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Outdoor survey of absorbed dose rate and annual effective dose in Port Said, Marsa Alam-Shalateen and Helwan areas – Egypt

Raghda Ahmed Eissa[1], Rania Shokry mohamed[2], Abd Elnaser Ahmed Mansour[1], Mossad EL-Metwally[3], Ashraf Ali Arafat [2,*]

[1] Physics and Mathematics Engineering Department, Faculty of Engineering, University of Port Said, Port Said, Egypt.

[2] Egyptian Atomic Energy Authority, Cairo, Egypt

[3] Physics Department, Faculty of Science, University of Port Said, Port Said, Egypt.

***Corresponding author:** ashraf.arafat@eaea.org.eg

ABSTRACT

In this paper, in situ measurements for outdoor absorbed dose rate (outdoor D) of port said, Marsa Allam Shalateen and Helwan areas using survey meter and the outdoor annual effective dose (outdoor AED) has been calculated for the investigated areas. These results were compared with worldwide average value and also, compared with our previous published results estimated the outdoor D and the outdoor AED from the soil or shore sediment only depending on their activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K for the same studied sites. In Marsa Allam-Shaltain area, measurements were done at sites have different elevations ranged from 4 to 588 m above Sea level and correlation between sites elevations and both outdoor D and outdoor AED was investigated. The contour maps of the outdoor D for Port Said, Marsa Allam-Shaltain and Helwan areas are discussed.

Outdoor D of Port Said and Helwan areas ranged from 4.29 and 10.00 to 31.43 and 41.43 (nGy/h) with averages 15.68 and 19.65 (nGy/h) respectively. Soil samples of Port Said and Helwan areas have outdoor AED values ranged from 5.26 and 12.26 (µSv/y) to 38.54 and 50.80 (µSv/y) and with averages 19.30 and 24.10 (µSv/y) respectively. Port Said and Helwan areas have outdoor D and outdoor AED values lower than the worldwide average values recommended by UNSCEAR 2000 but the highest values are around the industrial facilities in both cases of soil and shore sediment.

Soil and Shore Sediment of Marsa Allam Shalteen area has outdoor D and outdoor AED values ranged from 74.29 (nGy/h) and 91.104 (µSv/y) to 142.85 (nGy/h) and 175.2 (µSv/y) with averages 104.56 (nGy/h) and 127.36 (µSv/y) respectively. Marsa Allam-Shalteen area has outdoor D and outdoor AED values higher than the worldwide average values recommended by UNSCEAR 2000 and our previous published data.

Port Said, Marsa Allam Shalteen and Helwan areas have strong correlations between outdoor AED of this work and outdoor AED of our previous published data for the same studied areas. These correlations indicated that 79, 89 and 81 % of variation in measured outdoor AED values is due to the variation in

calculated outdoor AED that is dependent on soil radioactivity only not include the cosmic ray or background components.

Key Words:
Absorbed dose rate; Annual effective dose; Port Said; Marsa Alam-Shalateen; Helwan.

1. INTRODUCTION

The two types of radiation are ionizing radiation and non-ionizing radiation. Atoms can be ionized using energy from ionizing radiation, whereas non-ionizing radiation can only move or cause the vibration of the atoms within a molecule [1]. Non-ionizing radiation includes radio waves, visible light, and microwaves. While ionizing radiation include X-rays, gamma rays, and cosmic rays [2]. Ionizing radiation is released by radioactive materials in the form of gamma ray, beta particles, and/or alpha particles [3].

Ionizing radiation is carcinogenic and causes damage to genes [4, 5]. One of the most dangerous types of ionizing radiation is the gamma rays. Gamma ray has a high penetration level so, stopping it needs several inches of lead or concrete [6]. Gamma ray can pass through clothing, skin and completely penetrates the human body causing ionization and damaging to tissues and DNA [7].

Terrestrial radionuclides, cosmic radiation, and artificial sources (anthropogenic sources) are the sources of ionizing radiation. The primary sources of terrestrial exposure are rocks, soil, and construction materials, which contain different amounts of terrestrial radionuclides [8]. Terrestrial radionuclides have half-lives comparable to the age of the Earth such as ^{238}U and ^{232}Th [9]. The gamma exposure rate depends on the geology and geography of the area so, the activity concentrations of radionuclides in the environmental matrices varies with geological locations [10]. Sedimentary rocks (exceptions to phosphate and some shale) have lower radionuclide content when compared with igneous rocks as granite [11]. Higher concentrations of Terrestrial radionuclides, create what are known as high background areas. As reported in China, Iran, Germany, USA, Brazil, and India where, the absorbed gamma dose rate is greater than the worldwide average value [12].

Radiation that comes from the sun and stars is called cosmic rays. Protons, alpha particles, gamma rays, X-rays, electrons, and a few heavier nuclei make up most cosmic rays. Although it rarely reaches the surface of the planet, secondary cosmic radiation is produced by bombarding stable nuclides, producing ^{14}C, ^{3}H, and ^{7}Be [13-15]. Due to a bigger electromagnetic impact that bends radiation, overall cosmic radiation on earth has a greater impact at the poles than at the equator. Also, radiation increases with increasing altitude so at 2000 – 4000 m altitude radiation is about 25% higher than earth surface [16]. So, mountain and polar residents, frequent flyers and members of the flight crew have higher doses of cosmic radiation [17].

Artificial sources, which account for 5% of all radiation on Earth, becomes a serious issue in the second half of the 20^{th} century [16]. The nuclear accidents are the most dangerous type of the anthropogenic sources. In 2011 Fukushima nuclear accident released ^{137}Cs and ^{131}I between 7 and 20 picobecquerel (PBq) and 100 to 400 PBq, respectively to air and 0.18 to 10 PBq and 60 to 100 PBq, respectively across the Pacific Ocean. These released quantities of ^{137}Cs and ^{131}I are just 20 % and 10 % respectively from the released quantity in case of Chernobyl nuclear accident [18].

A baseline environmental radioactivity map is essential to monitor the anthropogenic radionuclides release to the environment and protect public health. An efficient approach for determining external radiation exposure and its effects on human health and environment is monitoring of ambient dose equivalent rate [19]. The amount of radiation which a person is exposed to, is related to consumed quantities of food and water in addition to Terrestrial radionuclides, cosmic radiation, and artificial sources [12]. The worldwide absorbed gamma dose rate varies from 18 to 93 nGy/h, and from 20 to 200 nGy/h with average values of 59 and 84 nGy/h for outdoor and indoor respectively according to UNSCEAR 2000 [12].

