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Impact of lockdown during COVID-19 pandemic on annual effective dose equivalent values of natural gamma radiation

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Abstract
The study aimed to determine the impact of COVID-19 on values of annual effective dose equivalent of the natural gamma dose rate of Balod, Durg and Bemetara districts of Chhattisgarh (India). COVID-19 is a severe problem for many countries and to control and prevent the spread of this problem, the lockdown approach has been implemented in many countries, including India. In this lockdown situation, almost all people stay at home for 24 h. Due to the present status of COVID-19, the Indian government also fixed the 67 days lockdown and one day was already successfully done as Janta Curfew, which worked the same as a lockdown. The value of indoor gamma dose rates was reported to be higher in most places compared to the outdoor gamma dose rate, but in this pandemic situation, occupancy factor values are not applicable as recommended by UNSCEAR for calculation of annual effective dose equivalent (AEDE). Therefore, the present study introduces the new equations, which can measure the extra AEDE value during lockdown for adults, children and infants.

Keywords Annual effective dose equivalent · Lockdown · COVID-19 · Gamma dose rate · Chhattisgarh region

Introduction

COVID-19 due to Coronavirus is distressing many countries and their territories around the world [1, 2]. This pandemic emerged during December 2019 from Wuhan city of China to other parts of the world [3]. In this problematic situation, every country is working on applying many strategies to prevent and control the spread of coronavirus among their people. Many countries already applied tremendous strategies, which include one of the dominant strategies is lockdown of state or country. The Indian government has also adopted this strategy and before applying lockdown, the prime minister of India has requested the Indian public to follow self-lockdown as called Janta Curfew for one day (22 March 2020), which was efficacious. The Indian government has declared a total of 21 days (from 24 March 2020 to 14 April 2020) as a lockdown, which extended three times from 15 April 2020 to 3 May 2020; 4 May 2020 to 17 May 2020 and 18 May 2020 to 31 May 2020 [4]. The annual effective dose of gamma radiation is the most important value to estimate the effect of gamma radiation on mankind, UNSCEAR was given the formula for calculation of these values and this formula is utilized around the world for estimation of AEDE values [5]. The annual effective dose is calculated by using indoor and outdoor gamma dose and based on many studies, indoor gamma dose rate values are usually higher than the outdoor gamma dose rate, except in a few countries or territories of the world [5, 6]. Lockdown situations where movement restricted will affect the AEDE values because, in this period, the public stays inside of the house instead of outside. Hence, the values of the annual gamma dose rate will change in the lockdown period. The intention of this study was to estimate the extra AEDE value of the natural background gamma dose rate during this lockdown period for adults, children and infants from areas (Balod, Durg and Bemetara) of the Chhattisgarh region.

Material and methodology

All researchers usually used the formulas for calculation of AEDE value, which were reported by UNSCEAR by applying the indoor and outdoor gamma dose rate, which was as [5, 7]:

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$$AEDE(indoor/outdoor) = D(indoor/outdoor) \times T \times conversion\ coefficient \times occupancy\ factor \quad (1)$$

where $D_{(indoor)}$ = Indoor absorbed gamma dose rate (nGy/h). $D_{(outdoor)}$ = Outdoor absorbed gamma dose rate (nGy/h). T = Time conversion factor (hour into a year) (1 year = 8760 h).

The dose conversion coefficient value for an adult was 0.7 (UNSCEAR), and the values of the occupancy factor for outdoor and indoor were 0.2 and 0.8, respectively [5]. The conversion coefficient values for the children and infants were approximately 10 and 30% higher than those for adults [5]. The value of the total AEDE value was calculated by the accumulation of the AEDE values of indoor and outdoor gamma dose rates.

In India (including all states), 68 days set for lockdown means people of the country will be spending 1632 h inside of houses. It indicated that out of 8670 h in a year, people utilize 1632 h inside of houses. Moreover, the remaining hours of the year 7128 h can be utilized as the normal distribution of occupancy factors of 0.8 and 0.2 for indoor and outdoor. As of now (18 July 2020), the COVID-19 condition is still continuing [1, 4]. The lockdown of the few places of Chhattisgarh State might be increased by the central government of India or state government of Chhattisgarh. The Indian government has declared June and July month as unlock-1 and unlock-2 means all work will start slowly but still education or few other organizations such as schools, colleges closed.

Results and discussion

The annual effective dose values were already published by many researchers and in our previous studies [6–9]. Table 1 shows the calculation of extra annual effective dose values by using Balod, Durg and Bemetara districts indoor and outdoor gamma dose rate values [6–9]. In columns, D and E present the AEDE values of indoor and outdoor, respectively, by using the 7128 h after subtracting the 1632 h of lockdown (period of lockdown) [4]. The F column indicates the AEDE value during lockdown and the addition of D, E and F is the total AEDE value with 68 days of lockdown. Annual effective dose values were also calculated by using Eq. 1 with occupancy factors of 0.8 and 0.2 for indoor and outdoor respectively, and these values were subtracted from lockdown values to obtain the total extra dose, which can be received by people during the lockdown period, which was precisely the same as calculated. The same value can be calculated directly by using the following formula.

