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Determination of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am concentrations and Action Level in the Foodstuffs Consumed by Inhabitants of Iraq

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ABSTRACT

The specific activity concentrations of (^{106}Ru, $^{134/137}$Cs, and ^{241}Am) nuclides in 40 imported foodstuffs which collected randomly in January 2012 from all Iraqi cities markets were studied.

The rang of specific activity concentrations of ^{106}Ru varies from (37.930±6.16) Bq kg^{-1} (S No. :17: Turkey Kidney bean) to 99.735±9.99 Bq kg^{-1} (S No.:32: Egypt Broad bean), with average value 71.667±8.47 Bq kg^{-1}. For ^{134}Cs varies from 0.200±0.45 Bq kg^{-1} (S No. :19 : Ukraine Chick-pea) to 2.365±1.54 Bq kg^{-1} (S No. :33 : Peru Broad bean) with average value (0.988±0.99) Bq kg^{-1}.The activity concentrations of ^{137}Cs varies from 0.164±0.40 Bq kg^{-1} (S No.:19 : Ukraine Chick-pea) to 5.291±2.30 Bq kg^{-1} (S No.: 39: Uzbekistan Mung bean) with average value 1.460±1.21, then for ^{241}Am the activity concentrations varies from 0.029±0.17 Bq kg^{-1} (S No.:23 : Iran Chick-pea) to 1.248±1.12 Bq kg^{-1} (S No.:40: Canada Green peas) with average value 0.399±0.63. All the values were less than the World average concentrations [15,17]. The high contributor for ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides were in Broad bean and other foodstuffs (which contained Brown grit, White grit, Mung bean and Green peas) as a 12%, Broad bean as 14%, corn as a 19% and other foodstuffs with 15% respectively

The lowest contributor of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in the studied foodstuffs were 6% in cowpea, 7% in semolina, 5% in lentil and 4% in lentil respectively.

The action level of the ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclide's for three age groups have been calculated and the foodstuffs were within the range permitted and free of any radiation and thus there was no seriousness in dealing with.

Keywords: The specific activity concentrations, the action level, foodstuffs, Iraqi markets and ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides.

1. INTRODUCTION

Radiation from natural sources gives more than 80 % of the total exposure received by the average member of a population and a portion of this exposure comes from dietary intake. The natural radioactivity elements are distributed everywhere in the environmental with different concentrations, their concentrations have been found to depend on the local geological condition and as such they vary from one place to another. It is necessary to monitor release of radioactivity into the environment in order to be able to provide an appropriate protection of humans[1-3].

There are four main components of general background radiation, Natural radioactivity in food and water and inhaled air, Natural terrestrial radiation from our immediate environment, including buildings, Natural cosmic radiation from Sun, stars and from galactic and intergalactic plasma and Medical and industrial applications. The biological effect of ionizing radiation, such as gamma rays, X rays, and fast electrons is often nearly proportional to the absorbed radiation energy; that is, it is proportional to the radiation dose[4]. Knowledge of natural radioactivity in man and his environment is important since naturally occurring radionuclides are the major source of radiation exposure to man[5]. Radioactive nuclides present in the natural environment enter the human body mainly through food and water and these measurements serve as the basic standards against which occupational exposures are assessed[6].

Although many different kinds of radionuclides can be discharged following a major nuclear emergency some are very short lived and other do not readily transfer into food. Radionuclide s generated in nuclear installations and that could be significant for the food chine include:
radioactive hydrogen (^{3}H), carbon (^{14}C), technetium (^{99}Tc), sulphur (^{35}S), cobalt (^{60}Co) strontium (^{89}Sr and ^{90}Sr), ruthenium (^{103}Ru and ^{106}Ru), iodine (^{131}I and ^{129}I), uranium (^{235}U) plutonium (^{238}Pu, ^{239}Pu and ^{240}Pu), caesium (^{134}Cs and ^{137}Cs), cerium (^{103}Ce), iridium (^{192}Ir), and americium (^{241}Am).The radionuclides of most concern for possible transfer to foods have been considered when setting the Codex Guideline levels described below. Of immediate concern is iodine-131, it is distributed over a wide area, found in water and on crops and is rapidly transferred from contaminated feed into milk. However, iodine-131 has a relatively short half-live and will decay within a few weeks. In contrast, radioactive caesium which can also be detected early on, is longer-lived (Cs-134 has a half life of about 2 years and Cs-137 has a half life of about 30 years) and can remain in the environment for a long-time. Radioactive caesium is also relatively rapidly transferred from feed to milk. Uptake of caesium into food is also of long term concern[7].