Port Said governate is bounded in the north by the Mediterranean Sea and in the east by Port Fouad city. The industrial area in the south of Port Said has many industrial facilities for production of cement and building materials, iron and steel, chemicals and petrochemicals and painting materials. Also, the international coastal road is near to some industrial activities such as Propylene and Polypropylene, gas field, Piping, mining and welding activities [20]. The area of Marsa Alam-Shalateen area is lying along the southern Red Sea coast. The area is rich in its archaeological sites, natural resources, and cultural heritage. Many areas have been declared as natural protectorates because of their unique fauna and flora such as Abraq, Wadi El Gemal and Qulan [21]. The diverse in geology and climate within the area provide favorable habitat for a wide variety of desert and coastal plants having valuable ecological benefits [22-23]. Helwan city is considered as one of the greatest industrial areas in Greater Cairo. It has many industrial activities (16.5 % of the total industries in Egypt) such as production of metals, chemicals and cement [24].

Our previous studies reported the radionuclides concentration of soil cover in Port Said, Helwan and Marsa Alam – Shaltien areas. Also, the outdoor absorbed gamma dose rate and annual effective dose from soil only in air at 1 m height above the earth surface depending on the concentrations of ^{226}Ra, ^{228}Ra and ^{40}K were estimated [20, 24-25]. In the current study, the total outdoor absorbed gamma dose rate was measured directly in situ and the annual effective dose was calculated. In addition, our present results were compared with our previous published results which estimated the dose rate and annual effective dose from soil only depending on soil content from ^{226}Ra, ^{228}Ra and ^{40}K for the same studied sites. The current results can be used as data base for the absorbed dose rate and the annual effective dose in case of radioactive release from nuclear accidents.

2. EXPERIMENTAL WORK

The outdoor gamma absorbed dose rate and annual effective dose can be determined by two ways, the first way by collecting soil samples and determining its terrestrial radionuclides activity concentrations. Then the absorbed dose rate and annual effective dose, in air at 1 m above ground can be determined using its terrestrial radionuclides activity concentrations [20,26]. The second way, the outdoor gamma absorbed dose rate is measured directly in situ using many techniques such as, survey meters based on NaI [27-28] or CsI [29] or based on GM tube [30-31] also, TLD [11] can be used. In case of fast assessment to a large area is necessary NaI positioned inside a car (car born survey technique) [32] or helicopter (Air born survey technique) can be used [33].

The outdoor absorbed dose rate $(D) = \frac{\mu Sv/h \times 1000}{0.7}(nGy/h)$ [27] (1)

The outdoor annual effective dose (AED) has been calculated for the investigated locations.

$$outdoor\ AED = \mu Sv/h \times T \times 0.2\ (\mu Sv/y) \quad [26] \quad (2)$$

Where, µSv/h is micro Sievert per hour, T is the number of hours in the year and 0.2 is the outdoor occupancy factor.

3. RESULTS AND DISCUSSIONS

In all the following sections, the expressions current study and our previous study will be used many times. To clarify, the previous study determined the absorbed dose rate and annual effective dose from soil and shore sediment only by the activities concentrations of ^{226}Ra, ^{228}Ra and ^{40}K. And the current study determined the outdoor absorbed dose rate (outdoor D) and outdoor annual effective dose (outdoor AED) from terrestrial, cosmic and background components by survey meter measurements to the same areas and sites of our previous study.

Outdoor absorbed dose rate

3.1 Outdoor absorbed dose rate of Port Said area: The locations and outdoor D results of soil and shore sediment for Port Said area are presented in table 1.

Table 1 Outdoor absorbed dose rate for soil and shore sediment of Port Said area.

Sample					**Dose nGy/h**
Site	Area	Location	Type	**Longitude, Latitude**	
1	**Industrial area**	Spegeco Factory (cement and building materials)	Soil	31°13'51.6"N, 32°17'23.0"E	18.57
2				31°13'45.1"N, 32°17'23.7"E	12.86
3		Schlumberger Company (Petroleum Services)		31°13'37.2"N, 32°17'25.4"E	15.71
4				31°13'38.2"N, 32°17'25.9"E	25.71
5		Port Said factory (Iron and Steel industry)		31°13'31.9"N, 32°17'37.0"E	12.86
6				31°13'27.8"N, 32°17'40.6"E	15.71
7		TCI Sanmar for petrochemical industries (C9 zone)		31°13'42.6"N, 32°17'04.2"E	7.14
8				31°13'45.9"N, 32°16'58.6"E	12.86
9		TCI sanmar factory South-east of Manzala Lake.	Shore sediment	31°13'58.9"N, 32°17'03.7"E	17.14
10				31°13'58.7"N, 32°17'03.7"E	20.00
11				31°13'59.2"N, 32°17'03.1"E	18.57
12				31°13'58.6"N, 32°17'00.7"E	15.71
13				31°13'59.5"N, 32°16'59.5"E	15.71
14				31°14'01.8"N, 32°16'52.5"E	17.14
15				31°13'54.1"N, 32°16'44.0"E	18.57
16				31°14'02.1"N, 32°16'27.7"E	18.57
17		KAPCI for coating paints industry	Soil	31°13'36.2"N, 32°17'37.7"E	15.71
18		Royal for chemicals industries		31°12'36.8"N, 32°17'54.1"E	31.43
19				31°12'28.3"N, 32°17'55.5"E	21.43
20		KAPC2 for coating paints industry		31°12'18.6"N, 32°17'22.7"E	12.86
21				31°12'26.8"N, 32°17'24.6"E	15.71
22		Ismailia -Port said		31°12'56.1"N, 32°17'59.2"E	7.14
23				31°12'42.5"N, 32°18'01.0"E	10.00
24	The International Coastal Road	Port said Beach	Shore Sediment	31°16'44.6"N, 32°12'39.9"E	18.57
25				31°17'21.4"N, 32°12'39.9"E	7.14
26		Egyptian Propylene & Polypropylene Company	Soil	31°18'17.2"N, 32°09'42.0"E	21.43
27		Zohr gas field		31°18'42.2"N, 32°08'54.0"E	20.00
28				31°19'24.5"N, 32°07'43.7"E	18.57
29		International Piping Industry Company IPIC		31°19'38.1"N, 32°07'19.1"E	7.14
30		Automatic Welding & Fabrication Pipe spools Workshops		31°20'14.2"N, 32°06'22.3"E	4.29
31		The international coastal road at 9.5 km		31°18'48.0"N, 32°08'38.5"E	15.71
32		Balaeim Petroleum Company		31°18'27.1"N, 32°09'21.1"E	18.57
33		East of Manzalla lake	Shore sediment	31°17'03.4"N, 32°12'50.5"E	22.86
34	The Residential Area	EL-Zohor district	Soil	31°16'05.5"N, 32°16'33.7"E	18.57
35		EL-Dawahy district (Henkel company for detergents industry)		31°14'45.2"N, 32°16'51.3"E	12.86
36				31°14'43.9"N, 32°16'59.9"E	22.86
37		Al-Arab district		31°16'05.2"N, 32°17'50.2"E	8.57
38		Port Fouad beach	Shore sediment	31°14'37.1"N, 32°20'09.9"E	10.00
39				31°14'40.7"N, 32°20'03.1"E	18.57
40		Port Fouad district	Soil	31°14'52.2"N, 32°19'19.4"E	12.86
41		El-Manakh district		31°16'09.3"N, 32°17'11.6"E	7.14