$$Extra\ AEDE\ value\ during\ lockdown = D(indoor - outdoor) \times Time\ of\ lockdown \times conversion\ coefficient \times difference\ in\ occupancy\ factor \quad (2)$$

$$Extra\ AEDE\ value\ during\ lockdown\ for\ adult = \left[(X \times 228) + \left\{(-2.42) \times e^{-11}\right\}\right] \quad (3)$$

$$Extra\ AEDE\ value\ during\ lockdown\ for\ children = \left[(X \times 261) + \left\{(-3.78) \times e^{-11}\right\}\right] \quad (4)$$

$$Extra\ AEDE\ value\ during\ lockdown\ for\ infants = \left[(X \times 294) + \left\{(-3.02) \times e^{-11}\right\}\right] \quad (5)$$

where X = difference between indoor and outdoor gamma dose rate.

The range of difference between indoor and outdoor gamma dose rates was found from −20 to 124 nSv/h. These difference values were used to calculate the extra annual dose rate during the lockdown period for adults, children and infants. The resultant values showed a strong correlation between indoor and outdoor gamma dose rates. The relation between both can be calculated by using Eqs. 3, 4 and 5 for adults, children and infants, respectively. The relationship between extra gamma dose rate values during lockdown and differences in indoor-outdoor gamma dose rate are shown in Figs. 1, 2 and 3 for adults, children and infants, respectively. The extra dose rate ranged from −4.57 to 28.33 μSv/y; − 5.22 to 32.38 μSv/y and −5.88 to 36.43 μSv/y for adults, children and infants, respectively.

Conclusions

- It has been observed that the calculation of extra AEDE values through Eq. 2 is the same as calculated by using AEDE separately; hence, it is suitable for estimation of additional natural gamma dose rate values during lockdown situations.
- This study will be helpful in calculating the extra annual effective dose value, and the mean values of extra AEDE for Balod, Durg and Beemetara districts of India were 10.66 μSv/y, 12.18 μSv/y and 13.70 μSv/y for adults, children and infants, respectively.
- This study will be applicable in lockdown situations only, and formula (Eqs. 3, 4, 5) can be used for the estimation of extra AEDE values of natural gamma dose in many countries during 2020 due to COVID-19.
- The value of AEDE due to lockdown have been obtained highest and lowest 28,332 nSv/y and −4570 nSv/y respectively at area Bortara (Bemetara district) and Piparchhedi (Balod district).

Table 1 Calculation of extra AEDE values during the lockdown period for adults, children and infants from Balod, Durg, Bemetara districts [6–9]

S. no.	Indoor Gamma Dose rate (nSv/h) (A)	Outdoor Gamma Dose rate (nSv/h) (B)	Indoor-Outdoor (C)	For adult			
				D = A × 7128 × 0.7 × 0.8	E = B × 7128 × 0.7 × 0.2	F = A × 1632 × 0.7 × 1	Total AEDE with lock-down = D + E + F
1	194	133	61	774,386	132,723	221,626	1,128,735
2	198	142	56	790,353	141,705	226,195	1,158,252
3	211	154	57	842,244	153,680	241,046	1,236,971
4	184	163	21	734,469	162,661	210,202	1,107,332
5	165	126	39	658,627	125,738	188,496	972,861
6	178	146	32	710,519	145,696	203,347	1,059,563
7	201	160	41	802,328	159,667	229,622	1,191,617
8	181	140	41	722,494	139,709	206,774	1,068,977
9	157	170	-13	626,694	169,646	179,357	975,697
10	185	147	38	738,461	146,694	211,344	1,096,499
11	198	145	53	790,353	144,698	226,195	1,161,246
12	232	159	73	926,070	158,669	265,037	1,349,776
13	174	107	67	694,552	106,777	198,778	1,000,107
14	175	126	49	698,544	125,738	199,920	1,024,202
15	132	103	29	526,902	102,786	150,797	**780,484**
16	180	127	53	718,502	126,736	205,632	1,050,870
17	182	133	49	726,486	132,723	207,917	1,067,126
18	185	120	65	738,461	119,750	211,344	1,069,555
19	221	115	106	882,161	114,761	252,470	1,249,392
20	200	119	81	798,336	118,752	228,480	1,145,568
21	174	147	27	694,552	146,694	198,778	1,040,024
22	198	135	63	790,353	134,719	226,195	1,151,267
23	192	139	53	766,403	138,711	219,341	1,124,454
24	232	130	102	926,070	129,730	265,037	1,320,836
25	189	179	10	754,428	178,628	215,914	1,148,969
26	196	125	71	782,369	124,740	223,910	1,131,020
27	213	127	86	850,228	126,736	243,331	1,220,295
28	221	126	95	882,161	125,738	252,470	1,260,370
29	260	165	95	1,037,837	164,657	297,024	1,499,518
30	179	135	44	714,511	134,719	204,490	1,053,720
31	209	153	56	834,261	152,682	238,762	1,225,704
32	177	158	19	706,527	157,671	202,205	1,066,404
33	193	154	39	770,394	153,680	220,483	1,144,557
34	181	201	-20	722,494	200,582	206,774	1,129,850
35	176	165	11	702,536	164,657	201,062	1,068,255
36	198	157	41	790,353	156,673	226,195	1,173,221
37	188	129	59	750,436	128,732	214,771	1,093,939
38	199	147	52	794,344	146,694	227,338	1,168,376
39	176	120	56	702,536	119,750	201,062	1,023,348

