IOSR Journal of Applied Physics (IOSRJAP)
ISSN – 2278-4861 Volume 1, Issue 6 (Sep-Oct. 2012), PP 22-35
www.iosrjournals.org

A Study of Energy Absorption Buildup Factor in Some Fly ash

[1]Barjinderpal Singh, [2]Jasbir Singh Dhillon, [3]Gurdeep Singh Sidhu
[1,2] Department of physics, Singhania University, Rajasthan,(India)
[3] Department of physics, Govt. Sports School Ghudda (Bathinda), Punjab

Abstract: *The dependence of the energy absorption buildup factor (EABF) of flyash samples viz Bituminous, Sub bituminous, Lignite, High-Calcium, High-Iron, Low-Calcium and Low-Iron on incident photon energy and penetration depth is investigated in the energy range 0.015 to 15.0 MeV and penetration depth upto 40 mfp (mean free path). It has been found that the energy absorption buildup factor changes significantly with the change of incident photon energy and penetration depth. This change results from the dominance of different interaction processes in different energy regions and the chemical composition of different flyash materials. Comparison of calculated energy absorption buildup factor with standard shows good agreements.*
Keywords: *Energy Absorption Buildup Factor (EABF), Penetration depth, Equivalent atomic number (Z_{eq}), Flyash, Shielding, Mean Free path(mfp)*

I. Introduction

For radiation shielding and dosimetery calculations by point kernel methods, buildup factor is the basic requirement. In the point kernel methods, a desired quantity such as flux, dose or dose equivalent is expressed as the product of the value of the quantity due to uncollided radiation and a factor that is known as buildup factor. So, buildup factor are the parameters that depend on the shielding material and the geometry which corrects the simple attenuation calculations so as to include the contribution to the radiation field produced by the collided part of the beam. Various Codes and methods has been used to calculate the buildup factor such as ASFIT(Gopinath D.V. and Samthanam K. 1971), PALLAS (Takeuchi K. and Tanaka S.1984), EGS4 (Nelson et.al.,1985), G-P fitting method (Harima et. Al. 1986), iterative method (Suteau and Chiron, 2005), Monte Carlo method (Sardari et al. 2009) and invariant embedding method (Sakamaoto an Tanaka, 1988; Shimizu, 2002; Shimizu et. Al. 2004). American National Standards (ANSI/ANS-6.4.3., 1991) has provided buildup factor data for 23 elements, one compound, two mixtures (i.e. air and water) and concrete in the energy range 0.015 -15.0 MeV and upto penetration depths of 40 mfp using G-P fitting method. The developed G-P fitting formula is known to be accurate within a few percent errors (Harima et al. 1986; Harima 1983). A detailed historical review on buildup factor calculation and use is given by Harima (1993). EI-Hosiny and EI-faramawy (2000) studied the build up factor as a function of absorber thickness in hydrated Portland cement lead pastes using ^{137}Cs gamma ray source. Flyash consisting mostly of silica, alumina and iron forms a compound similar to Portland cement when mixed with lime and water. Shimizu et al.(2004) compared the build up factor values obtained by three different approaches (G.P.fitting, Invariant Embedding and Monte Carlo method) and only small discrepancies were observed for low-Z elements up to 10 mean free path.

Since the buildup factor data for different Flyash samples are not found in any compilation or tabulation, So, the objective of the present investigations is to generate the energy absorption buildup factor data in seven different flyash samples in the incident photon energy range of 0.015 to 15.0 MeV and upto penetration depth of 40 mean free path (mfp). The energy absorption buildup factor is defined as the photon buildup factor in which the quantity of interest is the absorbed or deposited energy in the shield medium, and the detector response function is that of absorption in the material. The generated energy absorption buildup factor data have been studied as a function of incident photon energy and penetration depth.

II. Materials and Method

A. Selection of Materials

Flyash is one of the residue generated in combustion and comprises the fine particles that rise with the flue gases. Flyash is generally stored at coal power plants or placed in landfills. Mixing the flyash and bottom ash together brings the proportion level of contaminants within the range to qualify as nonhazardous waste. Flyash can be used as good radiation shielding material because of their low cost and easy availability. In the present investigations the energy absorption G-P fitting parameters and the corresponding buildup factor data have been computed for seven Flyash samples (Table 1), in the incident photon energy range of 0.015 to 15.0 MeV and upto penetration depth of 40 mfp.

Table: 1 Percentage Chemical Composition of the chosen Flyash sample**s.**

B. Computational work

To compute the values of energy absorption build up factor, the G-P fitting parameters were obtained by the method of interpolation from the equivalent atomic number (Z_{eq}) The computational of energy absorption build up factor have been divided

Component	Bituminous	Sub bituminous	Lignite	Class F Low -Fe	Class F High-Fe	Class C High-Ca	Class C Low-Ca
Sample	S1	S2	S3	S4	S5	S6	S7
SiO_2	20-60	40-60	15-45	46-57	42-54	25-42	46-59
Al_2O_3	5-35	20-30	20-25	18-29	16.5-24	15-21	14-22
Fe_2O_3	10-40	4-10	4-15	6-16	16-24	5-10	5-13
CaO	1-12	5-30	15-40	1.8-5.5	1.3-3.8	17-32	8-16
MgO	-	-	-	0.7-2.1	0.3-1.2	4-12.5	3.2-4.9
K_2O	-	-	-	1.9-2.8	2.1-2.7	0.3-1.6	0.6-1.1
Na_2O	-	-	-	0.2-1.1	0.2-0.9	0.8-6.0	1.3-4.2
SO_3	-	-	-	0.4-2.9	0.5-1.8	0.4-5.0	0.4-2.5
LOI	0-15	0-3	0-5	0.6-4.8	1.2-5.0	0.1-1.0	0.1-2.3
TiO_2	-	-	-	1-2	1-1.5	<1	<1

into three parts:3

Step 1 Computation of equivalent atomic number (Z_{eq})