Outdoor D of soil sites ranged from 7.14 to 31.42 nGy/h with an average value 15.71 nGy/h for the industrial area in south of Port Said, ranged from 4.29 to 21.43 nGy/h with an average value 15.10 nGy/h for the international coastal road and ranged from 7.14 to 22.86 nGy/h with an average value 13.81 nGy/h for the residential districts. Site 18 (Royal factory for chemicals industry) has the highest value (31.43 nGy/h), while site 30 (Pharaonic Petroleum Company) has the lowest value (4.29 nGy/h).

Soil sites of our pervious study [20], reported outdoor D values ranged from 0.84 to 28.16 nGy/h with an average value 21.16 nGy/h for the industrial area in the south of port said, ranged from 11.94 to 31.65 nGy/h with an average value 20.79 nGy/h for the international coastal road and ranged from 3.60 to 16.18 nGy/h with an average value 11.13 nGy/h for the residential districts. Site 29 (IPIC for pipes industry) has the highest value (31.66 nGy/h), while site 36 (EL-Dawahy district) has the lowest value (3.61 nGy/h) [20].

Outdoor D of shore sediment sites ranged from 15.71 to 20 nGy/h with an average value 17.68 nGy/h for the industrial area in south of Port Said, ranged from 7.14 to 22.86 nGy/h with an average value 16.19 nGy/h for the international coastal road, ranged from 10 to 18.57 nGy/h with an average value 14.29

nGy/h for the residential districts. Site 33 (west of Manzala lake) has the highest value (22.86 nGy/h) while site 25 has the lowest value (7.14 nGy/h).

Shore sediment sites of our pervious study [20] reported outdoor D values ranged from 5.78 to 25.39 nGy/h with an average value 20.57 nGy/h for the industrial area in the south of Port Said, ranged from 22.10 to 30.84 nGy/h with an average value 26.66 nGy/h for the both sides of the international coastal road and ranged from 2.34 to 11.90 with an average value 7.12 nGy/h for the residential districts. Site 24 (Port Said beach) has the highest value (30.84 nGy/h) while site 38 (Port Fouad beach) has the lowest value (2.34 nGy/h) [20].

Soil and shore sediment have outdoor D values ranged from 2.34 to 31.65 nGy/h with average 19.23 nGy/h for the previous study [20] and ranged from 4.28 to 31.42 nGy/h with average 15.67 nGy/h for the current study. Our current and previous studies have outdoor average D values lower than the average worldwide value (60 nGy/h) recommended by UNSCEAR 2000 but the highest maximum values are located around the industrial facilities in both cases of soil and shore sediment. About 70.73 % of sites of the previous study [20] have outdoor absorbed dose rate values higher than the values introduced by the current study and that may be related to the heterogeneity of the soil as a result of human activities.

Our current study indicated that the residential area has average outdoor D lower than the industrial area and the international coastal road in both cases of soil sites and shore sediment sites and that is in agreement with our previous study [20].

The outdoor D values don't show similarity between different sites in the previous study. Oppositely, same outdoor D values have been indicated to different sites in the same area or in different areas in the current work (eg. sites 1,11, 15, 16, 24, 28, 32, 34, and 39 have 18.57 nG/h, sites 3, 6, 12, 13, 17, 21 and 31 have 15.71 nG/h and sites 2, 5, 8, 20, 35 and 40 have 12.86 nGy/h.).

3.2 Outdoor absorbed dose rate of Marsa Allam Shalteen area: Outdoor D of Marsa Alam-Shalateen area for soil and shore sediment areas are presented in tables 2 and 3 respectively.

Table 2 Results of outdoor D for soil of Marsa Allam Shalteen area

Sample No.	Area	Latitude, longitude	Elevation (m)	D (nGy/h)
1	W. Abu Ghusoon	24º 25.539′ N, 35º 10.561′E	36	99.99
2	W. Abu Ghusoon	24º 25.186′N, 35º 09.685′E	55	99.99
3	Marsa Alam-Shelateen Road km 33	24º 49.716′N, 34º 59.610′E	16	142.85
4	W. Al Gemal	24º 40.718′N, 35º 05.002′E	16	99.99
5	Marsa Alam-Shelateen Road km69	24º 32.985′ N, 35º 08.496′E	11	99.99
6	Hamata Village	24º 16.321′N, 35º 22.762′E	14	74.285
7	Baranis village	23º 57.513′N, 35º 24.743′E	67	78.57
8	Marsa Homeira	23º 28.176′N, 35º 29.324′E	4	87.142
9	10 km Al -Gaheliya-Abraq road	23º 23.913′N, 35º 24.873′E	140	122.85
10	30 km Al Gaheliya-Abraq road	23º 25.813′N, 35º 14.353′E	250	87.14
11	20 km Al Gaheliya-Abraq road	23º 23.551′N, 35º 17.945′E	244	129.99
12	0.0km Al Gaheliya-Abraq road	23º 24.369′N, 35º 30.226′E	32	89.99
13	Shalateen	23º 07.386′N, 35º 33.755′E	25	77.142
14	18 km Shalateen-Marsa Alam Road	23º 10.021′N, 35º 31.287′E	27	98.57
15	10 km Baranis-Aswan Road	24º 02.095′N, 35º 19.325′E	161	114.28
16	20 km Baranis-Aswan Road	24º 01.479′N, 35º 14.367′E	326	109.99
17	30 km Baranis-Aswan Road	24º 00.031′N, 35º 09.703′E	410	114.28
18	37 km Baranis-Aswan Road	23º 57.201′N, 35º 10.072′E	476	101.42
19	47 km Baranis-Aswan Road	23º 54.382′N, 35º 06.703′E	588	142.85
20	5 km Shelateen-Marsa Alam Road	24º 00.238′N, 35º 22.737′E	77	97.14
21	W. Um Tendeba	24º 56.787′N, 34º 56.309′E	9	119.99
22	10 km, Marsa Alam-Idfo Road	25º 02.273′N, 34º 46.366′E	194	85.71
23	20 km Marsa Alam-Idfo Road	25º 01.529′N, 34º 41.391′E	330	81.42
24	30 km Marsa Alam-Idfo Road	25º 02.089′N, 34º36.071′E	494	128.57
25	40 km Marsa Alam-Idfo Road	25º03.015′N, 34º 30.107′E	481	101.42
28	W. Ghadeer	24º 49.350′N, 34º 59.693′E	7	132.85

Soil sites have outdoor D values ranged from 74.285 to 142.85 with average 104.55 nGy/h in the current study. These results indicated that the outdoor D values and the average value are higher than the worldwide average recommended by UNSCEAR 2000. On the other hand, our pervious study reported values ranged from 8.21 to 66.52 with average 30 nGy/h [25] which is lower than the worldwide average recommended by UNSCEAR 2000. Our current study has values greater than our previous study and that may be as a result of the survey meter measure terrestrial and cosmic gamma dose rate while the previous study estimated the absorbed dose rate from the soil only.