Table 1 (continued)

S. no.	Indoor Gamma Dose rate (nSv/h) (A)	Outdoor Gamma Dose rate (nSv/h) (B)	Indoor-Outdoor (C)	For adult			
				D = A × 7128 × 0.7 × 0.8	E = B × 7128 × 0.7 × 0.2	F = A × 1632 × 0.7 × 1	Total AEDE with lock-down = D + E + F
40	245	188	57	977,962	187,609	279,888	1,445,459
41	150	123	27	598,752	122,744	171,360	892,856
42	167	129	38	666,611	128,732	190,781	986,123
43	165	112	53	658,627	111,767	188,496	958,890
44	249	169	80	993,928	168,648	284,458	1,447,034
45	186	168	18	742,452	167,651	212,486	1,122,589
46	183	123	60	730,477	122,744	209,059	1,062,281
47	201	157	44	802,328	156,673	229,622	1,188,624
48	255	194	61	1,017,878	193,596	291,312	**1,502,787**
49	256	165	91	1,021,870	164,657	292,454	1,478,981
50	187	154	33	746,444	153,680	213,629	1,113,753
51	196	135	61	782,369	134,719	223,910	1,140,999
52	198	124	74	790,353	123,742	226,195	1,140,290
53	204	123	81	814,303	122,744	233,050	1,170,096
54	177	133	44	706,527	132,723	202,205	1,041,456
55	189	140	49	754,428	139,709	215,914	1,110,050
56	188	153	35	750,436	152,682	214,771	1,117,889
57	160	120	40	638,669	119,750	182,784	941,203
58	162	151	11	646,652	150,686	185,069	982,407
59	157	157	0	626,694	156,673	179,357	962,724
60	148	126	22	590,769	125,738	169,075	885,582
61	185	165	20	738,461	164,657	211,344	1,114,462
62	167	113	54	666,611	112,765	190,781	970,156
63	172	104	68	686,569	103,784	196,493	986,845
64	180	102	78	718,502	101,788	205,632	1,025,922
65	169	118	51	674,594	117,755	193,066	985,414
66	155	115	40	618,710	114,761	177,072	910,543
67	180	169	11	718,502	168,648	205,632	1,092,783
68	178	146	32	710,519	145,696	203,347	1,059,563
69	145	126	19	578,794	125,738	165,648	870,180
70	145	102	43	578,794	101,788	165,648	846,229
71	165	105	60	658,627	104,782	188,496	951,905
72	171	124	47	682,577	123,742	195,350	1,001,670
73	237	223	14	946,028	222,536	270,749	1,439,313
74	210	143	67	838,253	142,703	239,904	1,220,859
75	205	189	16	818,294	188,607	234,192	1,241,093
76	184	149	35	734,469	148,690	210,202	1,093,361

Table 1 (continued)

S. no.	Indoor Gamma Dose rate (nSv/h) (A)	Outdoor Gamma Dose rate (nSv/h) (B)	Indoor-Outdoor (C)	For adult			
				D = A × 7128 × 0.7 × 0.8	E = B × 7128 × 0.7 × 0.2	F = A × 1632 × 0.7 × 1	Total AEDE with lock-down = D + E + F
77	170	101	69	678,586	100,790	194,208	973,584
78	186	121	65	742,452	120,748	212,486	1,075,687
79	212	133	79	846,236	132,723	242,189	1,221,148
80	141	124	17	562,827	123,742	161,078	847,647
81	173	127	46	690,561	126,736	197,635	1,014,932
82	174	134	40	694,552	133,721	198,778	1,027,051
83	178	166	12	710,519	165,655	203,347	1,079,521
84	159	145	14	634,677	144,698	181,642	961,017
85	136	144	-8	542,868	143,700	155,366	841,935
86	166	138	28	662,619	137,713	189,638	989,970
87	154	129	25	614,719	128,732	175,930	919,380
88	172	103	69	686,569	102,786	196,493	985,848
89	201	165	36	802,328	164,657	229,622	1,196,607
90	197	136	61	786,361	135,717	225,053	1,147,131
91	150	117	33	598,752	116,757	171,360	886,869
92	172	141	31	686,569	140,707	196,493	1,023,768
93	181	124	57	722,494	123,742	206,774	1,053,011
94	231	107	124	922,078	106,777	263,894	1,292,750
95	171	107	64	682,577	106,777	195,350	984,705
96	174	184	-10	694,552	183,617	198,778	1,076,947
97	182	147	35	726,486	146,694	207,917	1,081,097
98	202	144	58	806,319	143,700	230,765	1,180,785
99	154	147	7	614,719	146,694	175,930	937,343
100	158	106	52	630,685	105,780	180,499	916,964
101	177	112	65	706,527	111,767	202,205	1,020,499
102	195	113	82	778,378	112,765	222,768	1,113,911
103	208	155	53	830,269	154,678	237,619	1,222,566
104	192	153	39	766,403	152,682	219,341	1,138,425
105	196	137	59	782,369	136,715	223,910	1,142,995
106	153	144	9	610,727	143,700	174,787	929,215
107	204	142	62	814,303	141,705	233,050	1,189,057
108	151	170	-19	602,744	169,646	172,502	944,892
109	202	158	44	806,319	157,671	230,765	1,194,756
110	237	143	94	946,028	142,703	270,749	1,359,480
111	205	156	49	818,294	155,676	234,192	1,208,162
112	253	160	93	1,009,895	159,667	289,027	1,458,589
113	177	152	25	706,527	151,684	202,205	1,060,416

