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Gross Alpha and Beta Activity and Annual Committed Effective Doses due to Natural Radionuclides in some Medicinal Plants commonly used in Ghana

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ABSTRACT

The average gross alpha and gross beta activities and the corresponding annual committed effective dose due to the major alpha and beta emitting radionuclides in the Uranium and Thorium series have been determine for nine different medicinal plants that are commonly used in Ghana using Canberra iMatic™ Automatic low background gas-less counter. Samples of the medicinal plants were obtained from the Centre for Scientific Research into Plant Medicine in Ghana and prepared using for different methods for analysis. The average gross alpha activity was found to be in the range of 11.73±0.61 Bq kg^{-1} to 132.67±7.22 Bq/kg in the raw sample of *Lippia multiflora* and the ethanol extraction sample of *Alstonia boonei* respectively. Likewise, the average gross beta activity was found to be in the range of 124.34±11.28 Bq/kg to 790.58±13.19 Bq/kg in the raw sample of *Cassia sieberiana* and the ethanol extraction sample of *Nauclea latifolia*. The average gross alpha activities were far less than the average gross beta activities in the samples. The activities increase across the various forms of sample preparation employed. That is average gross activity in Raw < Brewed < Infusion < Ethanol Extraction. All sample preparation methods of consumption except the ethanol extraction had average annual alpha and beta committed effective dose falling within the limit of average annual committed effective dose due to natural radiation which ranges between 0.2-0.8 mSv/yr with an average value of 0.3 mSv/yr.

Keywords: *Medicinal Plants, Natural Radioactivity, Gross alpha and Beta Activity, Annual committed effective dose*

1. INTRODUCTION

The presence of natural radioactivity in plants constitutes the pathway for their migration to human via the food chain. Current research activities have focused on natural and artificial radioactivity and other contamination in medicinal plants by the World Health Organization (WHO) [1]. In recent times, research into plant medicine has increased throughout the world with a large body of literature and experimental evidence collected to show the optimal potential of medicinal plant used in various traditional systems. Plants have been used as food and medicinal sources since the evolution of man. The therapeutic effect of these medicinal plants for the treatment of various diseases is based on the organic constituent (such as essential oil, vitamins, glycosides, etc) present in them [2]. However, stable inorganic elements like the unstable ones (radioactive element) find their way into these plants during the process of photosynthesis.

Natural radionuclides are found in every constituent of the environment; air, water and soil, and additionally in food and in humans, as humans are products of the environment. According to Kessaratikoon and Awaekechi (2008), these natural radionuclides and their decay products from U-238 and Th-232 series together with K-40 are primordial radionuclides, which originated from the earth's crust and are the sources of natural radioactivity in the environment [3]. They are available in trace quantities in all level of ground formation exposing radiation to all life forms [4-6]. These radionuclides are ingested or inhaled in the air, food and water.

The role of natural radioactivity (NORMS) in animal and plant metabolism has long been established, but the effect and influence of these Naturally Occurring Radioactive Materials (NORMS) on administration of medicinal plants had received relatively little attention without due regard to possible side effects because they have been perceived to be in smaller quantities.

Mankind has continually use traditional herbal medicine for the treatment of various diseases and aliments. In Ghana, traditional medicines are gradually gaining more roots in recent times as it is highly patronized because of their efficacy, safety, lesser side effects and the advocacy of Primary Health Care in developing countries [7-9]. A survey by the World Health Organisation (WHO) indicates that about 70 – 80% of the world population (up to about 90%, Ghana inclusive) rely on traditional medicine mainly from plant sources in their primary health care [10-11]. These medicinal plants are mostly used to cure diseases

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such as hypertension, migraine, nasal disorder, leucorrhoea (white), fever, abdominal and menstrual pains, rheumatoid arthritis, impotence, bleeding piles, waist pains, etc. Marrying traditional medicine with orthodox medicine will enhance health care delivery system throughout the country. However, due to the highly expensive nature of the orthodox medicine, herbal clinics are now springing up all over the country contributing immensely towards the health care delivery of the rural community. As a result, thousands of medicinal or herbal plants preparations and their extracts are on sale throughout the country. A wide variety of ailments has and continues to be treated by plants based medicine [12].

Information available in literature indicates radionuclides concentrations in medicinal plants in some countries. However, medicinal plants or herbal plants are not considered in the group of edible plants studied in the past by nutritionist. Ingestion of natural radioactive materials through the use of medicinal plants had not been recognized or considered significant in terms of quantity. Moreover, the activity concentration and the annual intake of the natural radionuclide by the Ghanaian population due to consumption of medicinal/herbal plant for therapeutic purposes have not been determined. Increased attention is therefore pointed to limiting internal contamination so that the maximum permissible dose is not exceeded [5].