Same outdoor D values have been indicated to different sites in this work, such as sites 1, 2, 4 and 5 have 99.99 nGy/h, sites 3 and 19 have 142 nGy/h, sites 8 and 10 have 87, sites 15 and 17 have 114.28 and sites 18 and 25 have 101.42 nGy/h. Also, our previous study indicated that there is more than one site, that has nearly the same outdoor D value, such as sites 2 and 27 have 20 nGy/h, sites 5 and 22 have 26 nGy/h, sites 6, 18 and 25 have 27 nGy/h, sites 7 and 29 have 16 nGy/h, sites 11 and 32 have 33 nGy/h, sites 13, 24, 29 and 33 have 35 nGy/h and sites 14 and 26 have 39 nGy/h [25]. In addition, the sites 18 and 25 have (27 nGy/h) in our previous study also, have the same value (101.42 nGy/h) in our current study and that may be related to these sites have the same radionuclide concentration in addition the same doses from cosmic rays and background component.

Table 3: Outdoor D of shore sediment in Marsa Allam Shalteen area

Sample No.	Area	Latitude, Longitude	Elevation	D (nGy/h)
1	Abu Ghuson	24º 26.351′N, 35º 12.599′E	7	74.28
2	Hamatta village	24º 16.321′N, 35º 22.762′E	14	74.28
3	North Abu Ghuson	24º 30.090′N, 35º 08.655′E	18	92.85
4	North Abu Ghuson	24º 49.714′N, 34º 59.611′E	16	99.99
5	Marsa Homeira	23º 28.219′N, 35 º 29.495′E	5	87.14
6	Shelateen	23º 08.748′N, 35º 37.180′E	6	92.85

In the shore sediment sites, the outdoor D ranged from 74.28 to 99.99 with average 86.90 nGy/h. These results are higher than the worldwide average range recommended by UNSCEAR 2000. On the other hand, our pervious study stated outdoor D values ranged from 13.63 to 40.34 nGy/h with average 23.63 nGy/h [25] which is lower than the worldwide average range recommended by UNSCEAR 2000. All sites of our current study have values greater than values of our previous study and that may be related to the survey meter measure terrestrial and cosmic gamma dose rate while the previous study estimated the outdoor absorbed dose rate from the shore sediment only.

Same outdoor D values have been indicated to different sites in this work, such as the sites numbers 1 and 2 have the same value (74.28 nGy/h) and, the two sites 3 and 6 have the same value (92.85 nGy/h). Also, we must mention that the sites 3 and 6 have closest values, 14.87 and 15.16 nGy/h respectively in our previous study [25].

In the previous study, Outdoor D for soil and shore sediment ranged from 8.21 to 66.52 nGy/h with average value 29.49 nGy/h which is lower than the average worldwide average value (60 nGy/h) recommended by UNSCEAR 2000. On the other hand, the current study stated outdoor D ranged from 74.28 to 142.85 nGy/h with average 110.24 nGy/h which is higher than the average worldwide average value (60 nGy/h) recommended by UNSCEAR 2000.

3.3 Outdoor absorbed dose rate of Helwan area: Outdoor D results of the current study of Helwan area for soil are indicated in table 4. In the soil samples, the outdoor D of the current study ranged from 11.43, 10.00, 11.42 and 11.43 nGy/h to 41.43, 31.43, 20.00 and 35.71 nGy/h with averages 20.77, 19.05, 14.00

and 20.99 nGy/h respectively for Thermal power plant, Tourah company for cement, Portland Helwan company for cement, and National company for cement. Site 19 (Thermal power plant) has the highest value (41.43 nGy/h), while site 33 (Tourah company) has the lowest value (10.00 nGy/h).

The outdoor D of our previous study ranged from 25.11, 22.00, 21.11 and 14.86 nGy/h to 59.79, 42.09, 30.11 and 55.89 nGy/h with averages 35.3, 33.4, 24.80 and 29.50 nGy/h respectively for Thermal power plant, Tourah company for cement, Portland Helwan company for cement, and National company for cement. Site 18 (Thermal power plant) has the highest value (59.79 nGy/h), while site 44 (Tourah company) has the lowest value (14.86 nGy/h) [24].

Table 4: Results of outdoor absorbed gamma dose rate of soil in Helwan area

SAMPLE	Area	Latitude, Longitude		Dose (nGy/h)
1	Iron and steel company and El Naser company for coke and chemicals	29° 46.265' N	31° 17.855'E	ND
2		29° 46.215' N	31° 17.566'E	ND
3		29° 46.089' N	31° 17.959'E	ND
4		29° 46.107' N	31° 17.949'E	ND
5		29° 46.110N'	31° 17.983'E	ND
6		29° 46.108' N	31° 18.063'E	ND
7		29° 45.889'N	31° 17.946'E	ND
8		29° 45.967' N	31° 18.021'E	ND
9		29° 46.134' N	31° 18.449'E	ND
10		29° 46.284' N	31° 19.221'E	ND
11		29° 45.475' N	31° 19.637'E	ND
12		29° 46.307' N	31° 20.158'E	ND
13		29° 45.985' N	31° 19.927'E	ND
14		29° 45.264' N	31° 19.210'E	ND
15		29° 45.490' N	31° 19.063'E	ND
16		29° 46.345' N	31° 19.514'E	ND
18	Thermal power plant	29° 52.165' N	31° 17.502'E	11.43
19		29° 52.165' N	31° 17.502'E	41.43
20		29° 52.071' N	31° 17.606'E	11.43
22		29° 51.940' N	31° 17.510'E	34.29
23		29° 52.044' N	31° 17.503'E	17.14
24		29° 52.195'N	31° 17.575'E	14.29
25		29° 52.249'N	31° 17.576'E	24.29
26		29° 52.468'N	31° 17.501'E	11.43
33	Tourah company for cement	29° 52.432' N	31° 17.367'E	10.00
34		29° 55.547'N	31° 17.318'E	24.29
35		29° 55.534' N	31° 17.041'E	31.43
36		29° 55.464' N	31° 17.483'E	22.86
37		29° 55.224' N	31° 17.678'E	15.71
38		29° 55.279' N	31° 17.828'E	10.00
39	Portland Helwan company for cement	29° 55.168' N	31° 17.753'E	11.42
40		29° 48.991' N	31° 18.597'E	11.43
41		29° 49.171' N	31° 18.488'E	20.00
42		29° 49.573' N	31° 18.480'E	17.14
43	National company for cement	29° 49.805' N	31° 18.770'E	22.86
44		29° 49.662'N	31° 18.594'E	20.00
45		29° 47.058' N	31° 20.154'E	15.71
46		29° 47.295' N	31° 19.694'E	11.43
47		29° 47.949' N	31° 19.581'E	35.71
48		29° 47.949' N	31° 19.581'E	35.71
49		29° 48.482' N	31°19.551'E	21.43
50		29° 47.779' N	31°19.565'E	15.71
51		29° 48.053'N	31°18.031'E	20.00
52		29° 49.333' N	31°18.031'E	11.43