The value of Compton partial attenuation coefficient (μ_{comp}) and total attenuation (μ_{tot}) in cm^2 /g were obtained for element from Z=1 to Z=40 and the chosen flyash samples in the energy range of 0.015 to15.0 MeV by using the state of art and convenient computer program WinXCOM computer program (Gerward et al. 2001; Gerward et al.,2004) initially developed as XCOM (Berger and Hubbell, 1999). By using a simple computer program, the ratio R (μ_{comp}/μ_{tot}) was obtained for element from Z=1 to Z=40 and the selected flyash samples. The value of equivalent atomic number (Z_{eq}) for these samples was calculated by matching the ratio R (μ_{comp}/μ_{tot}) of particular flyash sample at a given energy with corresponding ratios of elements at the same energy. The value of Zeq was interpolated by using the following formula of interpolation (Sidhu et al., 2000) given in equation

$$Z_{eq} = \frac{Z_1(\log R_2 - \log R) + Z_2(\log R - \log R_1)}{\log R_2 - \log R_1}$$

where Z_1 and Z_2 are the elemental atomic number of the elements corresponding to the ratios (μ_{comp}/μ_{tot}) R_1 and R_2 respectively and R is the ratio for selected flyash sample at a specified energy. Mathematically $R_1<R<R_2$. The computed values of Z_{eq} for the different flyash samples are given in Table 2.

Table 2. Equivalent atomic numbers of the chosen Flyash samples.

E (MeV)	S1	S2	S3	S4	S5	S6	S7
0.015	16.03	14.09	15.37	14.67	15.24	14.05	14.05
0.02	16.3	14.26	15.56	14.87	15.47	14.23	14.23
0.03	16.59	14.46	15.77	15.04	15.72	14.42	14.46
0.04	16.74	14.56	15.86	15.14	15.84	14.55	14.58
0.05	16.83	14.62	15.97	15.23	15.97	14.62	14.64
0.06	17	14.75	16.06	15.32	16.08	14.75	14.78
0.08	17.16	14.87	16.07	15.4	16.16	14.87	14.95

0.1	17.23	14.88	16.33	15.51	16.33	14.88	14.88
0.15	17.26	14.92	16.31	15.49	16.6	14.92	14.92
0.2	17.64	14.96	16.89	14.96	16.92	14.96	14.49
0.3	16.99	14.5	16.5	14.5	16.99	14.5	14.5
0.4	16.5	14.5	16.5	14.5	16.5	14.5	14.5
0.5	16.5	14.5	16.5	14.5	16.5	14.5	14.5
0.6	16.5	14.5	16.5	14.5	16.5	14.5	14.5
0.8	16.5	14.5	16.5	14.5	16.5	14.5	14.5
1	16.5	14.5	16.5	14.5	16.5	14.5	14.5
1.5	16.5	14.5	16.5	14.5	16.5	14.5	14.5
2	15.07	12.88	12.88	12.88	12.94	12.88	12.9
3	13.67	12.58	13.61	13.16	13.21	12.58	12.62
4	13.78	12.31	13.02	12.66	12.74	11.94	12.35
5	13.33	12.48	13.54	12.73	13.07	12.24	12.28
6	13.61	12.54	13.51	12.87	12.95	12.21	12.29
8	13.51	12.44	13.42	12.86	12.91	12.44	12.3
10	13.73	12.34	13.61	12.97	12.83	12.42	12.28
15	13.76	12.51	13.5	12.99	13.12	12.38	12.14

S1----- Bituminous Flyash
S2 ----- Sub bituminous Flyash
S3 ------ Lignite Flyash
S4------- High Calcium Flyash
S5------ High Iron Flyash
S6------- Low Calcium Flyash
S7------- Low Iron Flyash

Step 2. Computation of geometric Progression G-P fitting parameter

American National Standard (1991), ANSI/ANS-6.4.3 has provided the energy absorption G.P. fitting parameters of twenty three elements (Ca, Fe, Si etc.) in the energy range of 0.015-15.0 MeV and upto a penetration depth of 40mfp. The computed values of Zeq for the selected flyash were used to interpolate G.P. fitting parameters (b,c.a,X_k,d) for the energy absorption build up factor in the chosen energy range (0.015-15.0 MeV) and penetration depth (1-40 mfp). The formula (Sidhu et al.,2000) used for the purpose of interpolation of the G.P. fitting parameter given below:

$$P = \frac{P_1(\log Z_2 - \log Z) + P_2(\log Z - \log Z_1)}{\log Z_2 - \log Z_1}$$

Here P_1 and P_2 are the value of G-P fitting parameters corresponding to the atomic number Z_1 and Z_2 respectively at a given energy, where Z is equivalent atomic number of the chosen flyash sample at a given energy. Z_1 and Z_2 are the elemental atomic number between which the equivalent atomic number Z of the chosen flyash sample lies. Mathematically $P1<P<P2$. Using the above interpolation formula, GP fitting parameters for energy absorption buildup factors were computed at the selected incident photon energies for the chosen flyash samples. The calculated GP fitting parameters for Sub-bituminous, High-Calcium and Low-Calcium and Low-Iron flyash are given in Tables 3 to Table 6.

Table 3. Energy absorption G-P fitting parameters for sub-bituminos Flyash.