Among the natural radionuclides, alpha and beta emitters are considered the most important with respect to potential internal radiation exposure. They are responsible for a significant portion of the radiation exposure of humans to background radiation, particularly through ingestion of food [5]. Major amount of these radionuclides are absorbed by these medicinal plants during their growth processes. The major amount of these natural radionuclides enters the human body via ingestion and also contributes much to the exposure of man. For example, approximately 20% of Radium isotopes and 10-15% of the Lead isotopes which are decay products of ^{238}U and ^{232}Th considered for this work reaches the blood stream [13], distributed to the whole body and follows the same metabolism as Calcium. Since the percentage distribution of annual intakes of uranium and thorium series radionuclides in diet ranges between 4% to about 96% [5], accumulation of these radionuclides through the ingestion of the raw materials or products of these plants have significant health effects such as bone cancer, leukemia and increase in blood pressure. Hence, the study seeks to determine the gross alpha and beta activity concentrations of natural radionuclides of some medicinal plants commonly used in Ghana in order to ascertain the radiological risk associated with the use of these medicinal plants. Particular attention is focused on the major alpha and beta emitting radionuclides in the Uranium and Thorium Series. Lasheen et al. (2008) recognizes ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po for the Uranium series and ^{232}Th, ^{228}Ra and ^{228}Th for the Thorium series as the major alpha and beta emitting radionuclides which are of importance to internal irradiation [14].

2. MATERIALS AND METHODS

2.1 The Sampling and Sample Preparation

Parts of nine different medicinal plants commonly used in Ghana were sampled from the Centre for Scientific Research into Plant medicine (CSRPM), Mampong-Akuapem in the Eastern region of Ghana. The parts sampled are used at the CSRPM Out Patient Department (OPD) clinic for the treatment of various diseases. The CSRPM is the leading centre producing unprocessed and processed traditional or herbal medicine in Ghana. Today, CSRPM has become a leading research institution in Africa that has made Research and Development of herbal medicines its core business [15]. The medical uses of parts sampled are shown in Table 1.

The samples were open air dried on trays and then oven dried at 105ºC. The oven dried samples were then grounded into fine powder with a stainless steel ball grinder.

Four main methods by which these medicinal plants parts are prepared for consumption were employed for the sample preparation to allow adequate assessment of the radiological hazard associated with the intake of theses medicinal plants. The four methods are outlined in the following sections.

2.1.1 Preparation of Raw Product

This preparation procedure is based on the fact that each of the medicinal plant parts sampled with the exception of the leaves is taken in their dry raw form by chewing or swallowing in its powdered form. Therefore, four sub-samples of each of the prepared medicinal plants samples in powdered form were press into planchet, weighed and set aside for analysis.

2.1.2 Preparation by infusion

Only the leafy medicinal plant samples were prepared by this method since they are mostly taken in the form of a tea. Fifty milliliters (50 ml) of hot distilled water was added to 2.5 g of each of the prepared leafy powdered samples. The mixture was allowed to cool for 5 min at room temperature and then filtered. The filtrate was transferred into a beaker and heated on a hot plate to about one third the volume of the filtrate. The concentrated filtrate was then transferred into planchet and evaporated near dryness, weighed and set aside for analysis.

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2.1.3 Preparation by Brewing

In this method, 2.5 g of each of the prepared powdered form of the medicinal plants were boiled with Fifty milliliters (50 ml) of distilled water for 5 min. The mixture was held for 5 min at room temperature and then filtered. The residue was discarded and the filtrate was transferred into a beaker and heated on a hot plate to about one third the volume of the filtrate. The concentrated filtrate was then transferred into planchet and evaporated near dryness, weighed and set aside for analysis.

2.1.4 Preparation by Ethanol extraction

With the exception of the leafy medicinal plants, all the other medicinal plant may be taken in alcohol. Fifty milliliters (50 ml) of 50% ethanol was added to 2.5 g of each of the prepared powdered form of the medicinal plants and left for a period of 24 hours at room temperature. The extract was filtered and the filtrate was transferred into planchet and evaporated near dryness, weighed and set aside for analysis.

2.2 Analysis of the Medicinal Plant Samples

The samples were counted using a Canberra iMatic™ Automatic, low background, gas-less counting system with a solid state silicon PIPS detector for alpha and beta detection.

The samples were counted for 200 minutes. The activity concentration of both gross alpha and gross beta were determined using the expression in equation (1):

$$A_{\alpha/\beta} = \frac{Activity}{M_{sam}} \qquad (1)$$

Where $A_{\alpha/\beta}$ is the activity concentration of gross alpha or gross beta in Bq/kg and M_{sam} is the mass of the medicinal plant sample. The activity of alpha or beta in Bq was obtained by subtracting the background activity of both gross alpha and gross beta from the total activity of the sample.

The average annual alpha or beta committed effective dose for a particular sample was determined by averaging the individual annual committed effective doses contributed by the major alpha or beta emitters in the ^{238}U and ^{232}Th series of the naturally occurring radionuclides as shown in equation (2):

$$E_{avg}(\alpha/\beta) = \frac{I_{MP}}{M_{sam} \cdot N_R(\alpha/\beta)} \sum_i^{R(\alpha/\beta)} A_{\alpha/\beta} \times DCF_{ing}(\alpha/\beta) \qquad (2)$$

Where $E_{avg}(\alpha/\beta)$ is the average gross annual alpha or beta committed effective dose in the medicinal plant sample, $A_{\alpha/\beta}$ is the gross alpha or beta activity concentration in the medicinal plant sample, I_{MP} is the consumption rate for the intake of the medicinal plants, M_{sam} is the sample mass, $N_R(\alpha/\beta)$ is the number of radionuclides considered as major alpha or major beta emitters in the ^{238}U and ^{232}Th series of the naturally occurring radionuclides and $DCF_{ing}(\alpha/\beta)$ is the dose convection factor for ingestion of the natural radionuclides for an adult taken from UNSCEAR report [5].