All sites (all companies) have outdoor D values ranged from 10 to 41.43 (nG/h) with average 19.64 (nG/h) in the current study and ranged from 12.11 to 48.72 (nG/h) with average 25.90 (nG/h) in the present study. These results indicated that the outdoor D values are lower than the worldwide average range recommended by UNSCEAR 2000 in our current study and our previous study. Thermal power plant has the maximum value and tourah company has the lowest value in both cases of our current study and our previous study. About 65 % of the previous study have outdoor D values higher than our current study and that may be related to the heterogeneity of the soil as a result of human activities.

Different sites showed similar outdoor D values in current study (e.g. 33 and 38 have 10 nG/h, sites 18, 20, 26, 39, 40, 46 and 52 have 11.43 nG/h, sites 37, 45 and 50 have 15.71 nG/h, sites 32 and 42 have 17.34 nG/h, sites 41 and 44 have 20 nG/h, sites 36 and 43 have 22.86 nG/h and sites 47 and 48 have 35.71 nG/h) and also in previous study (eg sites 20 and 26 have 20 nG/h, sites 25, 36 and 42 have 24 nG/h, sites 19 and 43 have 25 nG/h and sites 24 and 34 have 26 nG/h). Site 25 has the same value (24 nG/h) in our previous and current study.

Outdoor annual effective dose (Outdoor AED) Results: -

3.4 Outdoor annual effective dose (Outdoor AED) of Port Said area: The outdoor annual effective dose (outdoor AED) of soil and shore sediment sites of port said of our current study and our previous study are presented in Figure 1. The soil samples of the current study have outdoor AED ranged from 8.76 to 38.54 µSv/y with an average value 19.27 µSv/y for the industrial area in south of Port Said, ranged from 5.25 to 26.28 µSv/y with an average value 18.52 µSv/y on both sides of the international coastal road and ranged from 8.76 to 28.03 µSv/y with an average value 16.93 µSv/y for the residential districts. In the current study, all values and average values are lower than the average worldwide value of outdoor AED (70 µSv/y) recommended by UNSCEAR 2000. Site 18 (Royal factory for chemicals industry) has the highest value (38.54 µSv/y) while, site 30 (Pharaonic Petroleum Company) has the lowest value (5.25 µSv/y).

The soil sites of our pervious study have outdoor AED values ranged from 13.29 to 34.54 µSv/y with an average value 25.95 µSv/y of the industrial area in south for Port Said, ranged from 14.65 to 38.82 µSv/y on both sides of the international coastal road with an average value 25.50 µSv/y, and ranged from 4.42 to 19.78 µSv/y with an average value 13.65 µSv/y for the residential districts. All values and the average value are lower than the average worldwide outdoor AED (70 µSv/y) recommended by UNSCEAR 2000. Site 29 (IPIC for pipes industry) has the highest value (38.82 µSv/y) while, site 36 (El-Dawahy district) has the lowest value (4.42 µSv/y) [20].

The shore sediment sites of our current study have outdoor AED values ranged from 19.27 to 24.52 µSv/y with an average value 21.68 µSv/y for the industrial area in south of Port Said, ranged from 8.76 to 28.03 µSv/y with an average value 19.85 µSv/y for the international coastal road, and ranged from 12.26 to 22.77 µSv/y with an average value 17.52 µSv/y for the residential districts. All values and the average values are lower than the average worldwide value of outdoor AED (70 µSv/y) recommended by UNSCEAR 2000. Site 25 (Port Said beach) has the lowest value (8.76 µSv/y), while Site 33 (west of Manzala lake) has the highest value (28.03 µSv/y).

The shore sediment sites of our previous study have outdoor AED values ranged from 7.09 to 31.15 µSv/y with an average value 25.23 µSv/y of the industrial area in south of Port Said, ranged from 27.11 to 37.83 µSv/y with an average value 32.70 µSv/y on both sides of the international coastal road, and ranged from 2.87 to 14.59 µSv/y with an average value 8.73 µSv/y of the residential districts. All values and the average values are lower than the average worldwide outdoor AED (70 µSv/y) recommended by UNSCEAR 2000. Site 24 (Port Said beach) has the highest value (37.83 µSv/y), while site 38 (Port Fouad beach) has the lowest value (2.87 µSv/y) [20].

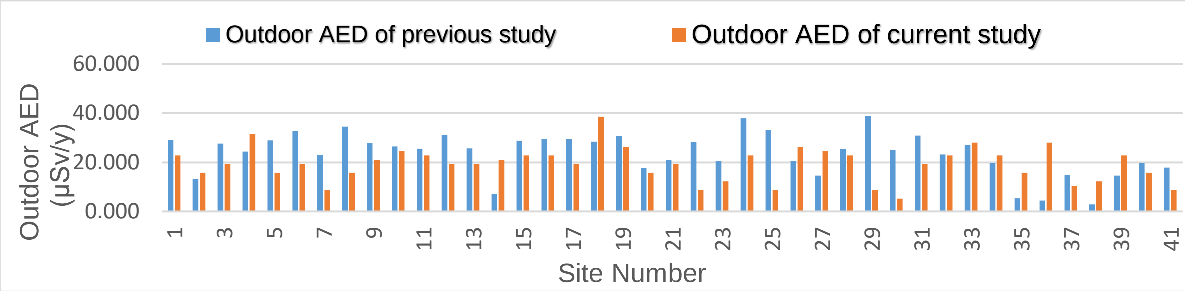

Figure 1: Outdoor annual effective dose for soil and shore sediment sites of Port Said area

As shown in Figure 1, about 71% of samples in Port Said sites (29 from 41samples) have values of outdoor AED estimated from radionuclides activity concentrations higher than the values of outdoor AED calculated from the survey meter measurements. While, about 30% of the previous study samples have outdoor AED values lower than the measured values of outdoor AED in the present study, as a result of the cosmic rays and background absorbed dose are considered by survey meter measurements.