Intervention in emergency exposure situations is carried out on the basis of intervention and action levels. Intervention levels (IL) are expressed in terms of the dose that is expected to be avoided or averted over time by a specific

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protective action associated with the intervention. Action levels (AL) are defined in terms of the dose rate or activity concentration above which protective or remedial actions are generally recommended. Action levels for food and water correspond to the radionuclide concentrations that could lead to an individual receiving a dose equal to a specified intervention level, assuming that the contaminated portion of the diet remain sat the action level for the duration of the assessment period[4].

In this paper the specific activity and action level of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in 40 samples of foodstuffs from Iraqi markets for three age groups were studied, the reason of this study is to investigation the foodstuffs of Iraqi market as well as to calculate the action level and the validity of such material for human ingestion as a preventive measure, all of the collected samples have been product in 2012 and still in use to 2014. The studying foodstuffs considered essential items in breakfasts and lunch meals for most simple Iraqi families which mixture two or three type of these foodstuffs to do the meals.

2. EXPERIMENTAL PROCEDURES

In order to measure the natural radioactivity in foodstuffs a total of 40 samples were collected randomly in January 2012, from all Iraqi cities, the sample were crushed to fine grain size and sieved in order to homogenize it and remove big size. The powdered samples were packed in a marinelli beaker, one kilogram from each sample and sealed tightly cap, each sample was counted for 5 hour on the Gamma spectrometer with scintillation detector 2"× 2" inch NaI (Tl) from SPECTRUM TECHNIQUES, INC.US, the background spectra was also collected for the same period of time and subtracted from the sample spectra.

The detector was calibrated using six radionuclides with eight γ-ray lines emitted ranged from 80keV for Ba-133 to 1332.5 keV for Co-60[8-9] which has been done for calculation the efficiency calibration see fig-1.

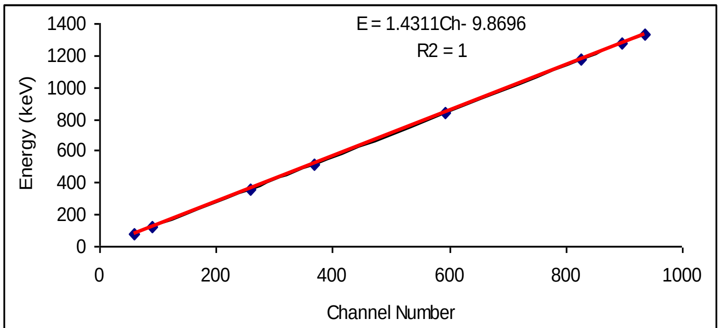

Fig. (1a):Energy calibration curve of 2"×2" NaI(Tl) detector.

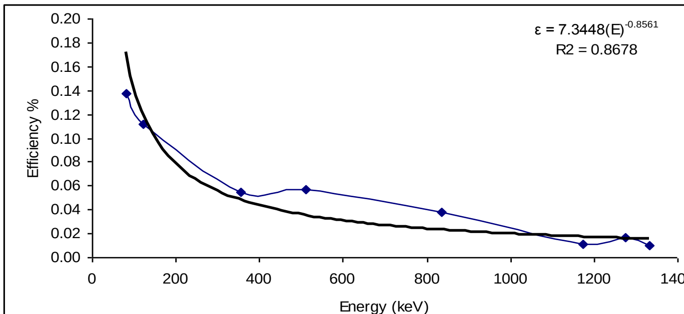

Fig. (1b):Full energy peak efficiency as a function of gamma ray energy for 2"×2"NaI(Tl) detector.