Since there is not a well-accepted consumption rate for medicinal plants, a consumption rate of 1.8 kg yr^{-1} was assumed for all the medicinal plants used in this study, assuming that a patient needs 100 ml/day (an upper average dosage) of the herbal preparation or product during the treatment period. Based on information from CSRPM, the average percentage plant material in grams used in herbal preparation or products is five percent (5%) of which the average dosage is two (2) table spoons full (30 ml), three (3) times daily equivalent to 90 ml/day [16]. Meaning that, for every 100 ml of herbal product, 5 g of each plant material sample was used.

3. RESULTS AND DISCUSSION

Table 1 shows the physical data on the medicinal plant samples used and their medical purposes. The medical used of these plants stated are the common alignment for which these medicinal plants are highly recommended and advertised for treatment. The continual used of these medicinal plants presents some level of significant radionuclide intake by the patient.

The data in Tables 2 and 3 presents the gross alpha and beta activities in the nine different medicinal plants samples per kilogram for the four main mode of consumption. The average gross alpha activity ranges from 11.73±0.61 Bq/kg (PM1) to 40.48±1.99 Bq/kg (PM8), 31.44±1.73 Bq/kg (PM5) to 63.77±2.67 Bq/kg (PM1), 71.93±4.16 Bq/kg (PM1) to 113.28±4.36 (PM4) and 35.53±3.94 Bq/kg (PM5) to 132.67±7.22 Bq/kg (PM8) for the raw, brewed, infusion and ethanol extraction respectively. Whilst the average gross beta activity ranges from 124.34±11.28 Bq/kg (PM3) to 255.50±12.47 Bq/kg (PM9), 298.40±11.11 Bq/kg (PM3) to 479.15±12.65 Bq/kg (PM9), 267.44±12.36 Bq/kg (PM1) to 307.58±12.34 Bq/kg (PM4) and 670.82±12.35 Bq/kg (PM8) to 790.58±13.19 Bq/kg (PM6) for the raw, brewed, infusion and ethanol extraction respectively. It is observed from Figures 1, 2 and 3 that although not all the nine samples underwent the four different preparations for intake namely, raw form, brewed, infusion and ethanol extraction, in all cases the average gross alpha activities were far less than the average gross beta activities. Also the activities increase across the various forms of sample preparation used. That is, average gross activity in Raw < Brewed < Infusion < Ethanol Extraction (Figure 3). This might be due to self attenuation and penetration power of

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the emitting particle in each state of the sample preparation from the planchet to the detector surface.

Table 4 and Figures 4 and 5 show the average annual committed effective dose calculated for the nine (9) different medicinal plants for each of the major alpha and beta emitting radionuclides of importance to internal irradiation from the Uranium and Thorium series considered in this study. The major alpha and beta emitting radionuclides considered in this study in the Uranium and Thorium series include ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{210}Po, ^{232}Th, ^{228}Th, and ^{228}Ra. All the average annual committed effective dose values for both alpha and beta fell within the limit of annual committed effective doses from the naturally occurring radionuclides in food and drinking water, with typical values ranging from 0.2-0.8 mSv/yr and an average value of 0.3 mSv/yr with the exception of the average annual beta committed effective dose for the ethanol extraction [5, 17]. The average values of the annual beta committed effective dose for the ethanol extraction were considerably high compared to the other methods of preparation for consumption and the limits for typical range of values. These average values were contributed by Pb-210 and Ra-288 considered as the major beta emitting radionuclides in the Uranium and Thorium series for this study. However, there might be minor beta emitting particles in the Uranium and Thorium series that might have contributed to the total beta gross activity per kilogram. Therefore it will be necessary to conduct a further study to ascertain whether or not all the activity concentrations were contributed by these major beta emitting radionuclides in the Uranium and Thorium series using radiochemical methods.

Averagely, PM8 present high level of average gross alpha activity and annual committed effective dose whiles PM6 present the highest level of gross beta activity and annual committed effective dose. However, from Figure 6, the total average annual committed effective dose due to intake of both gross alpha and gross beta for each of the medicinal plant was found to be lower in the raw sample of PM3 and higher in the ethanol extraction of PM6.

4. CONCLUSION

The average gross alpha and gross beta activities and the corresponding annual committed effective dose due to the major alpha and beta emitting radionuclides in the Uranium and Thorium series have been determine for nine different medicinal plants that are commonly used in Ghana using Canberra iMatic™ Automatic low background gas-less counter. Samples of the medicinal plants were obtained from the Centre for Scientific Research into Plant Medicine in Ghana and prepared using for different methods for analysis.

The average gross alpha activity was found to be in the range of 11.73±0.61 Bq/kg to 132.67±7.22 Bq/kg in the raw sample of *Lippia multiflora* and the ethanol extraction sample of *Alstonia boonei* respectively. Likewise, the average gross beta activity was found to be in the range of 124.34±11.28 Bq/kg to 790.58±13.19 Bq/kg in the raw sample of *Cassia sieberiana* and the ethanol extraction sample of *Nauclea latifolia*. In all cases for the different preparations of intake, the average alpha gross activities were far less than the average beta gross activities. The activities increase across the various forms of sample preparation used. That is, average gross activity in Raw < Brewed < Infusion < Ethanol Extraction.