E(MeV)	b	c	a	X_k	d
.0150	1.0216	.4134	.1920	11.2389	-.0822
.0200	1.0483	.4220	.1830	16.5572	-.1047
.0300	1.1617	.3927	.2169	14.1517	-.1197
.0400	1.3555	.4459	.1918	14.6384	-.1061
.0500	1.6117	.5544	.1422	15.8388	-.0750
.0600	2.0313	.5518	.1609	13.6659	-.0850
.0800	2.8038	.7379	.0920	13.5793	-.0634
.1000	3.4823	.9360	.0329	13.6993	-.0393
.1500	3.9563	1.2622	-.0434	19.5303	.0008
.2000	3.7097	1.4137	-.0697	16.0999	.0129
.3000	3.1212	1.5545	-.0954	14.3025	.0261
.4000	2.7932	1.5486	-.0959	14.9057	.0275
.5000	2.5802	1.5222	-.0934	15.0887	.0277
.6000	2.4381	1.4858	-.0890	14.9744	.0270
.8000	2.2435	1.4169	-.0795	15.1461	.0254
1.0000	2.1194	1.3580	-.0710	14.9953	.0242
1.5000	1.9420	1.2374	-.0500	14.6903	.0177
2.0000	1.8349	1.1606	-.0342	14.8355	.0110
3.0000	1.6948	1.0598	-.0114	12.4017	-.0005
4.0000	1.6064	.9920	.0060	13.9119	-.0091
5.0000	1.5412	.9333	.0251	13.5835	-.0249
6.0000	1.4685	.9328	.0245	15.2165	-.0288
8.0000	1.3773	.9108	.0316	12.9453	-.0248
10.0000	1.3087	.9131	.0314	14.4758	-.0274
15.0000	1.2294	.8383	.0611	14.1808	-.0553

Table 4 Energy absorption G-P fitting parameters for High Calcium Flyash.

E(MeV)	b	c	a	X_k	d
.0150	1.0193	.4035	.2049	11.7359	-.1116
.0200	1.0423	.4129	.1921	14.0922	-.0977
.0300	1.1399	.3899	.2188	13.8708	-.1225
.0400	1.3132	.4341	.1967	14.6730	-.1094
.0500	1.5501	.5144	.1612	15.1150	-.0872
.0600	1.9019	.5491	.1575	14.2037	-.0831
.0800	2.6699	.6942	.1082	13.3691	-.0722
.1000	3.3095	.8810	.0484	13.6434	-.0475
.1500	3.8922	1.2102	-.0325	16.4538	-.0053
.2000	3.7097	1.4137	-.0697	16.0999	.0129
.3000	3.1212	1.5545	-.0954	14.3025	.0261
.4000	2.7932	1.5486	-.0959	14.9057	.0275
.5000	2.5802	1.5222	-.0934	15.0887	.0277
.6000	2.4381	1.4858	-.0890	14.9744	.0270
.8000	2.2435	1.4169	-.0795	15.1461	.0254
1.0000	2.1194	1.3580	-.0710	14.9953	.0242
1.5000	1.9420	1.2374	-.0500	14.6903	.0177
2.0000	1.8349	1.1606	-.0342	14.8355	.0110
3.0000	1.6948	1.0577	-.0105	10.8787	-.0016
4.0000	1.6057	.9920	.0060	13.3095	-.0089
5.0000	1.5372	.9390	.0231	13.8685	-.0236
6.0000	1.4653	.9351	.0241	15.0965	-.0289

8.0000	1.3748	.9125	.0311	13.8538	-.0264
10.0000	1.3080	.9044	.0358	14.3078	-.0320
15.0000	1.2280	.8331	.0639	14.1996	-.0586

Table 5 Energy absorption G-P fitting parameters for Low Calcium Flyash.

E(MeV)	b	c	a	X_k	d
0150	1.0218	.4141	.1911	11.2039	-.0801
.0200	1.0486	.4225	.1825	16.6811	-.1051
.0300	1.1633	.3929	.2167	14.1729	-.1195
.0400	1.3563	.4461	.1918	14.6379	-.1061
.0500	1.6117	.5544	.1422	15.8388	-.0750
.0600	2.0313	.5518	.1609	13.6659	-.0850
.0800	2.8038	.7379	.0920	13.5793	-.0634
.1000	3.4823	.9360	.0329	13.6993	-.0393
.1500	3.9563	1.2622	-.0434	19.5303	.0008
.2000	3.7097	1.4137	-.0697	16.0999	.0129
.3000	3.1212	1.5545	-.0954	14.3025	.0261
.4000	2.7932	1.5486	-.0959	14.9057	.0275
.5000	2.5802	1.5222	-.0934	15.0887	.0277
.6000	2.4381	1.4858	-.0890	14.9744	.0270
.8000	2.2435	1.4169	-.0795	15.1461	.0254
1.0000	2.1194	1.3580	-.0710	14.9953	.0242
1.5000	1.9420	1.2374	-.0500	14.6903	.0177
2.0000	1.8349	1.1606	-.0342	14.8355	.0110
3.0000	1.6948	1.0598	-.0114	12.4017	-.0005
4.0000	1.6074	.9915	.0062	14.3851	-.0095
5.0000	1.5450	.9277	.0270	13.3045	-.0261
6.0000	1.4718	.9305	.0248	15.3398	-.0286
8.0000	1.3773	.9108	.0316	12.9453	-.0248
10.0000	1.3086	.9120	.0320	14.4540	-.0280
15.0000	1.2298	.8397	.0603	14.1756	-.0544

Table 6 Energy absorption G-P fitting parameters for Low Iron Flyash.

E(MeV)	b	c	a	X_k	d
.0150	1.0218	.4141	.1911	11.2039	-.0801
.0200	1.0486	.4225	.1825	16.6811	-.1051
.0300	1.1617	.3927	.2169	14.1517	-.1197
.0400	1.3539	.4456	.1919	14.6394	-.1061
.0500	1.6096	.5528	.1430	15.8069	-.0754
.0600	2.0255	.5498	.1618	13.6700	-.0853
.0800	2.7811	.7305	.0945	13.5427	-.0647
.1000	3.4823	.9360	.0329	13.6993	-.0393
.1500	3.9563	1.2622	-.0434	19.5303	.0008
.2000	3.6945	1.4581	-.0780	15.2625	.0184
.3000	3.1212	1.5545	-.0954	14.3025	.0261
.4000	2.7932	1.5486	-.0959	14.9057	.0275
.5000	2.5802	1.5222	-.0934	15.0887	.0277
.6000	2.4381	1.4858	-.0890	14.9744	.0270
.8000	2.2435	1.4169	-.0795	15.1461	.0254
1.0000	2.1194	1.3580	-.0710	14.9953	.0242
1.5000	1.9420	1.2374	-.0500	14.6903	.0177
2.0000	1.8349	1.1605	-.0342	14.8447	.0109
3.0000	1.6947	1.0597	-.0114	12.2411	-.0005
4.0000	1.6063	.9920	.0060	13.8422	-.0091
5.0000	1.5444	.9286	.0267	13.3514	-.0259
6.0000	1.4710	.9311	.0247	15.3096	-.0286