The detector was surrounded by a lead shield to reduce the background of the system. The activity of a specific radionuclide with a gamma energy transition could be expressed using the following equation[10-11].

$$A = \frac{N_{net}}{\varepsilon . I_{\gamma} . m . t} \pm \frac{\sqrt{N_{net}}}{\varepsilon . I_{\gamma} . m . t} [Bq.kg^{-1}] \qquad (1)$$

Where N_{net} is the net counts (area under the specified energy peak after back ground subtraction) in (C/s), $\sqrt{N_{net}}$ is the random error in (C/s), ε is the efficiency of the detector, I_γ is the transition probability of the emitted gamma ray, t is the time (in sec) for spectrum collected and m is the sample weight in (kg).

The specific activity concentrations of the ^{106}Ru, $^{134/137}$Cs, and ^{241}Am, were determined by the γ-ray transitions[8-9] are as follows:

1. ^{106}Ru (1050.41) keV.
2. ^{134}Cs (604.720) keV.
3. ^{137}Cs (661.657) keV.
4. ^{241}Am (59.5409) keV.

The action level for a given radionuclide within a particular food and age group is calculated as[12]:

$$AL_{i,j,k} = \frac{IL}{M_{j,k} \times DC_{i,k} \times f_j} \qquad (2)$$

Where $AL_{i,j,k}$ is the action level for radionuclide i in food group j and age group k in (Bq kg^{-1}), IL is the intervention level (Sv), $M_{j,k}$ is the mass of food group j consumed by age group k over the assessment period (kg/year), $DC_{i,k}$ is the ingestion dose coefficient for radionuclide i and age group k (Sv Bq^{-1}) and f_i = contamination factor, equivalent to intake of food group j assumed to be uniformly contaminated to the full value of $AL_{i,j,k}$.

Both the mass of food consumed and the radionuclide ingestion dose coefficients are age-specific, and their values reflect the classification of the population into a limited set of representative age groups. The above definition of the action level results in a distinct value for each radionuclide, age and food group combination[12-13].

If several radionuclides are present in a sample the following summation criterion must be satisfied:

$$\sum\left(\frac{A_i}{AL_i}\right)\leq 1 \qquad (3)$$

Where A_i is the measured activity of radionuclide i, and AL_i is its corresponding action level[11].

The radiological impact of a particular radionuclide released into the environment during a nuclear emergency is a function of its abundance and its environmental, biological and radiological properties. The radionuclides which are most likely to be predominant contributors to dose through ingestion following a nuclear reactor accident are dependent on the type of facility and the severity of the event, typically, those having the most significance to dose from the ingestion of contaminated food and water are $^{89/90}$Sr, $^{103/106}$Ru, ^{131}I, $^{134/137}$Cs, $^{238/239}$Pu and ^{241}Am[12-7]. This group of radionuclides is most likely to be of concern in terrestrially produced foods. Biological concentration processes in fresh water and marine systems can result in very rapid transfer and enrichment of specific radionuclides[12-15]. The gamma radionuclide's which are measured by NaI detector was (^{106}Ru, $^{134/137}$Cs, and ^{241}Am).

3. RESULTS AND DISCUSSION

Iraqi families dependent in Primary shape in preparing meals on mixing three types or more of foodstuffs per meal therefore which may be a major cause of the overflow allowed the concentration.

The specific activity concentrations of (^{106}Ru,, $^{134/137}$Cs, and ^{241}Am) nuclides in 40 imported foodstuffs which collected randomly from the Iraqi markets were in table 1.& fig. (2) the rang of specific activity concentrations of ^{106}Ru varies from (37.930±6.16) Bq kg^{-1} (S No. :17: Turkey Kidney bean) to 99.735±9.99 Bq kg^{-1} (S No.:32: Egypt Broad bean), with average value 71.667±8.47 Bq kg^{-1}. For ^{134}Cs varies from 0.200±0.45 Bq kg^{-1} (S No. :19 : Ukraine Chick-pea) to 2.365±1.54 Bq kg^{-1} (S No. :33 : Peru Broad bean) with average value (0.988±0.99) Bq kg^{-1}.

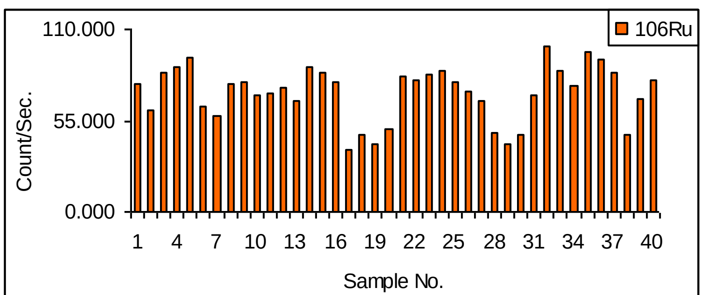

Fig. (2 a): The specific activity of 106Ru in Bq.kg-1.