The corresponding average gross annual alpha committed effective dose was found to be in the range of 0.006±0.001 mSv/yr to 0.071±0.010 mSv/yr in the raw sample of *Lippia multiflora* and the ethanol extraction sample of *Alstonia boonei* respectively. While the average annual alpha committed effective was found to be in the range 0.154±0.014 mSv/yr to 0.909±0.017 mSv/yr in the raw sample of *Cassia sieberiana* and the ethanol extraction sample of *Nauclea latifolia* respectively. However *Cassia sieberiana* recorded the least total committed effective dose due to the intake of gross alpha and gross beta in the raw sample analysis while *Nauclea latifolia* recorded the highest in the ethanol extraction analysis.

High values of the average gross annual beta committed effective dose were recorded for ^{210}Pb and ^{288}Ra considered as the major beta emitting radionuclides in the Uranium and Thorium series for this study across the nine (9) different medicinal plant samples for the ethanol extraction. However, all other sample preparation methods of consumption had average annual alpha and beta committed effective doses falling within the limit of average annual committed effective dose due to natural radiation which ranges between 0.2–0.8 mSv/yr, with an average value of 0.3 mSv/yr.

It is therefore recommended that further radio-analytical analysis is conducted to determine the actual activities of ^{210}Pb and ^{288}Ra considered as the major beta emitting radionuclides in the Uranium and Thorium and independent of the minor beta emitting particles in the sample by radiochemical methods.

Since the total average annual committed effective doses due to intake of both gross alpha and gross beta are higher in the ethanol extraction, it is also recommended that, users of these medicinal plants use more of the other methods of preparation or intake as described in this study.

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Table 1. Physical Data on Medicinal Plant SAmples used

Sample ID	**Name of Plant**	**Local name (Akan)**	**Part of Plant sampled**	**Medical Use**
PM 1	*Lippia multiflora*	Saresonunum	Leaves	Hypertension, Lactation failure, Insomnia, Conjunctivitis
PM 2	*Croton membranaceus*	None	Roots	Prostatic hypertrophy, Measles
PM 3	*Cassia sieberiana*	Prongkese Poto rodom	Root-bark	Menstrual pain, Abdominal pain, (Pain killer)
PM 4	*Bridelia ferruginea*	Opan fufuo	Leaves	Hypertension, Diabetes
PM 5	*Mondia whitei*	Mondi	Roots	Improve sex hormones (low sperm count), STD, Stroke
PM 6	*Nauclea latifolia*	None	Stem-bark	Diabetes mellitus, Insomnia, Prolong menstrual flow, Treatment of Wounds, Coughs, Gonorrhoea.
PM 7	*Blighia sapida*	Takwa dua Ankye fitaa	Stem-bark	Migraine, Diarrhoea
PM 8	*Alstonia boonei*	Nyame dua	Stem-bark	Malaria, Rheumatism, Boil
PM9	*Khaya ivorensis*	Odupon	Stem-bark	Fever, Anemia

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Table 2: Gross Alpha Activity for the nine (9) Different Medicinal Plants for the Different Sample Preparation Methods Applied

Sample ID	Specific Activity (Bq/kg)							
	Raw		Brewed		Infusion		Ethanol extraction	
	Range	Average	Range	Average	Range	Average	Range	Average
PM1	5.90-18.00	11.73±0.61	34.75-90.29	63.77±2.67	34.75-120.25	71.93±4.16	N/A	N/A
PM2	9.26-32.61	17.20±1.05	20.50-53.00	34.13±1.46	N/A	N/A	60.67-207.00	104.73±6.86
PM3	8.42-15.65	12.21±0.34	28.86-79.00	40.05±2.27	N/A	N/A	26.50-75.63	48.73±2.36
PM4	13.05-52.00	26.69±1.73	32.90-57.86	43.34±1.05	57.00-151.80	113.28±4.36	N/A	N/A
PM5	11.45-52.54	25.81±1.85	13.64-51.75	31.44±1.73	N/A	N/A	7.85-92.50	35.53±3.94
PM6	25.30-37.90	31.60±0.60	27.29-79.67	43.80±2.42	N/A	N/A	15.18-121.40	56.27±5.00
PM7	12.60-48.10	26.55±1.53	47.00-60.80	52.60±0.68	N/A	N/A	95.50-159.25	119.42±3.05
PM8	17.70-65.80	40.48±1.99	38.00-69.50	53.43±1.65	N/A	N/A	74.33-223.00	132.67±7.22
PM9	11.55-44.60	26.54±1.36	37.90-48.10	41.75±0.44	N/A	N/A	28.86-80.17	55.44±2.11

Note: N/A means sample preparation method not application

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Table 3: Gross beta activity for the nine (9) different medicinal plants for the different sample preparation methods applied