8.0000	1.3781	.9102	.0317	12.6356	-.0243
10.0000	1.3087	.9140	.0310	14.4922	-.0270
15.0000	1.2306	.8424	.0589	14.1658	-.0526

Step 3. Computation of Energy Absorption Buildup factor

The computed G.P. fitting parameters (b,c.a,X_k,d) were then used to compute the energy absorption buildup factor for the selected flyash samples at some standard incident photon energies in the range of (0.015-15.0 MeV) and upto a penetration depth of 40 mfp with the help of G.P. fitting formula (Harima et al., 1986) as given below: $B(E,x) = 1 + \frac{(b-1)(K^x - 1)}{K-1} \quad \text{for } K \neq 1$

$$B(E,x) = 1 + (b-1)x \quad \text{for } K = 1$$

$$K(E,x) = cx^a + d\frac{\tanh(x/X_k - 2) - \tanh(-2)}{1 - \tanh(-2)} \qquad x \le 40 \text{ mfp}$$

Where ‘x’ is source to detector distance in the medium, in mean free path, ‘b’ is the value of build up factor at one mfp, K(E,x) is the dose multiplication factor which represent the change in the shape of the dose weighed spectrum with increasing penetration depth and is represented by hyperbolic tangent function of penetration depth in mfp. The GP fitting parameters c, a, X_k, d are fitting parameters that depend on the attenuating medium and source energy. Thus the build up factor data for each chosen flyash sample is obtained by fitting the GP fitting formula. In order to standardize the above interpolation method, the energy absorption buildup factors were computed for water up to 40 mfp and in the chosen energy range 0.015 to 15.0 MeV with the help of this method. The results so obtained were compared with standard energy absorption buildup factor data of the American National Standards ANSI/ANS 6.4.3. for a few randomly selected energies of 0.015, 5.0, 10.0 and 15.0 MeV. It can be clearly seen from Table 7. that the energy absorption buildup factors generated by the present method are in good agreement with those of ANSI/ANS6.4.3.. Thus it can be safely assumed that the present method is appropriate and suitable for calculation of energy absorption buildup factor of the chosen flyash samples.

III. Result and Discussion

The results of present investigations are discussed in terms of the energy absorption buildup factor as a function of incident photon energy and penetration depth.

A. Energy absorption buildup factor (EABF) as a function of incident photon energy

Figures 1 to 7 show the variation in energy absorption buildup factor (EABF) with incident photon energy in energy region 0.015-15.0 MeV at different penetration depth for the chosen Flyash samples. All the flyash samples show almost similar variation of EABF in the continuous energy region based on domination of different photon interaction process in different energy region. From these figures, it is noted that for incident photon energies less than E_{pe}, the EABF values are relatively lower as compared to that at the neighbouring higher energies for all the chosen penetration depths. Here E_{pe} is the value of incident photon energy at which the photoelectric interaction coefficient matches the Compton interaction coefficient for a given flyash sample. Table 8 gives the approximate values of E_{pe} for the present flyash samples. These values have been estimated by matching the two interaction coefficients calculated with the help of a computer program and data base XCOM. The low value of EABF is due to the predominance of photoelectric effect in this energy region which results in the fast removal of low energy photons thereby not allowing these photons to buildup.

In the energy region $E_{pe}<E<E_{pp}$, the Compton effect is most dominant in energy degradation, where E_{pp}, is the incident photon energy value at which the pair-production interaction coefficient matches the Compton interaction coefficient for a particular Flyash sample. The approximate value of E_{pp} is also given in Table 8. It is further observed that in the energy range 0.08 to 1.0 MeV the buildup factor values are comparatively large for a given penetration depth owing to the dominance of the Compton effect which only helps in the degradation of photon energy and unable to remove a photon completely. Because of the multiple scattering of photons, they stay for a longer time in the material which leads to a higher value of buildup factor.

It is also noted that in the energy range 0.15 to 0.4 MeV, the EABF value is very large because of exclusive dominance of the Compton effect. This result in a broad peak around a particular value of incident photon energy, E_{peak} (Table 7). This implies that the contribution of secondary photons to the energy spectra has a maximum value in this energy range for all the seven flyash samples.

Furthermore it is also observed that for incident photon energy greater than 2.0 MeV, the dominance of the pair production phenomenon over the Compton effect increases resulting in lowering of the buildup factor above this energy for a chosen sample.

Table 7 . Comparison of calculated energy absorption build-up factors for water with standard ANSI/ANS 6.4.3. data.