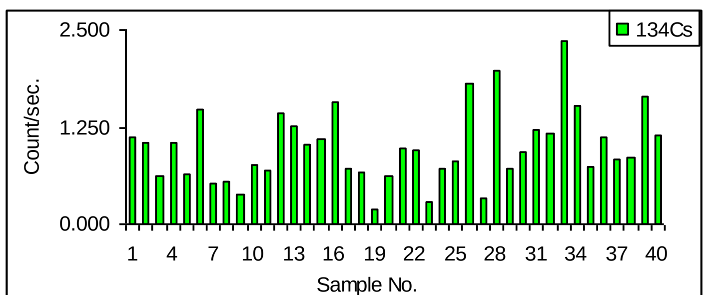

Fig. (2 b): The specific activity of 134Cs in Bq.kg-1.

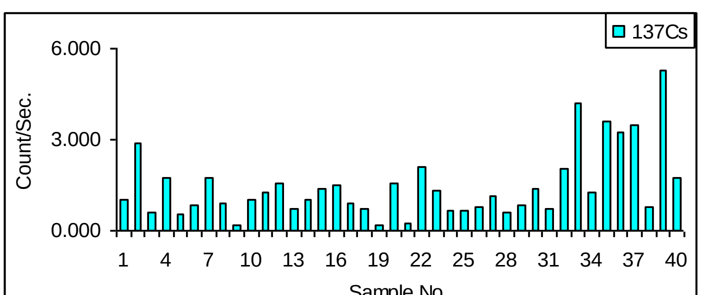

Fig. (2 c): The specific activity of 137Cs in Bq.kg-1.

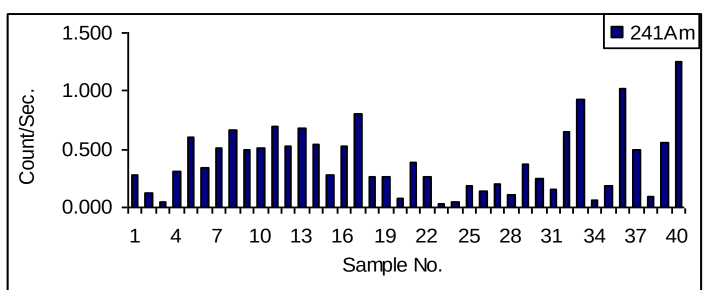

Fig. (2 d): The specific activity of 241Am in Bq.kg-1.

The specific activity concentrations of ^{137}Cs varies from 0.164±0.40 Bq kg^{-1} (S No.:19: Ukraine Chick-pea) to 5.291±2.30 Bq kg^{-1} (S No.: 39: Uzbekistan Mung bean) with average value 1.460±1.21, for ^{241}Am the specific activity concentrations varies from 0.029±0.17 Bq kg^{-1} (S No.:23 : Iran Chick-pea) to 1.248±1.12 Bq kg^{-1} (S No.:40: Canada Green peas) with average value 0.399±0.63. All the values were less than the world average concentrations[16-18].

Table-1: The specific activity concentrations of (^{106}Ru, $^{134/137}$Cs, and ^{241}Am). radionuclide s for each sample in (Bq. kg^{-1}).

