite (Gogolak, et al, 1986). An accurate knowledge of the natural background radiation in an environment is essential for a correct assessment of radiation level due to such pollution (Farai and Vincent 2006). One of the materials in the plastic factory contributing to the background radiation level is the polyvinyl chloride (PVC).

All fossil combustible materials, such as coal and crude oil, contain radioactive elements origin from the natural decay series of Uranium and Thorium. The basic material for the synthesis of plastics is crude oil. Therefore, such materials may contain radionuclides. Plastics can harm our health at every stage of their lifecycle-from extraction and production to transport, use, and disposal. Plastics are an environmental justice issue, an intrinsic part of the climate crisis, and a source of toxic pollution (Gogolak, et al, 1986). With the increasing emphasis on sustainable construction, it has become important to better understand the impacts of common materials to human health. For example, plastic PVC (polyvinyl chloride) is a type of plastic made with vinyl chloride, a carcinogen. Polyvinyl chloride/vinyl chloride monomer (VCM) can be seen as a material with potential for significant adverse effects on a multiplicity of levels, and the plastic industry is its single most significant consumer (Emina and Lydia, 2018). Recent studies have shown that VCM exposure is associated with hepatocellular cancer. In Taiwanese studies, the majority of VCM-exposed workers with liver cancer had history of hepatitis virus (HBV). Due to the alarming increase in contamination worldwide and excessive production of plastics and synthetic materials, it's expedient to investigate the degree of radiation exposure for safety of lives.

MATERIALS AND METHOD

Study location

Oracle Plastics and Sacks Company is a Company located in Industrial layout Makurdi, Benue State.The company has a working staff capacity of about 125 persons with a day (8:00am-6:00pm). and night shift (6:00pm-8:00am). The company is one of the major plastic producing company within the middle belt region of Nigeria. The plastics produced are; chairs, reading tables, pipes, etc. The estimated population of the inhabitant in that region is about 3465 (NPC, 2022; NBS, 2022). Fig. 3.1 shows the geographical location of Oracle Plastics and Sacks Company. It lies within latitude 12.992263 and longitude 77.652464 with a bearing of 287 in Makurdi local government area of Benue State (NBS, 2022).

Description of the equipment

The measurement of background radiation level was carried out using radiation meter (Digital Radiation alert inspector). The choice of this meter was depended on its portability, sensitivity, and response, which are appropriate since the radiation measurements are for low radiation field (Ode, 2018). The inspector is a health and safety instrument that is optimized to detect low levels of radiation. It measures alpha, beta, gamma, and x-ray radiation. The inspector is designed for use of conventional units (milliroentgens per hour and counts per minute) or SI units (microsieverts per hour and counts per second) (Steve and Robbin, 2020). Other materials used were stop watch and microprocessor.

Method

Background radiation of seven different departments were measured; marketing, Clinic, background entrance, sack section, leather/shopping bag section and polyvinyl section, and Injection mould section. The results obtained from the company were analyzed using the radiological health risk parameters.

The radiation measurement method adopted was a direct observation and measurement of radiation level from various site visited at Oracle Plastics and Sacks Company in Makurdi, Benue State with the digital radiation alert inspector. The background radiation within the environment was measured at about 350 meters away from the sites (Ode et al, 2017). A small hand microprocessor (Geiger tube) attached to the monitor was held at about 4-5 cm above the sea level and the radiation emitted was recorded within an interval of one minute (60 seconds) each. Three different readings were taking in four different locations namely; North, South, East and West within the company's environment and an average reading was obtained from the three readings. The average radiation rate was measured in count per minute and converted to exposure dose rate using 120 (CPM) = 1μSv/h as conversion factor. Also a conversion factor of 1μSv/h=1000 nGy/h for absorbed dose rate to enabled the estimation of annual effective dose rate (Steve and Robbin, 2020).

Radiological health risk parameters (Radiation hazard parameters)

The radiological health risk parameters are standard tools (mathematical expressions) used to assess and estimate the radiation risk of all relevant people (including members of the public) from work with ionizing radiation (UCL, 2022). The radiation health risks parameters associated with the measurement of different section's background radiation.