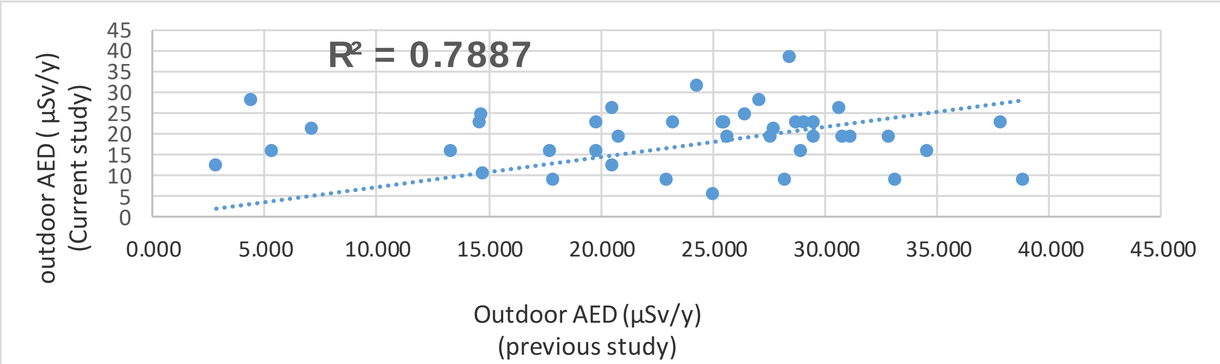

Fig 2: Correlation of outdoor AED between current study and previous study of Port Said area.

As shown in figure 2 there are significant positive correlation between the previous (calculated) and current (measured) value of outdoor AED in Port Said area (R^2=0.79) this indicated to 79% of variation in measured outdoor AED values is due to the variation in calculated outdoor AED that is dependent on soil radioactivity only not include the cosmic ray or background components.

3.5 Annual effective dose (AED) of Marsa Allam Shalteen area: The outdoor AED of soil and shore sediment samples of Marsa Allam Shalteen of our current study and the previous study are presented in Figure 3. The soil samples of the current study have outdoor AED ranged from 91.1 to 175.13 µS/y with average 128.18 µS/y which indicated the values and the average value are higher than the worldwide average outdoor AED recommended by UNSCEAR 2000. On the other hand, the soil sites of our pervious study have outdoor AED ranged from 10.1 to 81.55 µS/y with average 36.78 µS/y [25] which is lower than the worldwide average outdoor AED recommended by UNSCEAR 2000. These values are higher than our previous study values and that may be related to the current study measured terrestrial, cosmic gamma and background components AED while the previous study estimated the AED from the soil only.

Our current study indicated that there are two sites have the same outdoor AED value, such as the sites numbers 18 and 25 have the same value (124.392 µSv/y) also the two sites 8 and 10 have the same value (106.872 µSv/y). Also, we must mention that these sites have the same value in our pervious study (34.26 µSv/y in case of 124.392 µSv/y and 35.42 µSv/y in case of 106.872 µSv/y).

The shore sediment samples of current study have outdoor AED ranged from 91.1 to 122.58 with average 106.54 µS/y. These results indicated that the values and the average value are higher than the outdoor AED worldwide average recommended by UNSCEAR 2000. On the other hand, our pervious study has outdoor AED values ranged from 16.71 to 49.46 with average 28.97 µS/y [25] which is lower than the worldwide average recommended by UNSCEAR 2000. Our current study has values higher than our previous study and that may be related to the survey meter measure terrestrial, cosmic gamma dose rate while the previous study estimated the dose from the shore sediment only.

Outdoor AED showed similar values in different sites in the current work (e.g sites numbers 1 and 2 have the same value 91.1 µSv/y & sites 3 and 6 have the same value 113.88 µSv/y). In the previous work, two sites (3 and 6) have very close and similar AED values (18.59 and 18.24 µSv/y respectively).

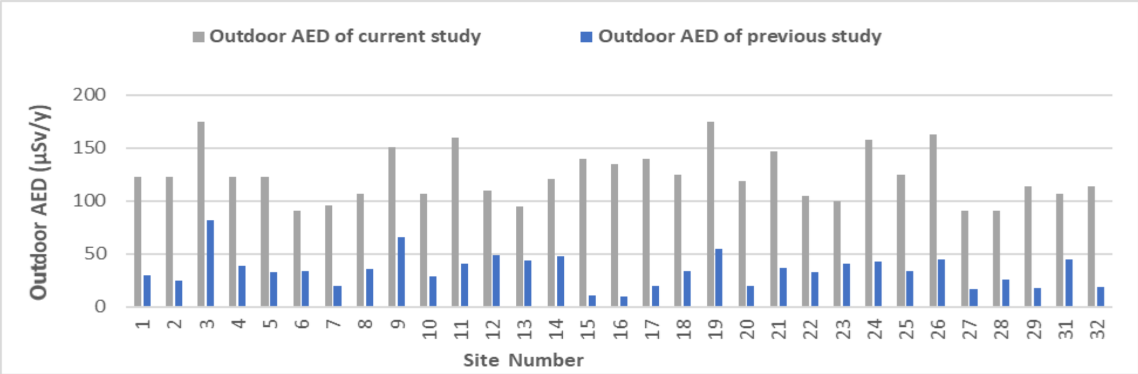

Figure 3: Outdoor AED for soil and shore sediment of Marsa Alam- Shalateen area.

As shown in figure 4 there are significant positive correlation (R^2= 0.88) between the previous and current values of outdoor AED in Marsa Alam-Shalateen. That correlation indicated that 88% of variation in measured outdoor AED values is due to the variation in calculated outdoor AED that is dependent on soil radioactivity only not include the cosmic ray or background components.

Fig 5 indicates a moderate correlation (R^2 = 0.45) between outdoor AED and the elevation from the sea level. That correlation may be related to the increase of cosmic radiation by increasing the elevation from sea level [16].