Sample No.	Type	Origin country	106Ru	134Cs	137Cs	241Am
1	Rice, (272)	India	76.574±8.75	1.123±1.06	1.033±1.02	0.273±0.52
2	Rice,(Alwalima)	India	61.629±7.85	1.058±1.03	2.881±1.70	0.131±0.36
3	Rice, (1121Sella)	India	83.882±9.16	0.608±0.78	0.625±0.79	0.049±0.22
4	Rice, (Alaella)	India	87.097±9.33	1.044±1.02	1.745±1.32	0.317±0.56
5	Rice	Thailand	93.533±9.67	0.649±0.81	0.522±0.72	0.600±0.77
6	Semolina	Turkey	63.991±8.00	1.465±1.21	0.860±0.93	0.345±0.59
7	Semolina	Italy	57.489±7.58	0.533±0.73	1.764±1.33	0.513±0.72
8	Semolina	Syria	77.339±8.79	0.559±0.75	0.928±0.96	0.659±0.81
9	Semolina	Lebanon	78.627±8.87	0.379±0.62	0.181±0.43	0.498±0.71
10	Semolina	Saudi Arabia	70.428±8.39	0.759±0.87	1.017±1.01	0.518±0.72
11	Semolina	Kuwait	71.140±8.43	0.702±0.84	1.284±1.13	0.697±0.83
12	Wheat (type 1)	Turkey	74.821±8.65	1.427±1.19	1.530±1.24	0.529±0.73
13	Wheat (type 2)	Turkey	67.333±8.21	1.252±1.12	0.738±0.86	0.682±0.83
14	Kidney bean	China	87.188±9.34	1.017±1.01	1.034±1.02	0.546±0.74
15	Kidney bean	Argentina	83.600±9.14	1.084±1.04	1.392±1.18	0.271±0.52
16	Kidney bean	Kyrgyzstan	78.271±8.85	1.574±1.25	1.497±1.22	0.527±0.73
17	Kidney bean	Turkey	37.930±6.16	0.723±0.85	0.898±0.95	0.807±0.90
18	Kidney bean	Lebanon	45.937±6.78	0.672±0.82	0.738±0.86	0.266±0.52
19	Chick-pea	Ukraine	41.138±6.41	0.200±0.45	0.164±0.40	0.260±0.51
20	Chick-pea	India	49.604±7.04	0.631±0.79	1.558±1.25	0.077±0.28
21	Chick-pea	Italy	82.172±9.06	0.980±0.99	0.225±0.47	0.380±0.62
22	Chick-pea	Russia	79.154±8.90	0.954±0.98	2.118±1.46	0.260±0.51
23	Chick-pea	Iran	82.857±9.10	0.284±0.53	1.307±1.14	0.029±0.17
24	Red lentil	Turkey	85.081±9.22	0.725±0.85	0.658±0.81	0.046±0.22
25	Grain lentil	Canada	78.693±8.87	0.800±0.89	0.690±0.83	0.191±0.44
26	Grain lentil	Lebanon	72.941±8.54	1.800±1.34	0.790±0.89	0.139±0.37
27	Grain lentil	Iran	67.114±8.19	0.341±0.58	1.144±1.07	0.207±0.46
28	Cowpea	Peru	47.991±6.93	1.972±1.40	0.615±0.78	0.111±0.33
29	Cowpea	Madagascar	40.608±6.37	0.704±0.84	0.841±0.92	0.376±0.61
30	Cowpea	Iran	46.559±6.82	0.918±0.96	1.360±1.17	0.242±0.49
31	Broad bean	Syria	69.934±8.36	1.207±1.10	0.710±0.84	0.153±0.39
32	Broad bean	Egypt	99.735±9.99	1.171±1.08	2.018±1.42	0.657±0.81
33	Broad bean	Peru	84.527±9.19	2.365±1.54	4.199±2.05	0.934±0.97
34	Corn	Turkey	75.515±8.69	1.512±1.23	1.241±1.11	0.066±0.26
35	Corn	Argentina	96.310±9.81	0.735±0.86	3.618±1.90	0.191±0.44
36	Corn	Saudi Arabia	91.836±9.58	1.121±1.06	3.220±1.79	1.020±1.01
37	Brown grit	Lebanon	84.193±9.18	0.826±0.91	3.479±1.87	0.501±0.71
38	White grit	Turkey	46.414±6.81	0.850±0.92	0.759±0.87	0.100±0.32
39	Mung bean	Uzbekistan	68.146±8.26	1.634±1.28	5.291±2.30	0.563±0.75
40	Green peas	Canada	79.331±8.91	1.150±1.07	1.738±1.32	1.248±1.12
Average			71.667±8.47	0.988±0.99	1.460±1.21	0.399±0.63
min.			37.930±6.16	0.200±0.45	0.164±0.40	0.029±0.17
max.			99.735±9.99	2.365±1.54	5.291±2.30	1.248±1.12

The relative contributions to concentrations of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in 40 samples of foodstuffs shown in fig.(3), we can notice that the high contributor for ^{106}Ru were in Broad bean and other foodstuffs (which contained Brown grit, White grit, Mung bean and Green peas) as a 12%, for ^{134}Cs Broad bean the high contributor was in Broad bean as 14%, for ^{137}Cs the high contributor was in corn as a 19% while for ^{241}Am, also the other foodstuffs were high contributor with 15% ratio. The lowest contributor of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in the studied foodstuffs were 6% in cowpea, 7% in semolina, 5% in lentil and 4% in lentil respectively.