Dose rate

Dose rate is the quantity of radiation absorbed or delivered per unit time. It is often indicated in milligrays per hour (mGy/h) or as an equivalent dose rate HT in rems per hour. However, for the purpose of this experiment and the equipment used (radiation alert inspector), count per minute (CPM) was used. It is obtained by taking the average of the readings at each location.

$$D_R = \frac{N}{M} \qquad (3.1)$$

where: N is the sum of dose received and n is the total number of dose received.

Actual dose rate (CPM)

It is obtained by subtracting the value of the background radiation from those of the Dose rate for each location.

$$AD_R = D_R - 40CPM \qquad (3.2)$$

where D_R is the dose rate for each location and 40CPM is the value of the background radiation.

Exposure dose rate (μSv/hr)

It is obtained by dividing the value of actual dose rate by 1200CPM.

***Annual effective dose equivalent** (mSv/yr)*

Effective dose is calculated for the whole body. It is the addition of equivalent doses to all organs, each adjusted to account for the sensitivity of the organ to radiation. Annual effective dose tells us the amount of effective radiation one received per year (Fredrick, 2017). It is expressed as

$$AEDE = ADR \times T \times OF \times 10^{-3} \qquad (2.3)$$

where: ADR is the actual dose rate, T is the total time per year (8760), OF is the occupancy factor. The occupancy factor used was 1.00 (IAEA, 2018).

Excess lifetime cancer risk (ELCR)

The ELCR values describe the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is a plausible upper bound estimate of the probability that a person may develop cancer sometime in his or her lifetime following exposure to that contaminant. To calculate this, we assume that the lifetime average daily intake (DL) of radiation is

70yrs, multiplying the estimated intake (AEDE) by a cancer potency factor (Risk factor RF, 0.01Sv^{-1}) produces an estimate of the lifetime excess cancer risk. It can be expressed as (Ramasamy, et al. 2009).

$$ELCR = AEDE \times DL \times RF \qquad (3.4)$$

Activity concentration (C)

Activity concentration sometimes refers to as Radioactivity concentration. It is the amount of radioactivity per unit volume and unit mass in materials that include radionuclides. The units for radioactivity include Bq/Kg and Bg/l. The activity concentrations of the radionuclides in the measured samples were computed using the following relation (Dabayneh, et al. 2008).

$$C(B_q/Kg) = \frac{Ca}{I \times E_{ff} \times M_S} \qquad (3.5)$$

where Ca is the net counting rate (CPM), E_{ff} is the detector's efficiency, I is the intensity of the radionuclide, and M_S is the mass of the sample.

The External/Internal Hazard Index (H_{ext}, H_{in})

The external hazard (H_{ext}) index is defined as a radiation hazard parameter used to evaluate the indoor radiation dose rate due to the external exposure to gamma radiation from the natural radionuclides in building materials of dwellings. While the Internal radiation hazard (H_{in}) is the principal hazard encountered in the use of unsealed radioactive materials. When radioactive materials actually get inside the body it gives rise to an internal radiation hazard (Nasrin, et al. 2013). The value of H_{ext} and H_{in} must be lower than unity in order to keep the radiation hazard insignificant. It is measured in Bq/Kg. They can be calculated using (Ramasamy, et al. 2009).

$$H_{in} = \frac{C}{ADR} \qquad (3.6)$$

$$H_{ext} = \frac{C}{EDR} \qquad (3.7)$$

Annual Gonadal Dose Equivalent (AGED)

AGED is a measure of risk for cells sensitive to a specific amount of radiation. These sensitive cells include the gonad, bone marrow, and surface cells. An increased in AGDE is known to affect the bone marrow, causing the destruction of red blood cells which are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal. It is measured in mSv/

year.

Result And Discussion

The results of the data collected at various units are presented in Table 1. The measurement of the radiation from various offices and production units were obtained using Digital Radiation Alert inspector. From Table 2, it can be seen that different values were obtained for different sections in the company.

The estimated dose rate in Table 1 ranges from 58.33 CPM (Clinic hall and Leather/shopping bag) to 71.67 CPM (Sack and Injection mould section) with mean value of 63.3337.994. The radiation dose varies from place to place depending on the amount of radiation emitted from the source.