	Energy =5.0 MeV			**Energy = 0.015 MeV**		
mfp	**Standard Value**	**Calculated value**	**Error (%)**	**Standard value**	**Calculated value**	**Error (%)**
1.0	1.19	1.199	0.76	1.57	1.571	0.06
2.0	1.28	1.302	1.72	2.10	2.112	0.57
3.0	1.34	1.371	2.31	2.62	2.636	0.61
4.0	1.40	1.423	1.64	3.12	3.149	0.93
5.0	1.44	1.465	1.74	3.63	3.655	0.69
6.0	1.48	1.502	1.49	4.14	4.155	0.36
7.0	1.51	1.535	1.66	4.64	4.652	0.26
8.0	1.54	1.565	1.62	5.14	5.146	0.12
10.0	1.59	1.619	1.82	6.14	6.133	0.11
15.0	1.69	1.738	2.84	8.62	8.608	0.14
20.0	1.77	1.833	3.56	11.10	11.10	0.00
25.0	1.83	1.902	3.93	13.50	13.55	0.37
30.0	1.88	1.948	3.62	15.90	15.91	0.06
35.0	1.93	1.991	3.16	18.30	18.22	0.44
40.0	1.96	2.047	4.44	20.70	20.64	0.29

	Energy =10.0 MeV			**Energy =15.0 MeV**		
mfp	**Standard Value**	**Calculated Value**	**Error (%)**	**Standard value**	**Calculated value**	**Error (%)**
1.0	1.38	1.367	0.94	1.29	1.274	1.24
2.0	1.70	1.693	0.41	1.51	1.512	0.13
3.0	2.00	1.998	0.10	1.72	1.730	0.58
4.0	2.29	2.288	0.09	1.93	1.937	0.36
5.0	2.57	2.567	0.12	2.14	2.135	0.23
6.0	2.85	2.840	0.35	2.34	2.328	0.51
7.0	3.13	3.107	0.73	2.53	2.516	0.55
8.0	3.40	3.371	0.85	2.73	2.702	1.03
10.0	3.94	3.892	1.22	3.11	3.068	1.35
15.0	5.24	5.188	0.99	4.04	3.981	1.46
20.0	6.51	6.481	0.45	4.93	4.901	0.59
25.0	7.75	7.732	0.23	5.81	5.790	0.34
30.0	8.97	8.913	0.64	6.64	6.592	0.72
35.0	10.20	110.09	1.08	7.42	7.316	1.40
40.0	11.30	11.40	0.88	8.09	8.050	0.49

B. Energy absorption buildup factor (EABF) as a function of penetration depth

The variation of generated energy absorption buildup factor (EABF) data is studied with the penetration depth upto 40 mfp for different incident photon energies from 0.015 to 15.0 MeV for the chosen flyash samples. From the present results shown in figures 8 to 21, it is concluded that in general, the buildup factor increases with increase in penetration depth. This is attributed to the fact that the increase in penetration depth increases the interaction of gamma-radiation photons with matter resulting in generation of large number of low energy photons due to occurrence of Compton scattering process. Which results in the increase in EABF with the increase in penetration depth.

From the figures, 8, 10, 12, 14, 16, 18, 20, it can be seen that in case of lower incident photon energy, mainly in energy region 0.015 to 0.10 MeV, the value of buildup factor is small, it is due to the absorption of photons, because in this energy region i.e. < 100 keV photoelectric interaction is more dominant process resulting in the complete absorption of photons due to which EABF is small.

It is analyzed from figures 8 to 21 that for a fixed value of penetration depth, the buildup factor increases with increase in incident photon energy from 0.015 to 0.3 MeV. Thus the buildup factor values is highest at 0.3 MeV after which a reversed trend is observed i.e. the buildup factor decreases with the increase in incident photon energies from 0.6 to 15.0 MeV. It is seen that for energies greater than 1.0 MeV, there is a sharp fall in the value of buildup factor, which ultimately depicts the dominance of pair production process in the region.

Table:8 Approximate values of E_{pe}, E_{pp} and E_{peak} for chosen flyash samples.

Flyash sample	E_{pe}	E_{pp}	E_{peak}
Low-Calcium	0.2 MeV	3.0 MeV	0.25 MeV
High-Calcium	0.2 MeV	3.0 MeV	0.25 MeV
Low-Iron	0.2 MeV	3.0 MeV	0.25 MeV
Sub bituminous	0.2 MeV	3.0 MeV	0.25 MeV
Lignite	0.3 MeV	3.0 MeV	0.25 MeV
High-Iron	0.3 MeV	3.0 MeV	0.25 MeV
Bituminous	0.3 MeV	3.0 MeV	0.25 MeV

IV. Conclusions

The generated energy absorption buildup factor data will be helpful in estimating the penetration and diffusion of gamma rays in flyash samples. Normally, in laboratory experiments, lead is used for shielding purposes but in field conditions its use is cumbersome because it is costly and has limited abundance. It can be stolen from the places where nuclear wastes are dumped. Instead of lead, Flyash can be used as a gamma-ray shielding material in field experiments which is suitable from the points of view of cost and availability. Above studies projects flyash as an potential radiation shielding materials.

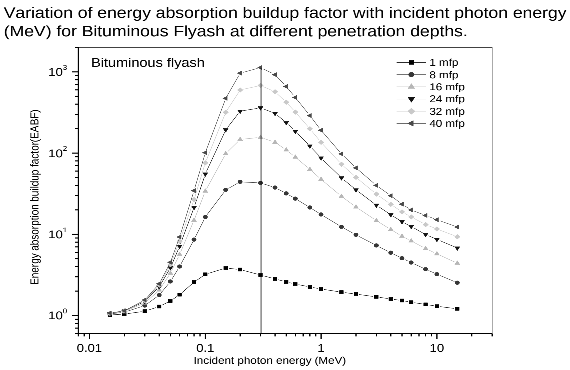

Figure: 1

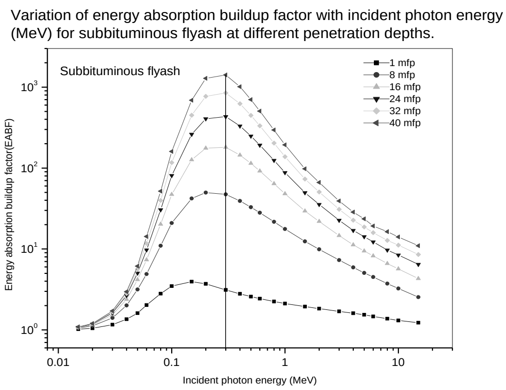

Figure: 2

Variation of energy absorption buildup factor with incident photon energy (MeV) for Lignite Flyash at different penetration depths.