The action level result of the determination of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in 40 samples of foodstuffs from Iraqi markets for three age groups were presented in table-2. The mass of food group j consumed by age group k over the assessment period (kg/year) were (M=499, 519 and 450 kg/year) for adult, (12-19) year and (5-11) groups respectively. The ingestion dose coefficient for radionuclide i and age group k (Sv Bq^{-1}) were as in table-3[19].

Table-2: The action level for ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclide within afood stuffs and three age groups.

Sample No.	Foodstuff type	The action level AL (Bq kg^{-1})		
		For adult	For (12- 19) year	For (5-11) year
1	Rice, (272)	0.0656	0.0826	0.194
2	Rice,(Alwalima)	0.0551	0.0695	0.160
3	Rice, (1121Sella)	0.0661	0.0852	0.210
4	Rice, (Alaella)	0.0732	0.0914	0.213
5	Rice	0.0830	0.1038	0.241
6	Semolina	0.0563	0.0696	0.158
7	Semolina	0.0559	0.0688	0.153
8	Semolina	0.0719	0.0889	0.201
9	Semolina	0.0669	0.0832	0.194
10	Semolina	0.0638	0.0789	0.179
11	Semolina	0.0685	0.0840	0.186
12	Wheat (type 1)	0.0695	0.0857	0.192
13	Wheat (type 2)	0.0660	0.0808	0.178
14	Kidney bean	0.0761	0.0940	0.215
15	Kidney bean	0.0726	0.0921	0.217
16	Kidney bean	0.0766	0.0961	0.218
17	Kidney bean	0.0475	0.0570	0.116
18	Kidney bean	0.0415	0.0518	0.119
19	Chick-pea	0.0374	0.0472	0.111
20	Chick-pea	0.0406	0.0511	0.120
21	Chick-pea	0.0683	0.0852	0.200
22	Chick-pea	0.0656	0.0816	0.189
23	Chick-pea	0.0635	0.0812	0.200
24	Red lentil	0.0632	0.0802	0.196
25	Grain lentil	0.0632	0.0798	0.191
26	Grain lentil	0.0591	0.0740	0.174
27	Grain lentil	0.0540	0.0677	0.161
28	Cowpea	0.0408	0.0506	0.115
29	Cowpea	0.0402	0.0496	0.110
30	Cowpea	0.0441	0.0554	0.126
31	Broad bean	0.0567	0.0714	0.169
32	Broad bean	0.0907	0.1125	0.256
33	Broad bean	0.0896	0.1083	0.227
34	Corn	0.0642	0.0825	0.197
35	Corn	0.0792	0.0992	0.233
36	Corn	0.1012	0.1261	0.277
37	Brown grit	0.0782	0.0970	0.219
38	White grit	0.0385	0.0485	0.114
39	Mung bean	0.0768	0.0955	0.205
40	Green peas	0.0872	0.1052	0.221
Average		0.0645	0.0803	0.184
Min.		0.0374	0.0472	0.110
Max.		0.1012	0.1261	0.277

The intervention level (Sv) and contamination factor were (1mSv and 0.2) for other commercial Foods and Beverages for all age group[12].

The AL for adult group one was (0.0645) Bq kg^{-1} average with minimum value (0.0374) Bq kg^{-1} in sample no. 19 and maximum (0.1012) Bq kg^{-1} in sample no. 36 fig. (4a), AL for (12-19) year, group two was (0.0803) Bq kg^{-1} average with minimum value (0.0472) Bq kg^{-1} in sample no.19 and maximum value (0.1261) Bq kg^{-1} in sample no. 36 fig. (4b) while AL for (5-11) year group three was (0.184) Bq kg^{-1} average with minimum value (0.110) in sample no.19 and maximum value (0.277) Bq kg^{-1} in sample no 36. fig. (4c).