The measured annual effective dose equivalent (AEDE) as presented in Table 1 varies between 0.099 mSv/yr (PVC) to 0.230 mSv/yr with a mean value of 0.169±0.057 When compared to the standard value as given by the International Commission for Radiological Protection (ICRP, 2007) and UNSCEAR (2008) to be 1.00 mSv/yr for general public and 20.00 mSv/yr for occupational risk.

From Table 1, it can be deduced that the Actual dose rate ranges between 31.67CPM (Sack and Injection Mould) and 13.33 CPM (PVC) with mean value of 23.33 ±7.994.

The estimated excess lifetime cancer risk (ELCR) as presented in Table 2, varies from 0.069 (Polyvinyl Chloride) to 0.161 (Marketing, sack section and the injection mould) with a mean value of 0.118 ±0.040. The ELCR mean value was also found to be lower than the world average safe limit of 0.29. This shows that the environment appears safe, however, the likelihood of people living around contacting cancer associated risk overtime owing to their external hazard index which is greater than one (1) and radiation emitting materials might be introduced/exposed to the environment in the near future.

The average activity concentration measured from different sections as presented in Fig 4 ranges from 9.017 Bq/Kg (Marketing and Injection Mould) to 21.322 Bq/Kg (Polyvinyl Chloride) with mean value of 13.413 ±4.742. When compared to the standard value given by IARC 2022, (approximately 13-26 Bq/Kg), it can be shown that workers in other departments are somewhat safe while those in PVC units may have high radiation dose.

The calculated External hazard index (H_{ext}) varies between 0.274 (Sack section) to 1.590 (Polyvinyl Chloride) with a mean value of 0.695±0.331. The estimated internal hazard index H_{in} ranged between 0.121 (Sack section) to 0.399 (Polyvinyl Chloride) with a mean value of 0.222± 0.104. All the units (department) had both their internal and external hazard indices to be less than the safe limit, i.e., less than unity (1) except for the PVC section in the external hazard

Table 1: The different measurement of the background radiation from various offices and production units.

S/No	Department	Dose Rate (CPM)	Actual Dose Rate (CPM)	Exposure (μSv / hr)	Annual Effective Dose (mSv / yr)
1	Marketing	71.66	31.66	0.026	0.23

2	Clinic Waiting Room	58.33	18.33	0.016	0.14
3	Background Entrance	58.34	18.34	0.015	0.13
4	Sack Section	71.67	31.67	0.027	0.23
5	Leather/Shopping Bag	58.33	18.33	0.015	0.13
6	Polyvinyl Chloride (PVC)	53.33	13.33	0.011	0.099
7	Injection Mould	71.67	31.67	0.026	0.23
Mean		63.333 ± 7.994	23.333 ± 7.994	0.019 ± 0.007	0.169 ± 0.057

Table 2: Radiation Hazard Parameters obtained from Oracle Plastics and Sacks Company Makurdi, Benue State.

S/NO	**Department**	**C(Bq / Kg)**	**ELCR**	**H_{ext}(Bq / Kg)**	**H_{in}(Bq / Kg)**	**AGDE (mSv / yr)**	**AEDE (mSv / yr)**
1	Marketing	9.017	0.161	0.284	0.125	31.08	0.23
2	Clinic Waiting Room	14.650	0.098	0.790	0.251	40.75	0.14
3	Background Entrance	15.631	0.091	0.850	0.267	25.36	0.130
4	Sack Section	8.684	0.161	0.274	0.121	23.03	0.230
5	Leather/Shopping bag	15.631	0.091	0.790	0.268	30.78	0.130
6	Polyvinyl Chloride (PVC)	21.322	0.069	1.590	0.399	78.96	0.099
7	Injection Mould	9.017	0.161	0.284	0.126	32.33	0.230
Mean		13.413 ± 4.742	0.118 ± 0.040	0.695 ± 0.331	0.222 ± 0.104	37.470 ± 23.362	0.169 ± 0.024
World Average		1.00	0.29	1.00	1.00	300.00	1.00