Sample ID	Specific Activity (Bq/kg)							
	Raw		Brew		Infusion		Ethanol Extraction	
	Range	Average	Range	Average	Range	Average	Range	Average
PM1	179.03-246.79	215.33±12.86	378.89-397.14	398.38±11.48	271.43-309.00	267.44±12.36	N/A	N/A
PM2	125.33-157.14	139.83±11.34	260.00-365.00	396.25±13.13	N/A	N/A	442.10-955.15	697.14±12.96
PM3	113.67-140.00	124.34±11.28	301.43-318.33	298.40±11.11	N/A	N/A	422.56-948.40	684.77±12.60
PM4	209.00-233.50	221.75±11.28	310.00-390.00	344.56±12.01	260.00-350.00	307.58±12.34	N/A	N/A
PM5	222.00-264.00	239.38±11.90	348.18-384.55	365.70±11.56	N/A	N/A	535.62-908.89	721.40±13.04
PM6	158.00-208.00	187.75±12.20	358.75-372.00	345.81±11.56	N/A	N/A	591.52-992.10	790.58±13.19
PM7	224.00-257.00	239.25±11.50	320.00-422.00	370.86±12.80	N/A	N/A	419.40-925.55	672.25±12.34
PM8	215.00-275.00	241.75±12.51	388.00-450.00	413.75±12.44	N/A	N/A	416.03-926.30	670.82±12.35
PM9	222.00-280.00	255.50±12.47	372.86-493.33	479.15±12.65	N/A	N/A	561.55-904.02	732.26±13.53

Note: N/A means sample preparation method not application

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Table 4: The average annual gross committed effective dose for the nine (9) different medicinal plant samples for the different sample preparation methods

Sample ID	Average Annual Alpha Committed Effective Dose (mSv/yr)				Average Annual Beta Committed Effective Dose (mSv/yr)			
	Raw	Brew	Infusion	Ethanol Extraction	Raw	Brew	Infusion	Ethanol Extraction
PM1	0.006±0.001	0.034±0.005	0.039±0.005	N/A	0.267±0.016	0.495±0.014	0.332±0.015	N/A
PM2	0.009±0.001	0.018±0.003	N/A	0.056±0.008	0.174±0.014	0.492±0.016	N/A	0.866±0.016
PM3	0.007±0.001	0.021±0.003	N/A	0.026±0.004	0.154±0.014	0.371±0.014	N/A	0.850±0.016
PM4	0.014±0.002	0.023±0.003	0.061±0.008	N/A	0.275±0.014	0.428±0.015	0.382±0.015	N/A
PM5	0.014±0.002	0.017±0.002	N/A	0.019±0.003	0.297±0.015	0.454±0.014	N/A	0.896±0.016
PM6	0.017±0.002	0.023±0.003	N/A	0.030±0.004	0.233±0.015	0.429±0.014	N/A	0.982±0.016
PM7	0.014±0.002	0.028±0.004	N/A	0.064±0.009	0.297±0.014	0.461±0.016	N/A	0.835±0.015
PM8	0.022±0.003	0.029±0.004	N/A	0.071±0.010	0.300±0.016	0.514±0.015	N/A	0.833±0.015
PM9	0.014±0.002	0.022±0.003	N/A	0.030±0.004	0.317±0.015	0.595±0.016	N/A	0.909±0.017

Note: N/A means sample preparation method not application

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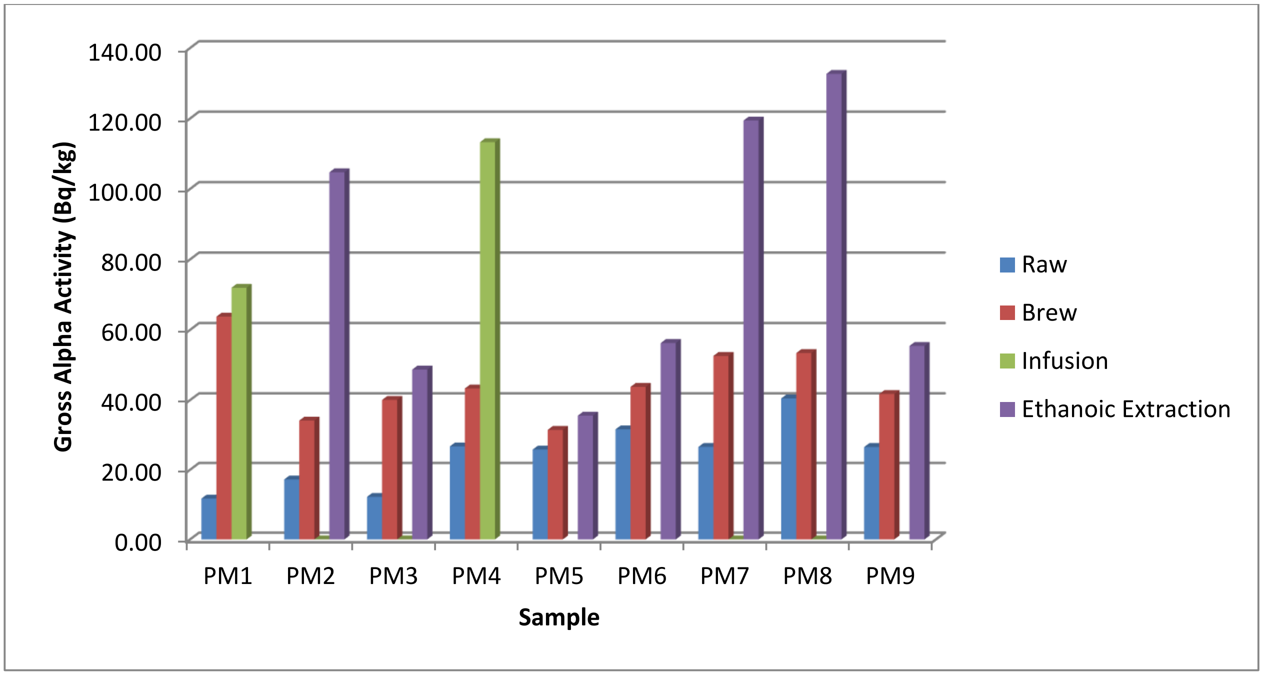