Table 1 (continued)

S. no.	Indoor Gamma Dose rate (nSv/h) (A)	Outdoor Gamma Dose rate (nSv/h) (B)	Indoor-Outdoor (C)	For adult			
				D = A × 7128 × 0.7 × 0.8	E = B × 7128 × 0.7 × 0.2	F = A × 1632 × 0.7 × 1	Total AEDE with lock-down = D + E + F
114	211	147	64	842,244	146,694	241,046	1,229,985
115	202	151	51	806,319	150,686	230,765	1,187,770
116	198	154	44	790,353	153,680	226,195	1,170,228
117	198	154	44	790,353	153,680	226,195	1,170,228
118	202	151	51	806,319	150,686	230,765	1,187,770
119	205	134	71	818,294	133,721	234,192	1,186,208
120	240	145	95	958,003	144,698	274,176	1,376,878
121	226	145	81	902,120	144,698	258,182	1,305,000
122	192	181	11	766,403	180,624	219,341	1,166,367
123	249	162	87	993,928	161,663	284,458	1,440,049
124	183	117	66	730,477	116,757	209,059	1,056,293
125	207	144	63	826,278	143,700	236,477	1,206,455
126	186	175	11	742,452	174,636	212,486	1,129,575
127	186	171	15	742,452	170,644	212,486	1,125,583
128	188	166	22	750,436	165,655	214,771	1,130,862
129	198	185	13	790,353	184,615	226,195	1,201,163
130	177	138	39	706,527	137,713	202,205	1,046,445
131	200	170	30	798,336	169,646	228,480	1,196,462
132	175	148	27	698,544	147,692	199,920	1,046,156
133	223	159	64	890,145	158,669	254,755	1,303,569
134	184	129	55	734,469	128,732	210,202	1,073,402
135	236	153	83	942,036	152,682	269,606	1,364,325
136	198	152	46	790,353	151,684	226,195	1,168,232
137	210	153	57	838,253	152,682	239,904	1,230,839
138	145	141	4	578,794	140,707	165,648	885,148
139	187	165	22	746,444	164,657	213,629	1,124,730
140	224	154	70	894,136	153,680	255,898	1,303,714
141	205	171	34	818,294	170,644	234,192	1,223,131
142	170	154	16	678,586	153,680	194,208	1,026,473
143	251	176	75	1,001,912	175,634	286,742	1,464,288
144	165	145	20	658,627	144,698	188,496	991,822
145	201	135	66	802,328	134,719	229,622	1,166,669
146	207	124	83	826,278	123,742	236,477	1,186,497
147	196	165	31	782,369	164,657	223,910	1,170,936
148	195	162	33	778,378	161,663	222,768	1,162,809
149	191	164	27	762,411	163,659	218,198	1,144,268
150	197	132	65	786,361	131,725	225,053	1,143,139

Table 1 (continued)

S. no.	Indoor Gamma Dose rate (nSv/h) (A)	Outdoor Gamma Dose rate (nSv/h) (B)	Indoor-Outdoor (C)	For adult			
				D = A × 7128 × 0.7 × 0.8	E = B × 7128 × 0.7 × 0.2	F = A × 1632 × 0.7 × 1	Total AEDE with lockdown = D + E + F
151	202	181	21	806,319	180,624	230,765	1,217,708
152	224	115	109	894,136	114,761	255,898	1,264,795
153	191	189	2	762,411	188,607	218,198	1,169,216
154	221	156	65	882,161	155,676	252,470	1,290,307