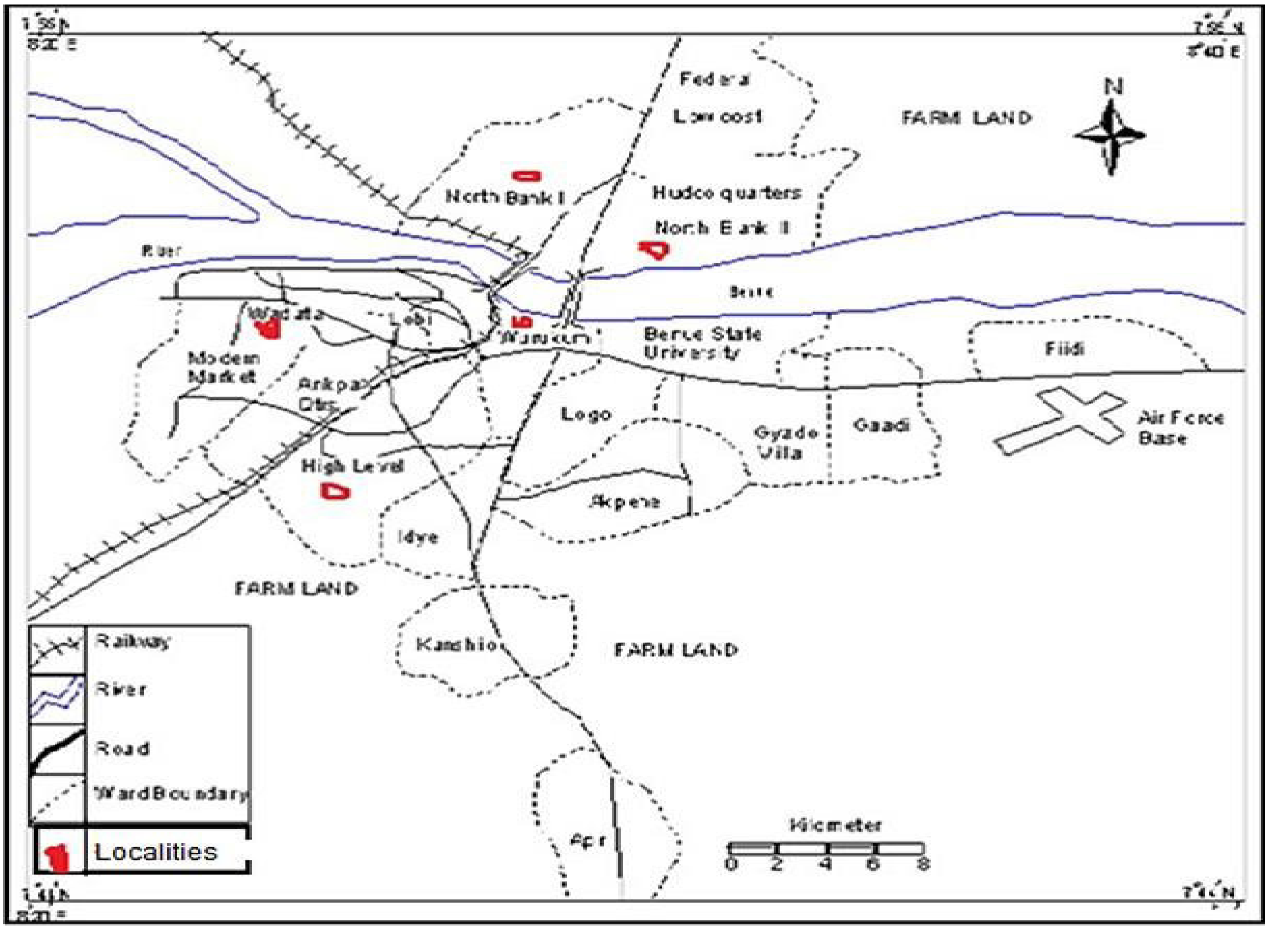

Fig. 1 showing the map of Makurdi town (BSMLS, 2011).