Figure 1: **Comparison of the average gross alpha activity concentration in the various medicinal plant samples due to NORMS for the different sample preparation methods**

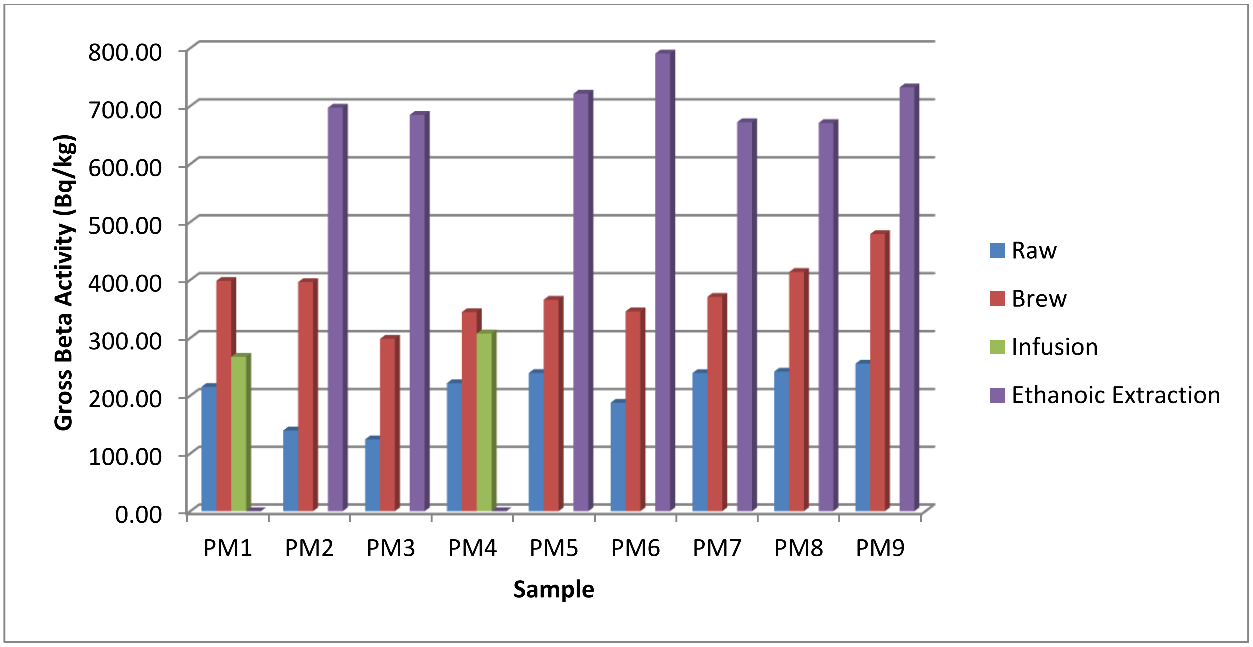

Figure 2: **Comparison of the average gross beta activity concentration in the various medicinal plant samples due to NORMS for the different sample preparation methods**

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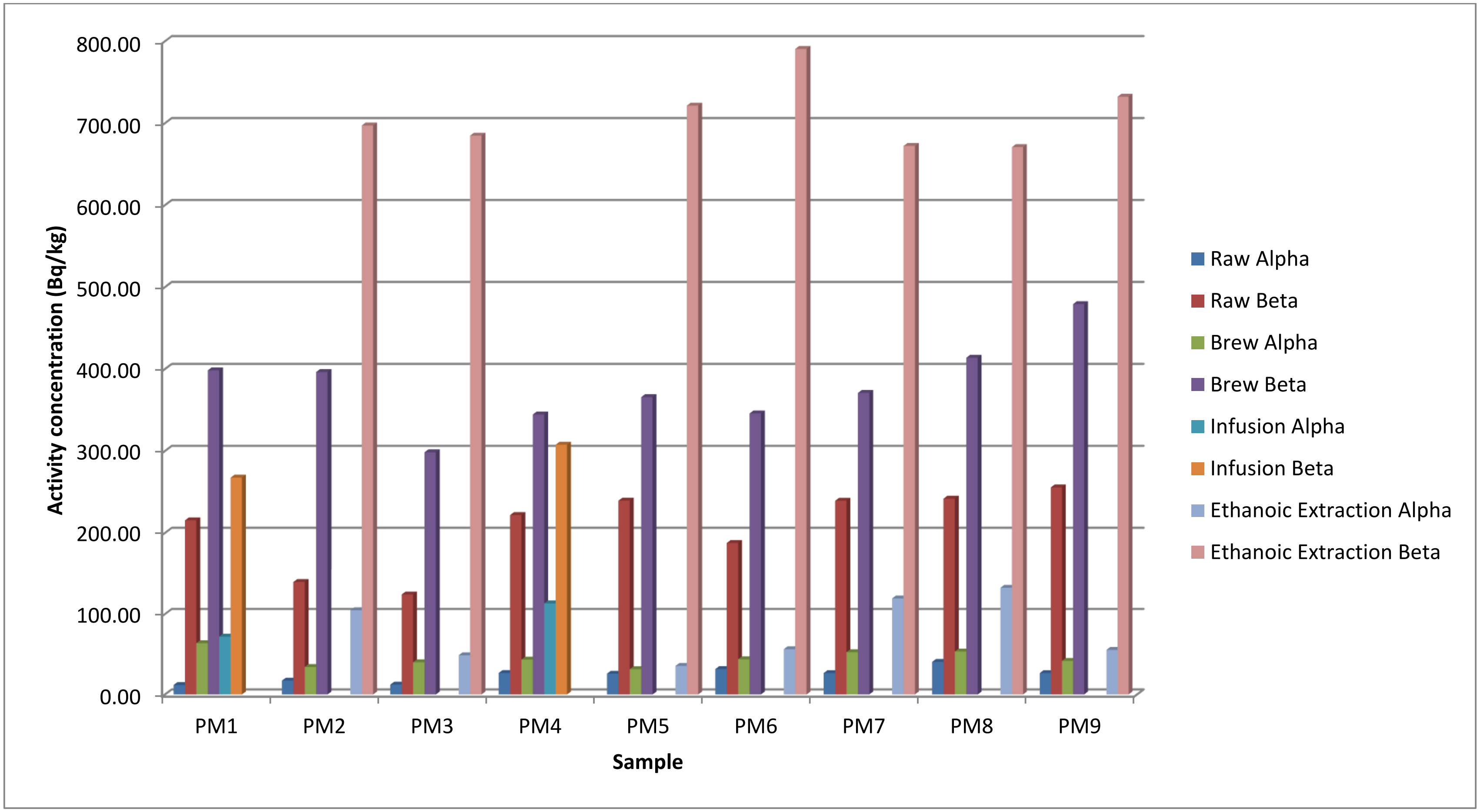