Average value

S. no.	For adult				For children	For infants
	G = A × 8760 × 0.7 × 0.8	H = B × 8760 × 0.7 × 0.2	Total AEDE without lockdown = G + H	Total AEDE with lockdown-Total AEDE without lockdown (Extra Dose = C × 1632 × 0.7 × 0.2 nSv/y)	C × 1632 × 0.8 × 0.2 (nSv/y)	C × 1632 × 0.9 × 0.2 (nSv/y)
1	951,686	163,111	1,114,798	13,937	15,928	17,919
2	971,309	174,149	1,145,458	12,795	14,623	16,451
3	1,035,082	188,866	1,223,947	13,023	14,884	16,744
4	902,630	199,903	1,102,534	4798	5484	6169
5	809,424	154,526	963,950	8911	10,184	11,457
6	873,197	179,054	1,052,251	7311	8356	9400
7	986,026	196,224	1,182,250	9368	10,706	12,044
8	887,914	171,696	1,059,610	9368	10,706	12,044
9	770,179	208,488	978,667	− 2970	− 3395	− 3819
10	907,536	180,281	1,087,817	8682	9923	11,163
11	971,309	177,828	1,149,137	12,109	13,839	15,569
12	1,138,099	194,998	1,333,097	16,679	19,062	21,444
13	853,574	131,225	984,799	15,308	17,495	19,682
14	858,480	154,526	1,013,006	11,196	12,795	14,394
15	647,539	126,319	**773,858**	6626	7572	8519
16	883,008	155,753	1,038,761	12,109	13,839	15,569
17	892,819	163,111	1,055,930	11,196	12,795	14,394
18	907,536	147,168	1,054,704	14,851	16,973	19,094
19	1,084,138	141,036	1,225,174	24,219	27,679	31,139
20	981,120	145,942	1,127,062	18,507	21,151	23,795
21	853,574	180,281	1,033,855	6169	7050	7932
22	971,309	165,564	1,136,873	14,394	16,451	18,507
23	941,875	170,470	1,112,345	12,109	13,839	15,569
24	1,138,099	159,432	1,297,531	23,305	26,634	29,964
25	927,158	219,526	1,146,684	2285	2611	2938
26	961,498	153,300	1,114,798	16,222	18,540	20,857
27	1,044,893	155,753	1,200,646	19,649	22,456	25,263
28	1,084,138	154,526	1,238,664	21,706	24,806	27,907

Table 1 (continued)

S. no.	For adult				For children	For infants
	G = A × 8760 × 0.7 × 0.8	H = B × 8760 × 0.7 × 0.2	Total AEDE without lockdown = G + H	Total AEDE with lockdown-Total AEDE without lockdown (Extra Dose = C × 1632 × 0.7 × 0.2 nSv/y)	C × 1632 × 0.8 × 0.2 (nSv/y)	C × 1632 × 0.9 × 0.2 (nSv/y)
29	1,275,456	202,356	1,477,812	21,706	24,806	27,907
30	878,102	165,564	1,043,666	10,053	11,489	12,925
31	1,025,270	187,639	1,212,910	12,795	14,623	16,451
32	868,291	193,771	1,062,062	4341	4961	5581
33	946,781	188,866	1,135,646	8911	10,184	11,457
34	887,914	246,506	1,134,420	**− 4570**	**− 5222**	**− 5875**
35	863,386	202,356	1,065,742	2513	2872	3231
36	971,309	192,545	1,163,854	9368	10,706	12,044
37	922,253	158,206	1,080,458	13,480	15,406	17,332
38	976,214	180,281	1,156,495	11,881	13,578	15,276
39	863,386	147,168	1,010,554	12,795	14,623	16,451
40	1,201,872	230,563	1,432,435	13,023	14,884	16,744
41	735,840	150,847	886,687	6169	7050	7932
42	819,235	158,206	977,441	8682	9923	11,163
43	809,424	137,357	946,781	12,109	13,839	15,569
44	1,221,494	207,262	1,428,756	18,278	20,890	23,501
45	912,442	206,035	1,118,477	4113	4700	5288
46	897,725	150,847	1,048,572	13,709	15,667	17,626
47	986,026	192,545	1,178,570	10,053	11,489	12,925
48	1,250,928	237,922	**1,488,850**	13,937	15,928	17,919
49	1,255,834	202,356	1,458,190	20,792	23,762	26,732
50	917,347	188,866	1,106,213	7540	8617	9694
51	961,498	165,564	1,127,062	13,937	15,928	17,919
52	971,309	152,074	1,123,382	16,908	19,323	21,738
53	1,000,742	150,847	1,151,590	18,507	21,151	23,795
54	868,291	163,111	1,031,402	10,053	11,489	12,925
55	927,158	171,696	1,098,854	11,196	12,795	14,394
56	922,253	187,639	1,109,892	7997	9139	10,282
57	784,896	147,168	932,064	9139	10,445	11,750
58	794,707	185,186	979,894	2513	2872	3231
59	770,179	192,545	962,724	0	0	0
60	726,029	154,526	880,555	5027	5745	6463
61	907,536	202,356	1,109,892	4570	5222	5875
62	819,235	138,583	957,818	12,338	14,100	15,863
63	843,763	127,546	971,309	15,537	17,756	19,976
64	883,008	125,093	1,008,101	17,821	20,367	22,913
65	829,046	144,715	973,762	11,652	13,317	14,982

Table 1 (continued)