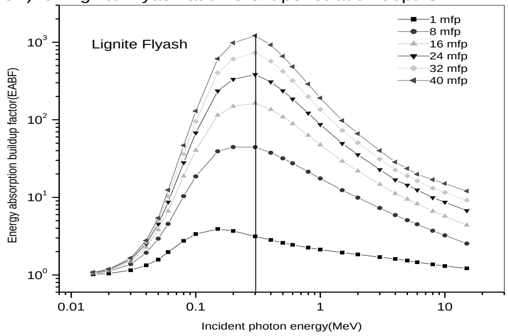

Figure: 3

Variation of energy absorption buildup factor with incident photon energy (MeV) for High Calcium Flyash at different penetration depths.

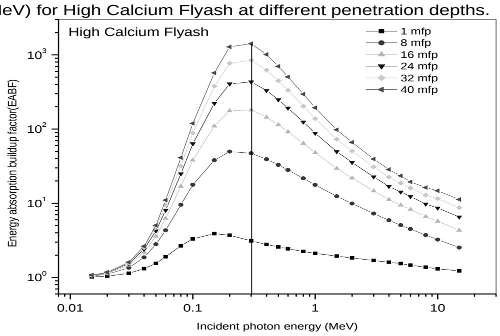

Figure: 4

Variation of energy absorption buildup factor with incident photon energy (MeV)for High Iron flyash at different penetration depths.

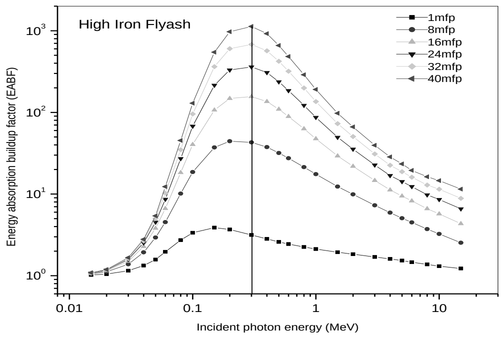

Figure: 5

Variation of energy absorption buildup factor with incident photon energy (MeV) for Low Calcium flyash at different penetration depths.

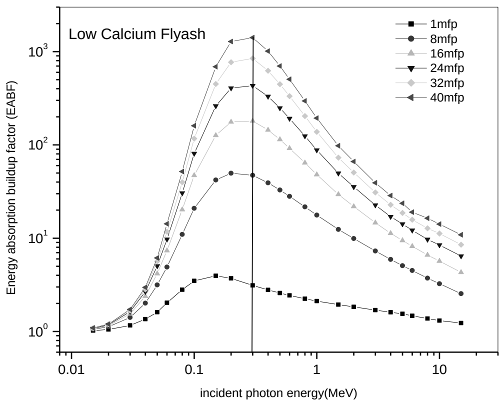

Figure: 6

Variation of energy absorption buildup factor with incident photon energy (MeV) for Low Iron flyash at different penetration depths.

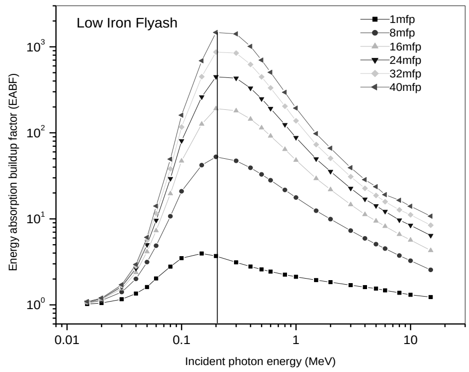

Figure: 7

Variation of energy absorption buildup factor with penetration depth for Bituminous Flyash at chosen energies.

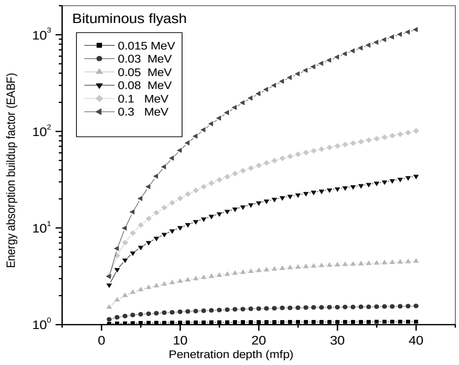

Figure: 8

Variation of energy absorption buildup factor with penetration depth for Bituminous Flyash at chosen energies.

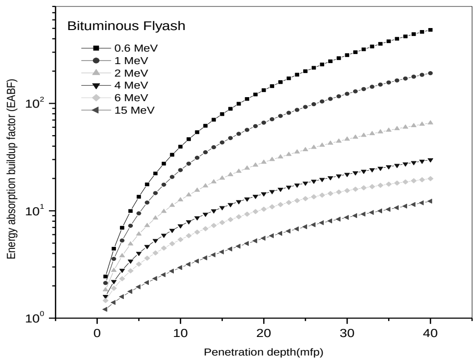

Figure: 9

Variation of energy absorption buildup factor with penetration depth for Sub bituminous Flyash at chosen energies.