Figure 3: Comparison of the average gross alpha and average gross beta activity concentration in the various medicinal plant samples due to NORMS for the different sample preparation methods

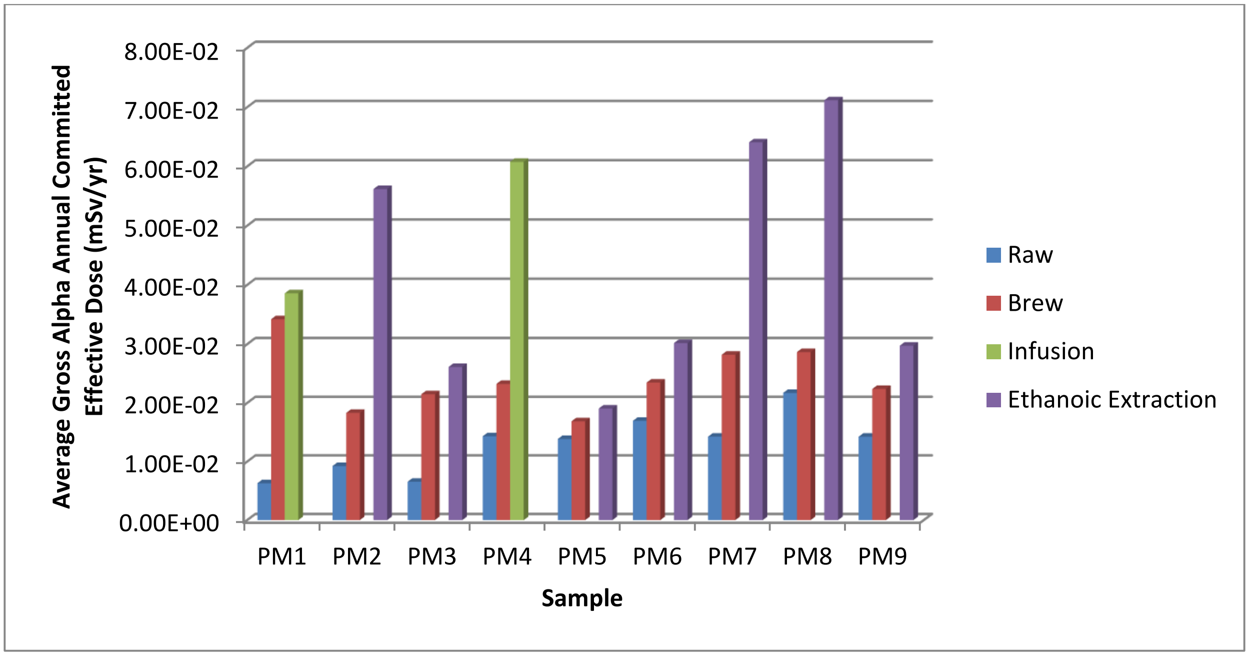

Figure 4: **Average Gross Alpha Annual committed effective doses in the various medicinal plant samples due to NORMS for the different sample preparation methods**