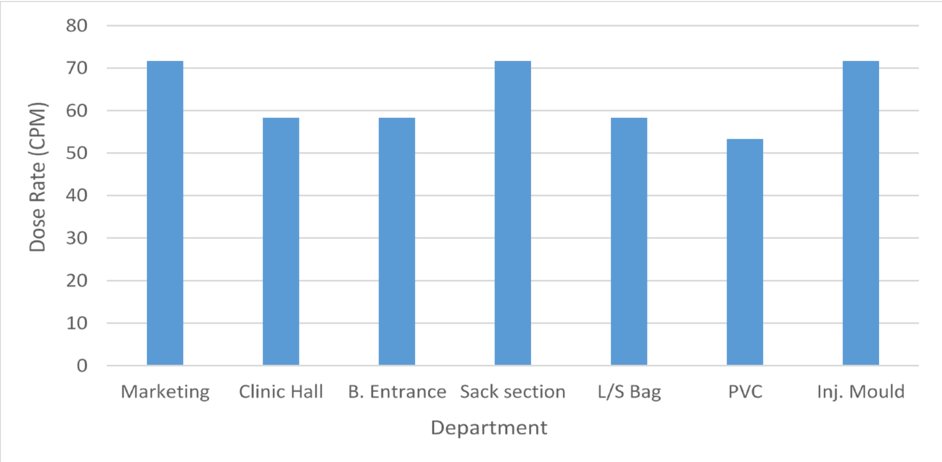

Fig. 2 Shows the dose rate obtained from various units at Oracle Plastics and Sacks Makurdi.

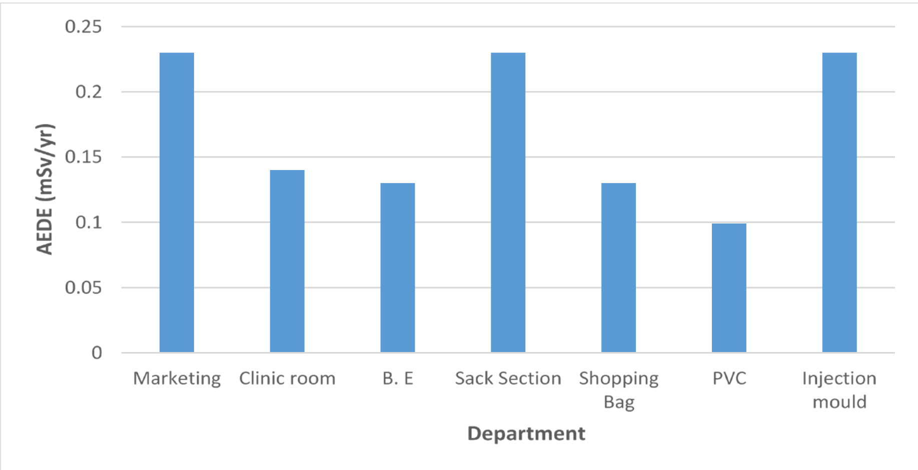

Fig.3 Shows average annual effective dose equivalent obtained from Oracle Plastics and Sacks.

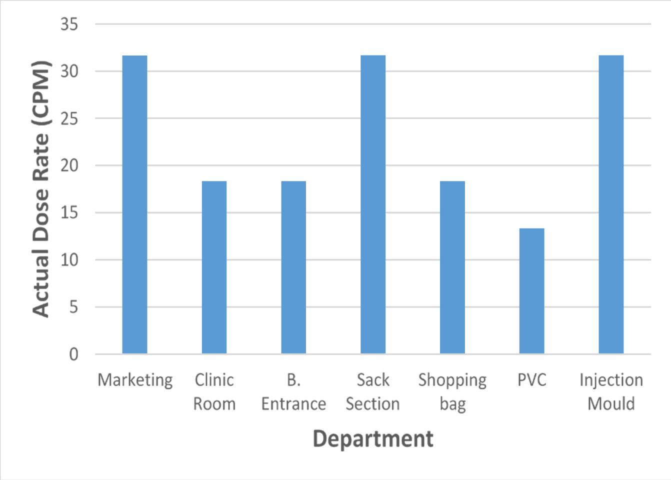

Fig. 4 Shows Actual Dose Rate obtained from Oracle Plastics and Sacks.

index.