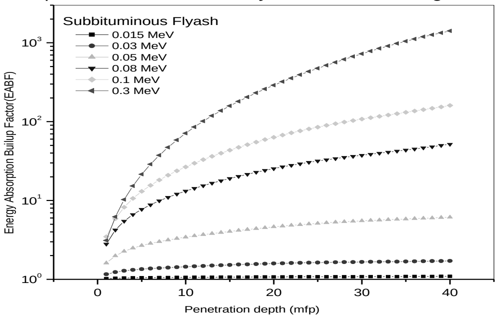

Figure: 10

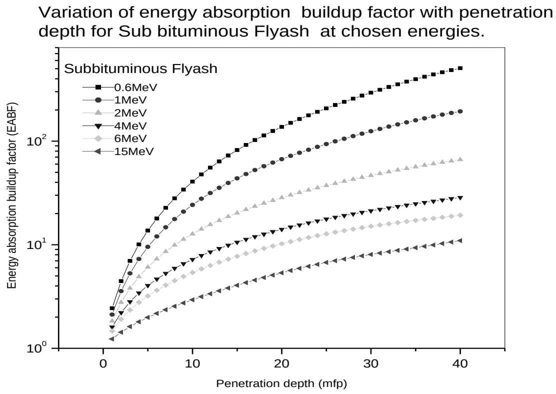

Figure: 11

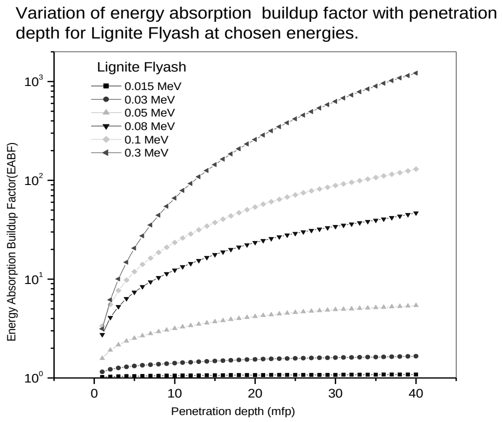

Figure: 12

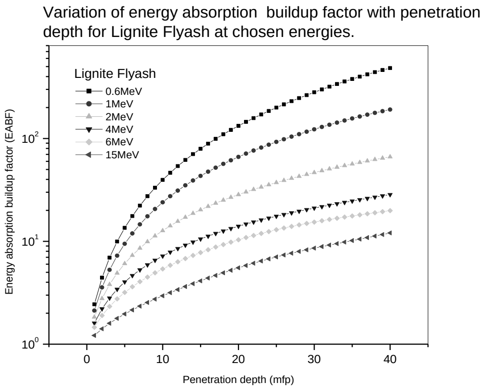

Figure: 13

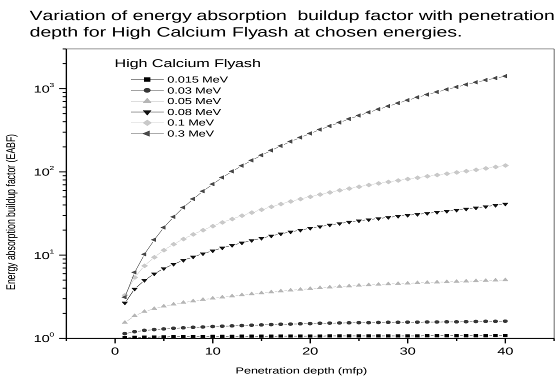

Figure: 14

Variation of energy absorption buildup factor with penetration depth for High Calcium Flyash at chosen energies.

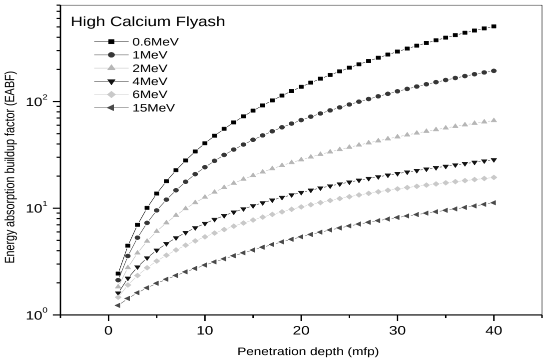

Figure: 15

Variation of energy absorption buildup factor with penetration depth for High Iron Flyash at chosen energies.

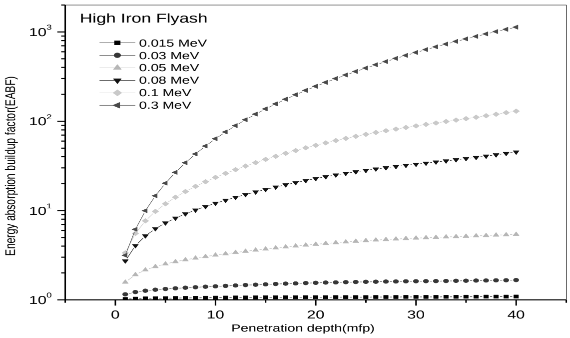

Figure: 16

Variation of energy absorption buildup factor with penetration depth for High Iron Flyash at chosen energies.

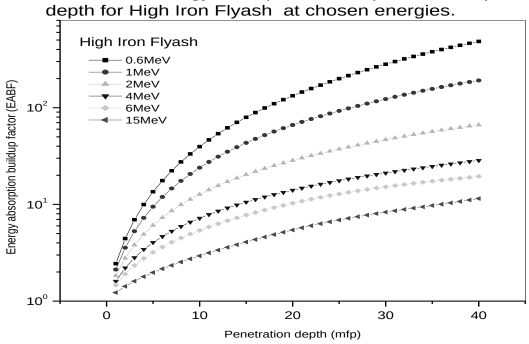

Figure: 17

Variation of energy absorption buildup factor with penetration depth for low Calcium Flyash at chosen energies.