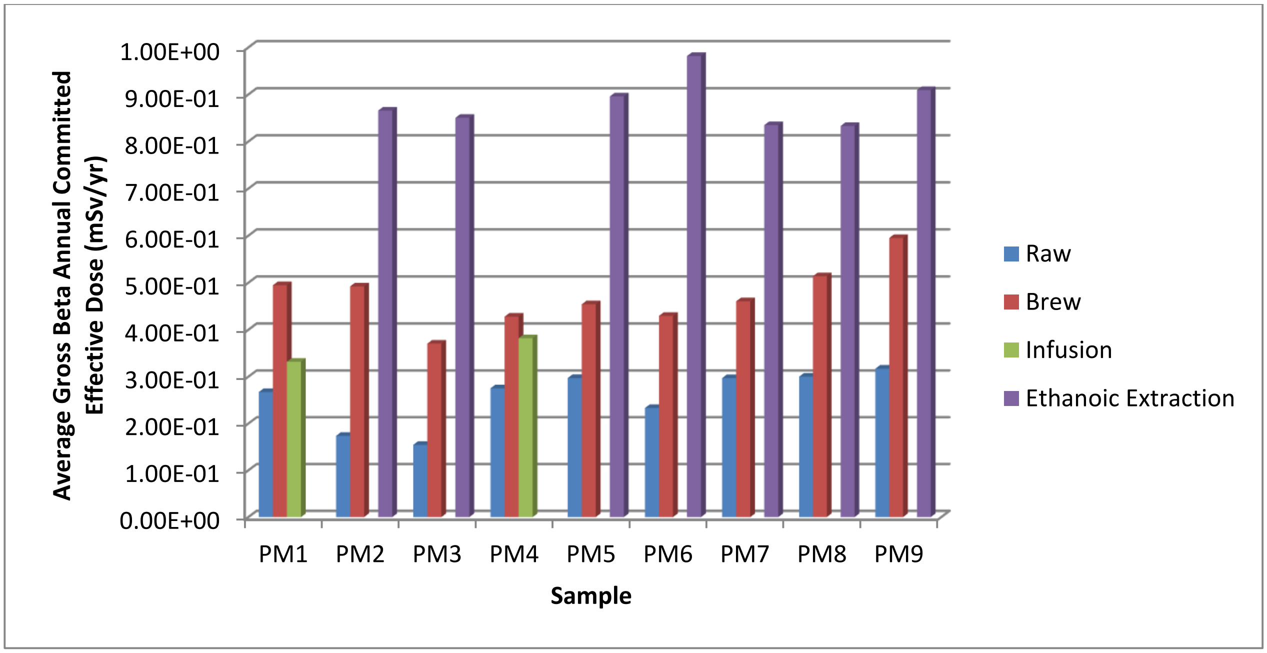

Figure 5: **Average Gross Beta Annual committed effective doses in the various medicinal plant samples due to NORMS for the different sample preparation methods**

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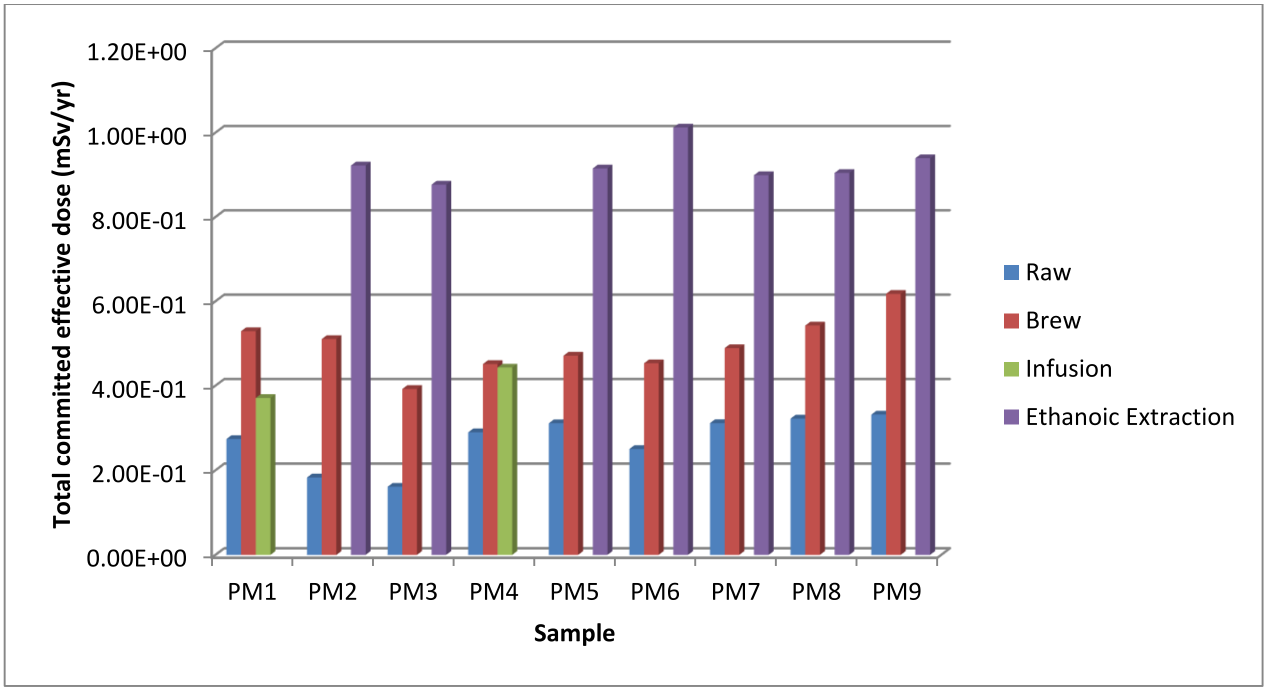

Figure 6: Total average annual committed effective dose due to intake of both gross alpha and gross beta for each of the medicinal plants for the different sample preparation methods.