As shown the foodstuffs were within the range permitted and free of any radiation and thus there was no seriousness in dealing with[20-22]

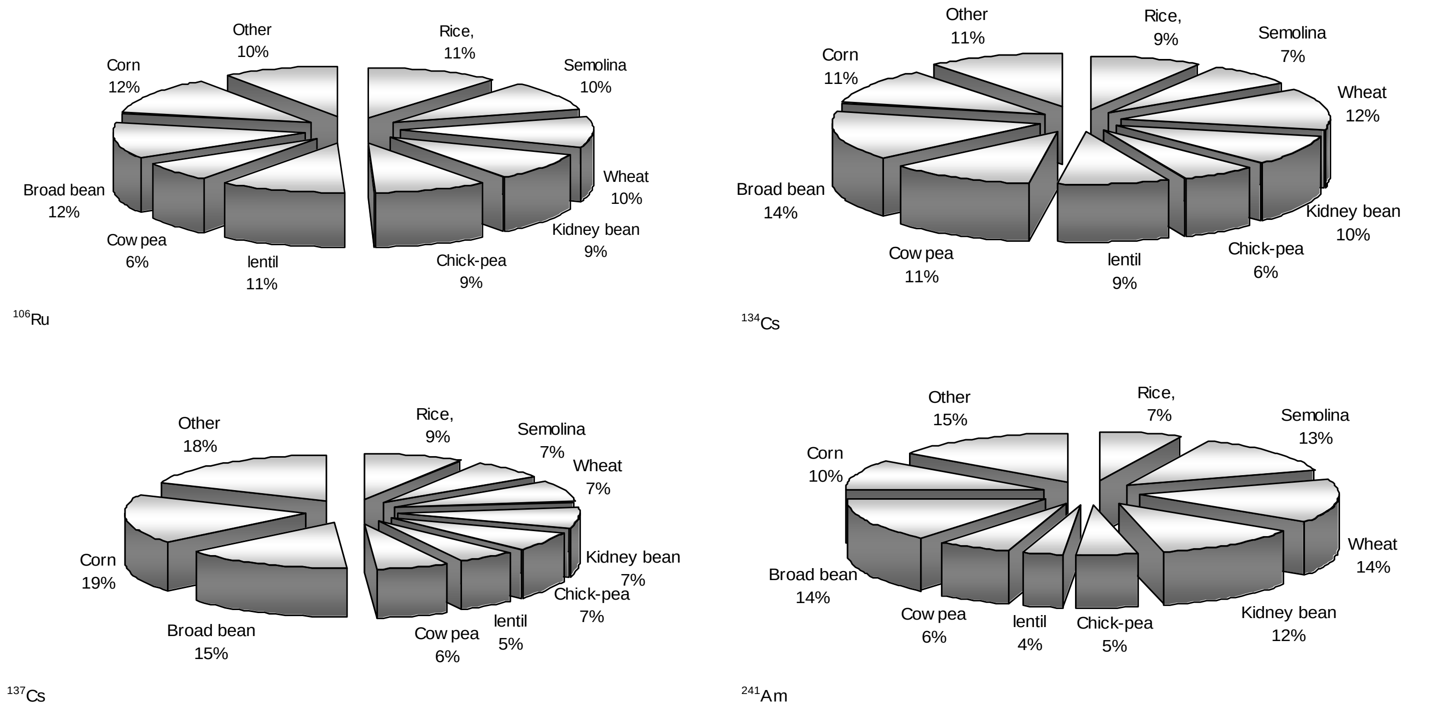

Fig-3: The relative contributions to concentrations of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclide s in 40 samples of foodstuffs.