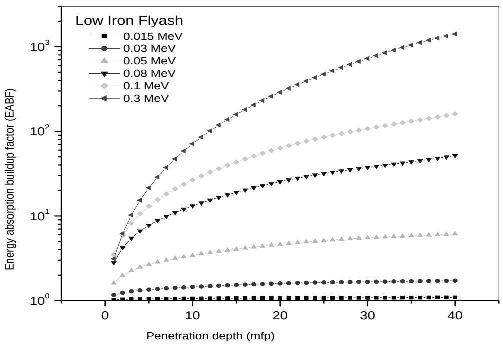

Figure: 18

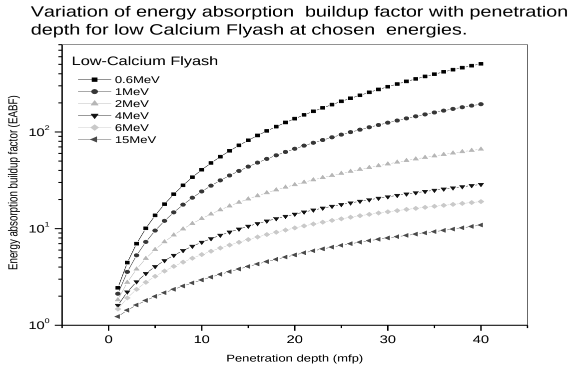

Figure: 19

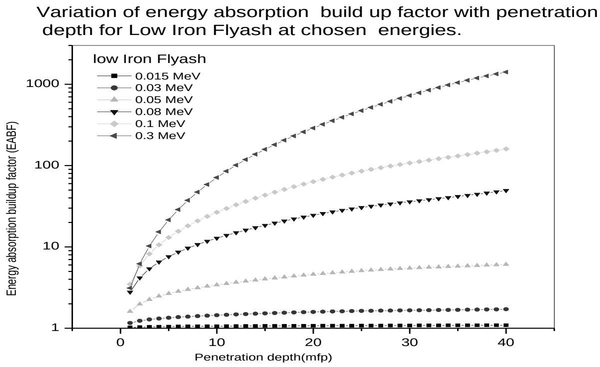

Figure: 20

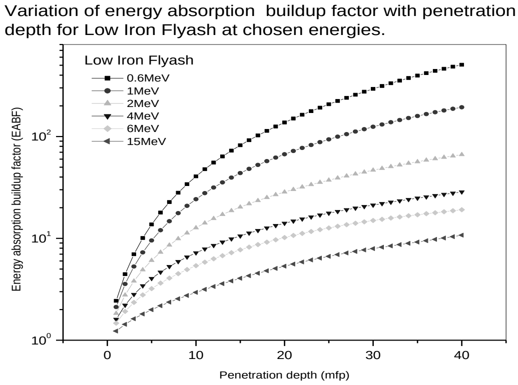

Figure: 21

References:

[1] ANSI, 1991. American National Standard Gamma – "Ray Attenuation Coefficients and Buildup Factor for Engineering Materials", *ANSI/ANS*-**6.4.3**.

[2] El-Hosiny, FI., El-Faramawy, N.A. 2000. "Shielding of gamma radiation by hydrated Portland cement-lead pastes. Radiat. Meas.", 32,93.

[3] Gopinath D.V.and Samthanam K. (1971) "Radiation transport in one dimensional finite systems - part I. Development in the anisotropic source - flux technique", *Nucl. Sci. Eng.* **43**, 186.

[4] Gerward, L., Guilbert, N, Jensen, K.B., Levring, H., 2001. "X-ray absorption in matter Reengineering" , XCOM. Radiat. Phys. Chem. 60,23-24

[5] Gerward, l., Guilbert, N., Jensen, K.B., Levring, H, 2004 "WinXcom- A program for calculating X-ray attenuation cofficients" Radit. hys. hem., 71, 653-654

[6] Harima Y. (1983) "An approximation of gamma ray buildup factors by modified geometrical progression". *Nucl. Sci. Eng.* **83**, 299-309.

[7] Harima Y., Sakamoto Y., Tanaka S. and Kawai M. (1986a) "Validity of the geometric- progression formula in approximating the gamma ray buildup factors", *Nucl. Sci. Eng.* **94**, 24.

[8] Harima. Y., 1993 "A historical review and current status of buildup factor calculations and applications", Radiat. Phys. Chem. 41, 631-672.

[9] Harima Y., Sakamoto Y., Tanaka S. and Kawai M. (1986a) "Validity of the geometric- progression formula in approximating the gamma ray buildup factors", *Nucl. Sci. Eng.* **94**, 24.

[10] Harima Y., Sakamoto Y., Tanaka S., Kawai M., Fujita T., Ishikawa T., Kinno M., Hayashi K., Matsumoto Y., and Nishimura T. (1986b) "Applicability of geometrical progression approximation (G-P method) of gamma-ray buildup factors", *Japan Atomic Energy Research Institute (JAERI)-M*, **86-071**.

[11] Nelson W. R., Hirayama H., Rogers D. W. O. (1985) "EGS4 code system", *SLAC* - **265**. Stanford Linear Accelerator Center, Stanford California.

[12] Sardari., D., Abbbaspour, A., Baradaran, S, Babapour,F., 2009 "Estimation of gamma and X ray photons build up factor in soft tissue with Monte Carlo method", Appl.Radiat.Isot.67,1438-1440

[13] Suteau, C., Chiron 2005 "An iterative method for calculating gamma ray build up factor in multi layer shields", radiat.prot.dosim.116,489-492

[14] Shimizu, A., 2002, "Calculations of gamma-ray buildup factors up to depths of 100 mfp by the method of invariant embedding, (I) analysis of accuracy and comparison with other data", J. Nucl. Sci. Technol. 39,477-486.

[15] Shimizu. A., Onda, T., Sakamoto, Y., 2004 "Calculations of gamma-ray buildup factors up to depths of 100 mfp by the method of invariant embedding, (III) generation of an improved data set", J. Nucl. Sci. Technol. 41, 413-424.

[16] Sakamoto, y. Tanaka, S., Harima, Y., 1988. "Interpolation of gamma ray build up factors for point isotropic source with respect to atomic number", Nucl.Sci.Eng.100,33-42

[17] Sidhu, G. S., Singh , Parjit S. and Mudahar, Gurmel S. (2000) "A study of energy and effective atomic number dependence of the exposure buildup factors in biological samples", *J. Radiol. Prot. 20, 53.*

[18] Takeuchi K. and Tanaka S. (1984) PALLAS - ID (VII); "A code for direct integration of transport equation in one - dimensional plane and spherical geometries. Japan Atomic Energy Research Institute", *JAERI*-**M 84**, 214.