S. no.	For adult				For children	For infants
	G = A × 8760 × 0.7 × 0.8	H = B × 8760 × 0.7 × 0.2	Total AEDE without lockdown = G + H	Total AEDE with lockdown-Total AEDE without lockdown (Extra Dose = C × 1632 × 0.7 × 0.2 nSv/y)	C × 1632 × 0.8 × 0.2 (nSv/y)	C × 1632 × 0.9 × 0.2 (nSv/y)
66	760,368	141,036	901,404	9139	10,445	11,750
67	883,008	207,262	1,090,270	2513	2872	3231
68	873,197	179,054	1,052,251	7311	8356	9400
69	711,312	154,526	865,838	4341	4961	5581
70	711,312	125,093	836,405	9825	11,228	12,632
71	809,424	128,772	938,196	13,709	15,667	17,626
72	838,858	152,074	990,931	10,739	12,273	13,807
73	1,162,627	273,487	1,436,114	3199	3656	4113
74	1,030,176	175,375	1,205,551	15,308	17,495	19,682
75	1,005,648	231,790	1,237,438	3656	4178	4700
76	902,630	182,734	1,085,364	7997	9139	10,282
77	833,952	123,866	957,818	15,765	18,017	20,269
78	912,442	148,394	1,060,836	14,851	16,973	19,094
79	1,039,987	163,111	1,203,098	18,050	20,628	23,207
80	691,690	152,074	843,763	3884	4439	4994
81	848,669	155,753	1,004,422	10,510	12,012	13,513
82	853,574	164,338	1,017,912	9139	10,445	11,750
83	873,197	203,582	1,076,779	2742	3133	3525
84	779,990	177,828	957,818	3199	3656	4113
85	667,162	176,602	843,763	− 1828	− 2089	− 2350
86	814,330	169,243	983,573	6397	7311	8225
87	755,462	158,206	913,668	5712	6528	7344
88	843,763	126,319	970,082	15,765	18,017	20,269
89	986,026	202,356	1,188,382	8225	9400	10,575
90	966,403	166,790	1,133,194	13,937	15,928	17,919
91	735,840	143,489	879,329	7540	8617	9694
92	843,763	172,922	1,016,686	7083	8095	9107
93	887,914	152,074	1,039,987	13,023	14,884	16,744
94	1,133,194	131,225	1,264,418	**28,332**	**32,379**	**36,426**
95	838,858	131,225	970,082	14,623	16,712	18,801
96	853,574	225,658	1,079,232	− 2285	− 2611	− 2938
97	892,819	180,281	1,073,100	7997	9139	10,282
98	990,931	176,602	1,167,533	13,252	15,145	17,038
99	755,462	180,281	935,743	1599	1828	2056
100	775,085	129,998	905,083	11,881	13,578	15,276
101	868,291	137,357	1,005,648	14,851	16,973	19,094
102	956,592	138,583	1,095,175	18,735	21,412	24,088

Table 1 (continued)

S. no.	For adult				For children	For infants
	G = A × 8760 × 0.7 × 0.8	H = B × 8760 × 0.7 × 0.2	Total AEDE without lockdown = G + H	Total AEDE with lockdown-Total AEDE without lockdown (Extra Dose = C × 1632 × 0.7 × 0.2 nSv/y)	C × 1632 × 0.8 × 0.2 (nSv/y)	C × 1632 × 0.9 × 0.2 (nSv/y)
103	1,020,365	190,092	1,210,457	12,109	13,839	15,569
104	941,875	187,639	1,129,514	8911	10,184	11,457
105	961,498	168,017	1,129,514	13,480	15,406	17,332
106	750,557	176,602	927,158	2056	2350	2644
107	1,000,742	174,149	1,174,891	14,166	16,189	18,213
108	740,746	208,488	949,234	− 4341	− 4961	− 5581
109	990,931	193,771	1,184,702	10,053	11,489	12,925
110	1,162,627	175,375	1,338,002	21,477	24,545	27,613
111	1,005,648	191,318	1,196,966	11,196	12,795	14,394
112	1,241,117	196,224	1,437,341	21,249	24,284	27,320
113	868,291	186,413	1,054,704	5712	6528	7344
114	1,035,082	180,281	1,215,362	14,623	16,712	18,801
115	990,931	185,186	1,176,118	11,652	13,317	14,982
116	971,309	188,866	1,160,174	10,053	11,489	12,925
117	971,309	188,866	1,160,174	10,053	11,489	12,925
118	990,931	185,186	1,176,118	11,652	13,317	14,982
119	1,005,648	164,338	1,169,986	16,222	18,540	20,857
120	1,177,344	177,828	1,355,172	21,706	24,806	27,907
121	1,108,666	177,828	1,286,494	18,507	21,151	23,795
122	941,875	221,978	1,163,854	2513	2872	3231
123	1,221,494	198,677	1,420,171	19,878	22,717	25,557
124	897,725	143,489	1,041,214	15,080	17,234	19,388
125	1,015,459	176,602	1,192,061	14,394	16,451	18,507
126	912,442	214,620	1,127,062	2513	2872	3231
127	912,442	209,714	1,122,156	3427	3917	4406
128	922,253	203,582	1,125,835	5027	5745	6463
129	971,309	226,884	1,198,193	2970	3395	3819
130	868,291	169,243	1,037,534	8911	10,184	11,457
131	981,120	208,488	1,189,608	6854	7834	8813
132	858,480	181,507	1,039,987	6169	7050	7932
133	1,093,949	194,998	1,288,946	14,623	16,712	18,801
134	902,630	158,206	1,060,836	12,566	14,362	16,157
135	1,157,722	187,639	1,345,361	18,964	21,673	24,382
136	971,309	186,413	1,157,722	10,510	12,012	13,513
137	1,030,176	187,639	1,217,815	13,023	14,884	16,744
138	711,312	172,922	884,234	914	1044	1175
139	917,347	202,356	1,119,703	5027	5745	6463