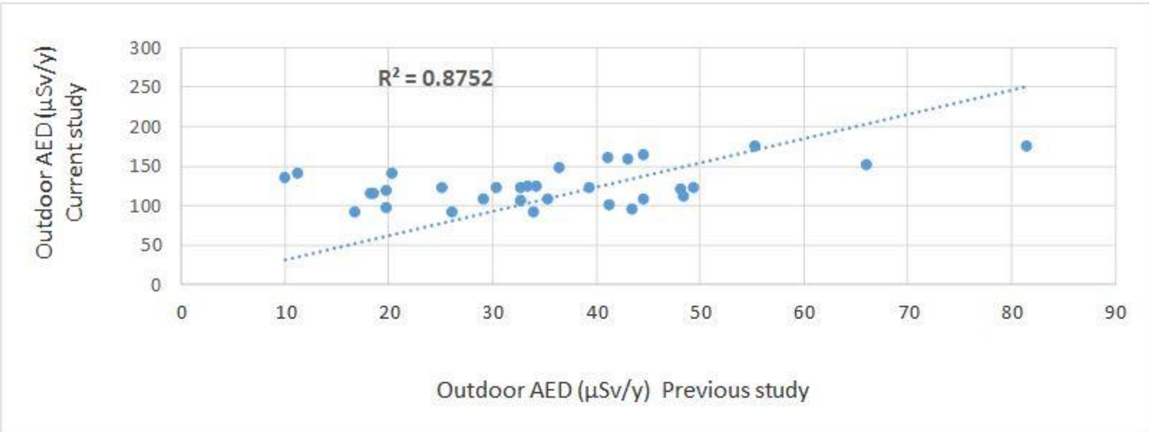

Fig 4: Correlation between current study and previous study outdoor annual effective dose rate of Marsa Alam-Shalteen area.

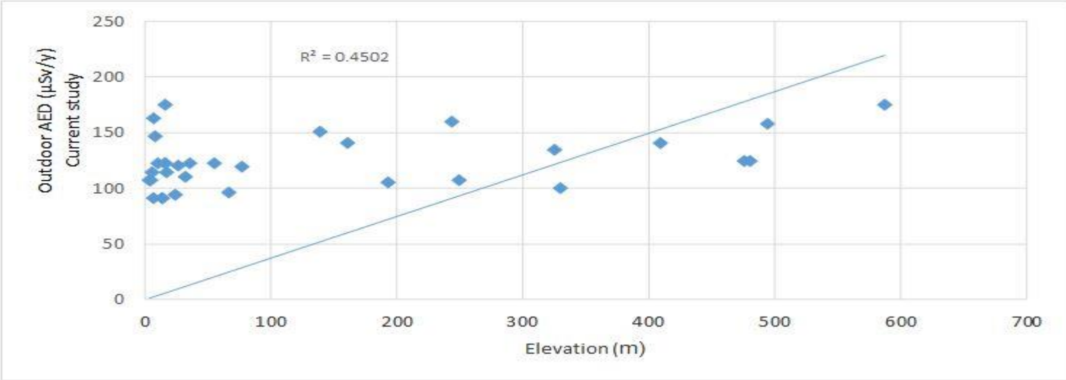

Fig 5: The relationship between elevation and outdoor annual effective dose Marsa Allam-Shalten area.

3.6 Annual effective dose (AED) of Helwan area: The outdoor AED of soil sites of Helwan area of our present study and the previous study are presented in Figure 6. The soil sites of the current study have outdoor absorbed dose ranged from 12.26, 14.00, 14.00 and 14.01 µSv/y to 38.54, 24.53, 43.8 and 50.8 µSv/y with averages 23.36, 18.4, 25.75 and 25.40 µSv/y respectively for Tourah company for cement, Portland Helwan company for cement, National company for cement and thermal power plant. All values and the average values are lower than the world wide average (70 µSv/y).

The soil sites of the previous study have outdoor absorbed dose ranged from 22, 21.11, 14.86 and 25.11 µSv/y to 42.1, 30.11, 55.89 and 59.79 µSv/y with averages 33.4, 24.8, 29.5 and 35.3 µSv/y respectively for Tourah company for cement, Portland Helwan company for cement, National company for cement and thermal power plant [24]. All values and the average values are lower than the world wide average (70 µSv/y).

The outdoor AED values are similar in different sites in current studies (sites 18 and 25 have same value, 124.392 µSv/y & sites 8 and 10 have same value, 106.872 µSv/y). The AED values of the indicated sites were also similar in the previous work but considerably lower than that indicated in the present work (in the previous work AED equal 34.26 µSv/y for samples no. 18 and 25 and equal 35.42 µSv/y for samples 8 and 10).

As shown in Fig. 6, outdoor AED values in Helwan industrial area are higher in previous work than current work in 61.5% of sites and lower in the rest.

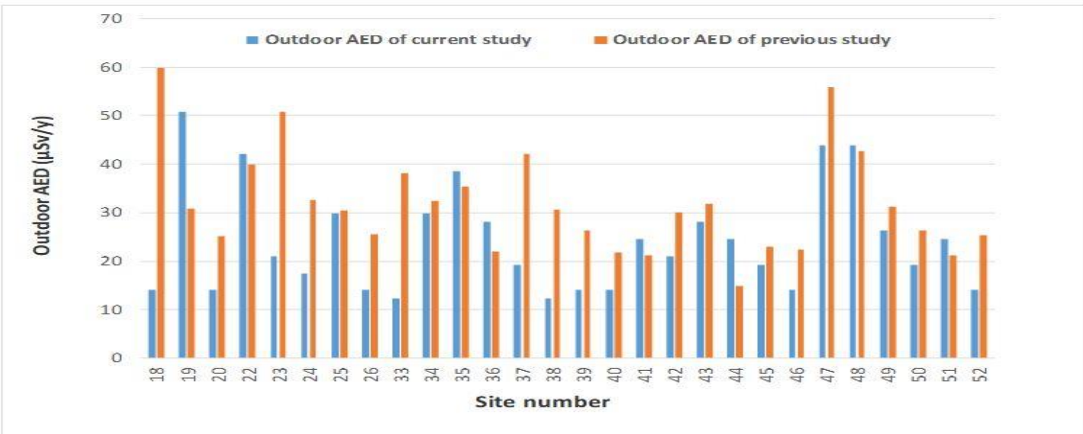

Figure 6: Outdoor AED for soil and shore sediment of Helwan area **As shown in figure 7, there is strong positive correlation (R^2=0.81) between the current study values and previous study values of outdoor AED in Helwan area.**

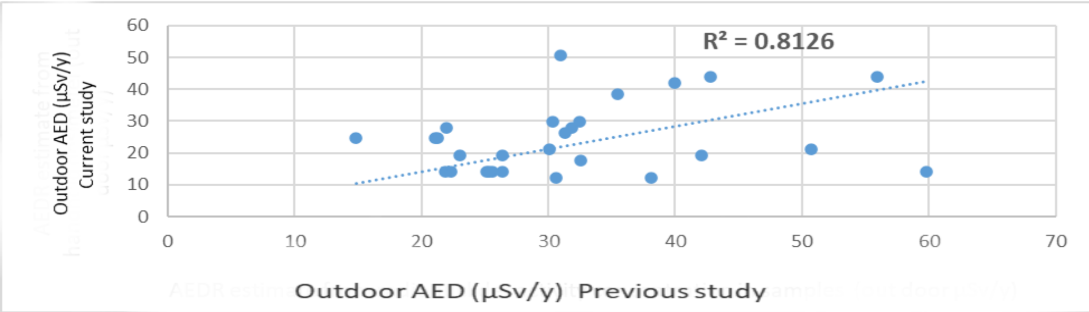

Fig 7: Correlation between outdoor AED values of the current study and the previous study of Helwan area.