Table-3: Age–specific committed effective dose coefficients for ingestion[18]

Radionuclide	Half -life	Ingestion Dose Coefficient to Age (Sv/Bq)		
		Adult	(12-19) year	(5-11) year
^{106}Ru	1.01y	7.0e-09	8.6e-09	1.5e-08
^{134}Cs	2.06 y	1.9e-08	1.9e-08	1.4e-08
^{137}Cs	30 y	1.3e-08	1.3e-08	1.0e-08
^{241}Am	432 y	2.0e-07	2.0e-07	2.2e-07

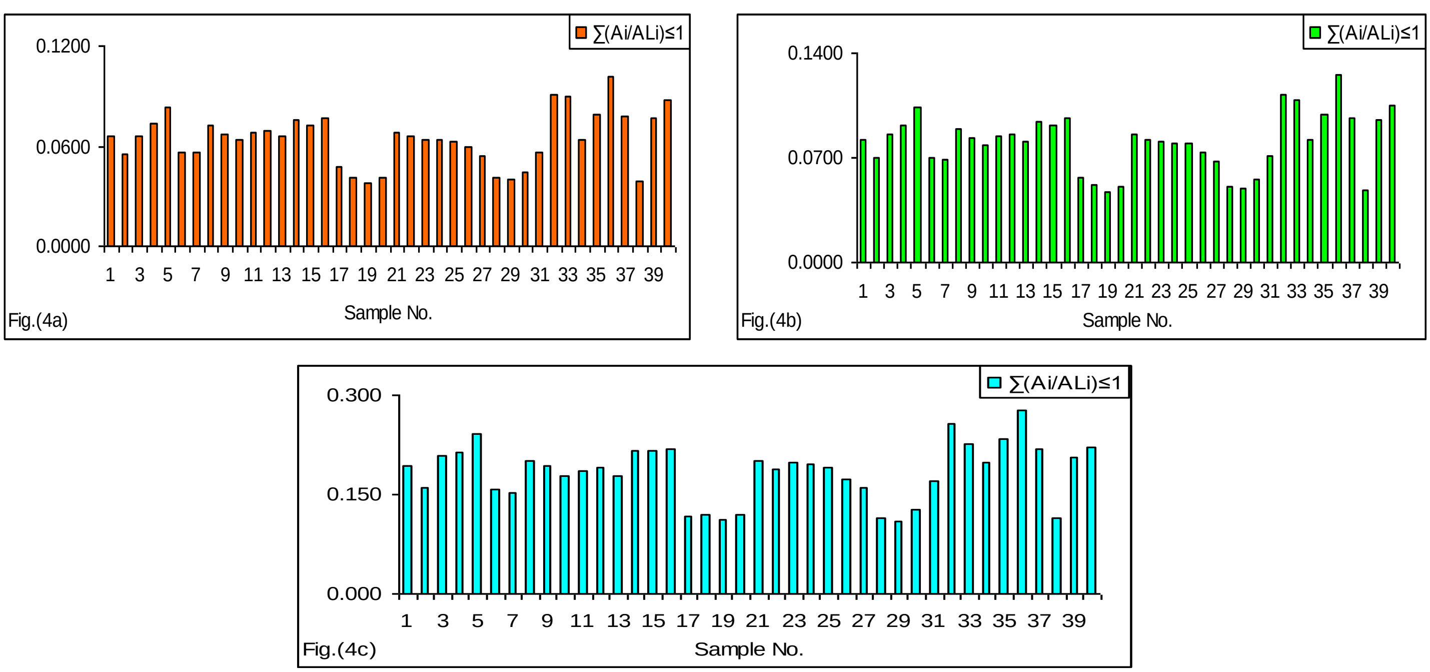

Fig-4: The action level (AL) for ^{106}Ru,$^{134/137}$Cs, and ^{241}Am radionuclide within a Food stuffs and three age groups, (4a) for adult, (4b) for (12- 19) year and (4c) for (5-11)year.

5. CONCLUSIONS

The specific activity concentrations of (^{106}Ru,, $^{134/137}$Cs, and ^{241}Am) nuclides in 40 imported foodstuffs were coincident with world average concentrations. The high contributor for ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides were in Broad bean and other foodstuffs (which contained Brown grit, White grit, Mung bean and Green peas) as a 12%, Broad bean as 14%, corn as a 19% and other foodstuffs with 15% respectively

The lowest contributor of ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclides in the studied foodstuffs were 6% in cowpea, 7% in semolina, 5% in lentil and 4% in lentil respectively.

The action level of the ^{106}Ru, $^{134/137}$Cs, and ^{241}Am radionuclide's for three age groups were within the range permitted and free of any radiation and thus there was no seriousness in dealing with.

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