Table 1 (continued)

S. no.	For adult				For children	For infants
	G = A × 8760 × 0.7 × 0.8	H = B × 8760 × 0.7 × 0.2	Total AEDE without lockdown = G + H	Total AEDE with lockdown-Total AEDE without lockdown (Extra Dose = C × 1632 × 0.7 × 0.2 nSv/y)	C × 1632 × 0.8 × 0.2 (nSv/y)	C × 1632 × 0.9 × 0.2 (nSv/y)
140	1,098,854	188,866	1,287,720	15,994	18,278	20,563
141	1,005,648	209,714	1,215,362	7768	8878	9988
142	833,952	188,866	1,022,818	3656	4178	4700
143	1,231,306	215,846	1,447,152	17,136	19,584	22,032
144	809,424	177,828	987,252	4570	5222	5875
145	986,026	165,564	1,151,590	15,080	17,234	19,388
146	1,015,459	152,074	1,167,533	18,964	21,673	24,382
147	961,498	202,356	1,163,854	7083	8095	9107
148	956,592	198,677	1,155,269	7540	8617	9694
149	936,970	201,130	1,138,099	6169	7050	7932
150	966,403	161,885	1,128,288	14,851	16,973	19,094
151	990,931	221,978	1,212,910	4798	5484	6169
152	1,098,854	141,036	1,239,890	24,904	28,462	32,020
153	936,970	231,790	1,168,759	457	522	588
154	1,084,138	191,318	1,275,456	14,851	16,973	19,094
Average value				10,657 nSv/y	12,179 nSv/y	13,702 nSv/y

*Bold values represent the maximum and minimum

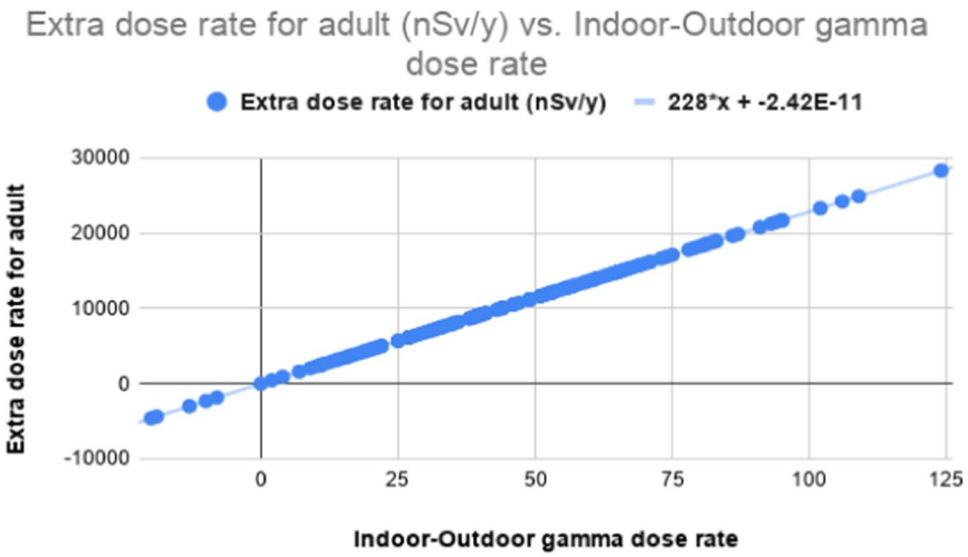

Fig. 1 Relationship between extra gamma dose rate values during lockdown and difference values of indoor–outdoor gamma dose rate for adults

- During COVID-19, most of the people are inside the shelter, so the scenario of radiations upon outside and inside are drastically varied. Due to population, it varies somewhere low and high; however, geology and civil structure may be one cause of this variation.
- The range of relative difference in lockdown versus non-lockdown AEDEs varies from − 0.46 to 2.24% (− 4570 to 28,332 nSv/y, absolute difference). The impact of lockdown appears inconsequential because the variability across the locations studied has a 48% relative difference in non-lockdown AEDE values (773,858–1,488,850 nSv/y) and lockdown AEDE values (780,484–1,502,787 nSv/y). In other words, while the lockdown produces a small difference in AEDE, the total effect is small compared to the variability in AEDE.
- This study will be beneficial for mankind to predict the annual gamma dose rate during the pandemic situation.