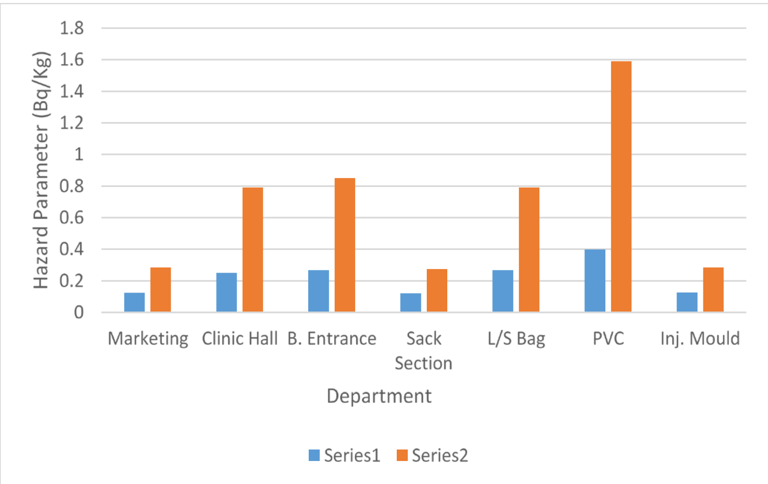

Fig. 5 Shows the External (Series2) and Internal (Series1) Hazard index obtained from measuring different department.

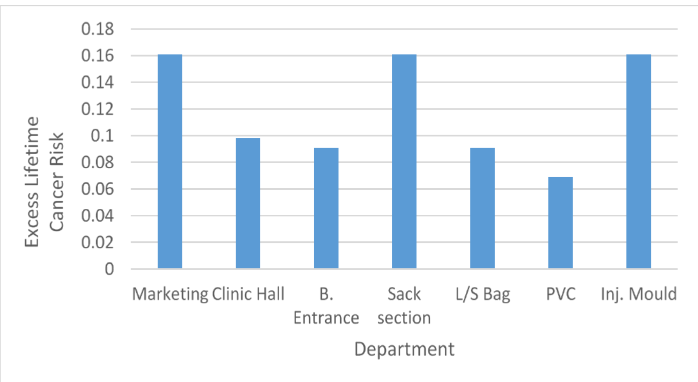

Fig. 6 Shows the estimated excess lifetime cancer risk.

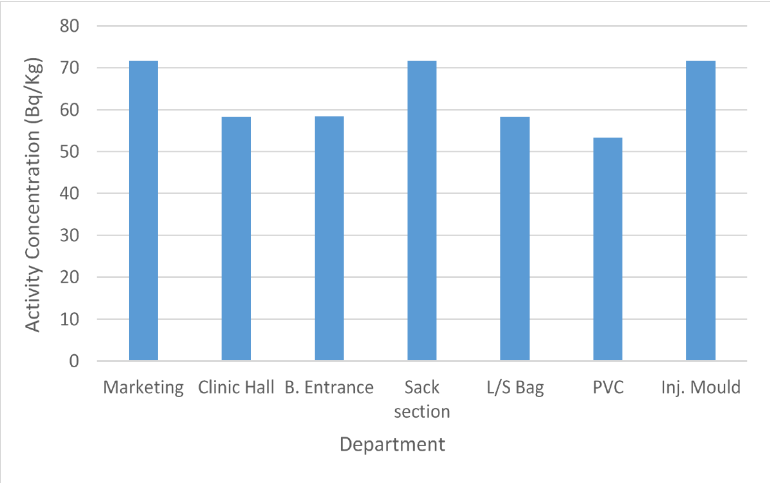

Figure 7 Shows the average activity concentration.

Conclusion

The use of radioactive materials (radiation emitting sources) is on the rise as modern engineers and scientist advances technological applications. As a result of this, humans and other living and non-living matters are constantly being exposed to high dose of radiation over time. The annual effective dose and the exposure dose rate obtained when measuring the amount of background radiation present in the Company (check Table 3.2) is smaller compared to the one recommended by the International Commission for Radiological Protection. The annual gonadal equivalent dose and the excess lifetime cancer risk obtained from the measurement were also less than the recommended safe limit of 300mSv/yr and 0.29 world global average respectively.

In conclusion, measuring the background radiation of any environment or region is not enough, but going further to know the type of radiation that is being emitted and its sources and possible ways of reducing the emission of such radioactive material(s) is the sure way. Further investigation is hereby recommended to determine specific radiation sources to ascertain the most dominant radioactive material(s) present in the environment and ways to minimize the risk.

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