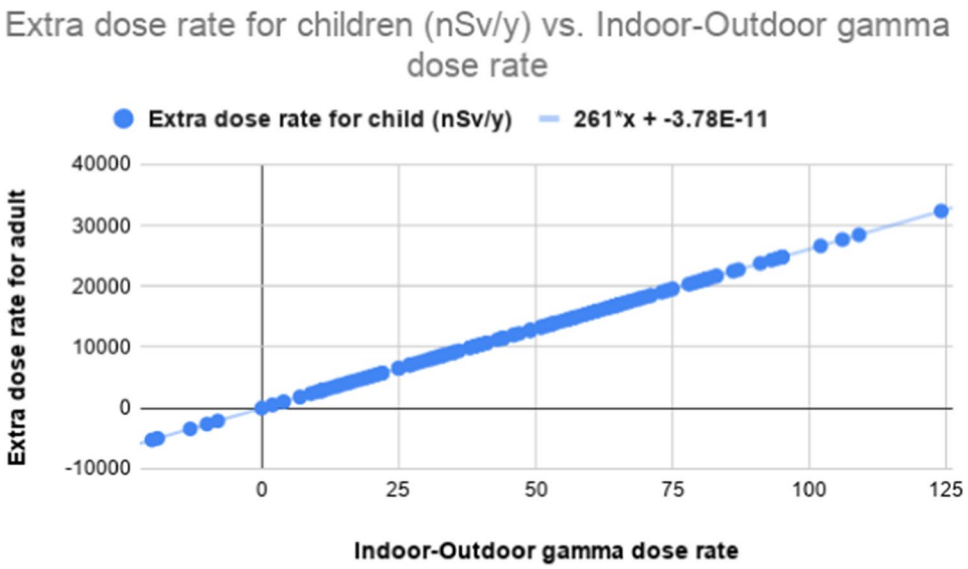

Fig. 2 Relationship between extra gamma dose rate values during lockdown and difference values of indoor–outdoor gamma dose rate for children

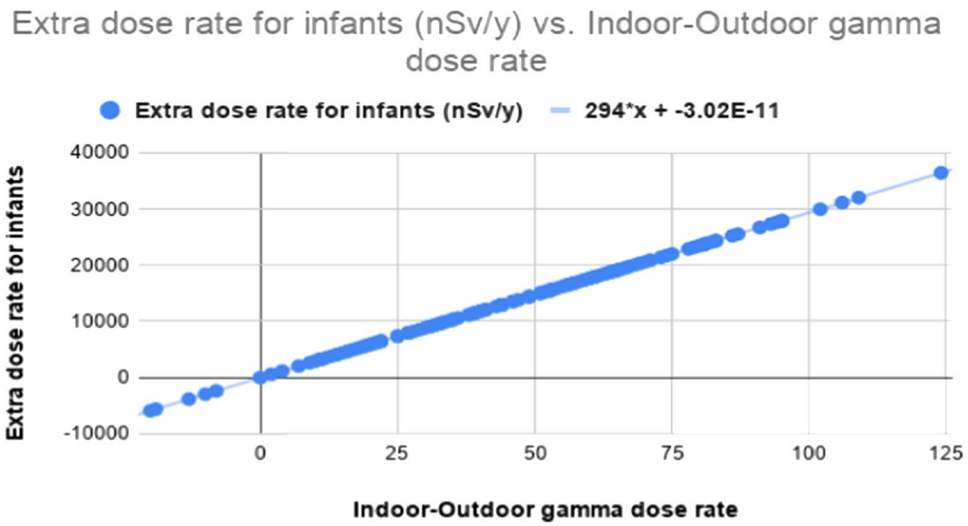

Fig. 3 Relationship between extra gamma dose rate values during lockdown and difference values of indoor–outdoor gamma dose rate for infants

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Coronavirus disease (COVID-2019) situation reports. https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed 10 July 2020
2. Worldometer. https://www.worldometers.info/coronavirus. Accessed 18 July 2020
3. Mackenzie JS, Smith DW (2020) COVID-19: a novel zoonotic disease caused by a coronavirus from China: what we know and what we don't. Microbiology Australia. https://doi.org/10.1071/MA20013
4. National Portal of India. https://www.india.gov.in and https://www.mygov.in/covid-19. Accessed 10 July 2020
5. UNSCEAR (United Nation Scientific Committee on the effect of Atomic Radiations) (2000) Ionizing radiation. Sources and biological effects report to the general assembly with scientific annexes. United Nations, New York
6. Jindal MK, Sar SK (2020) Blueprint of indoor gamma dose rate through statistical modelling for Kabirdham district. J Radioanal Nucl Chem 325:121–131. DOI https://doi.org/10.1007/s10967-020-07205-6
7. Jindal MK, Sar SK, Singh S, Arora A (2018) Risk assessment from gamma dose rate in Balod District of Chhattisgarh, India. J Radioanal Nucl Chem 317(1):387–395. https://doi.org/10.1007/s10967-018-5846-9
8. Jindal MK, Sar SK, Arun A, Singh S, Sahu M, Diwan V (2018) Annual effective dose equivalent of population staying in industrial area Bhilai, Chhattisgarh India estimated using Gamma dose rate measurements. Res J Chem Environ 22(12):22–27
9. Jindal MK, Sar SK (2020) Statistical comparative study of the gamma dose rate and associated risk assessment in rural and urban areas of durg District, Chhattisgarh, India. Radiochemistry 62(2):275–287. https://doi.org/10.1134/S1066362220020186