3.6 Lateral distribution of outdoor absorbed dose rate (D):

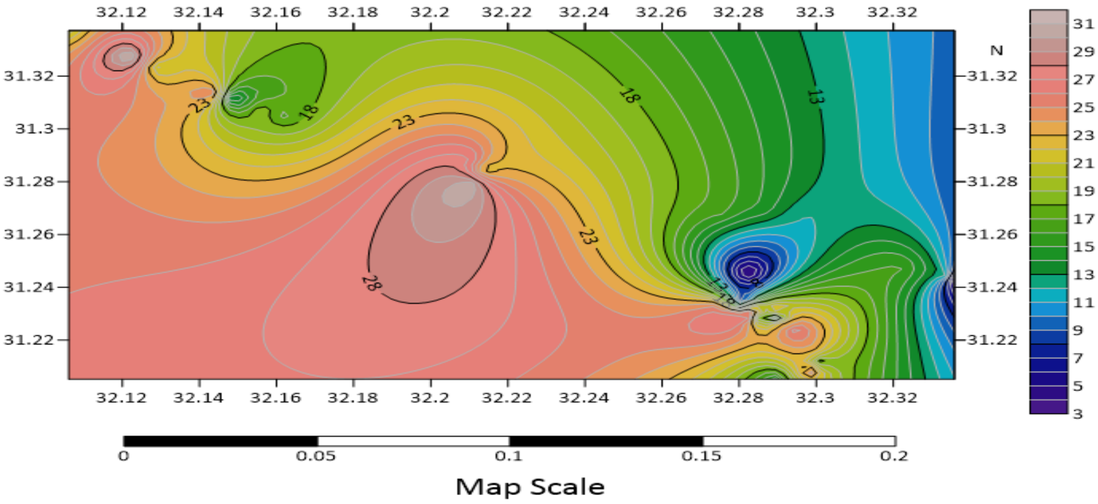

Figure 8: Contour map of outdoor D of Port Said governorate (previous study)

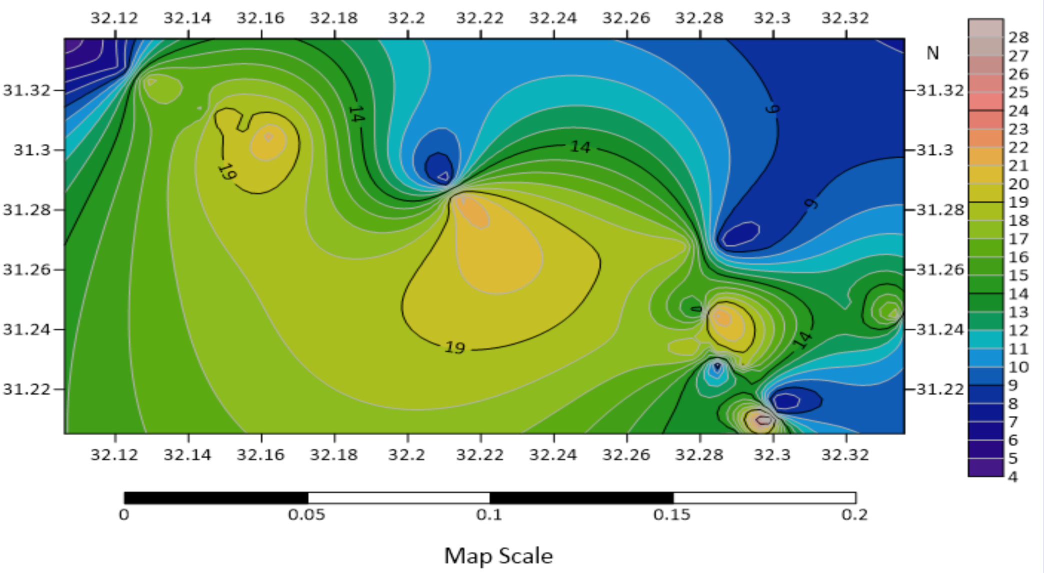

Figure 9: **Contour map of outdoor D of Port Said governorate (current study).**

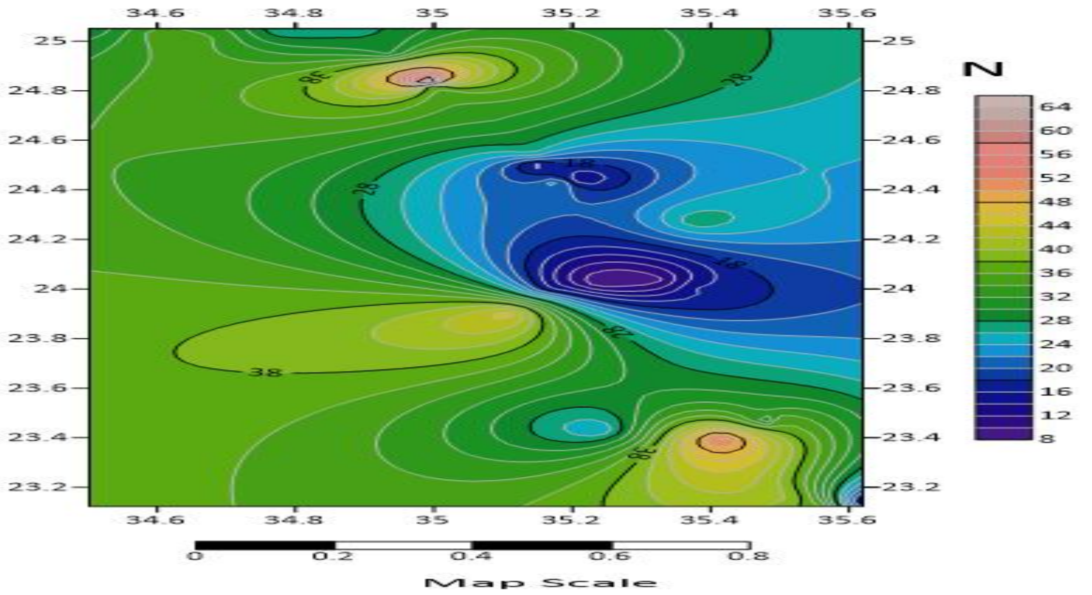

Figure 10: Contour map of outdoor D of Marsa Allam Shalteen (previous study)

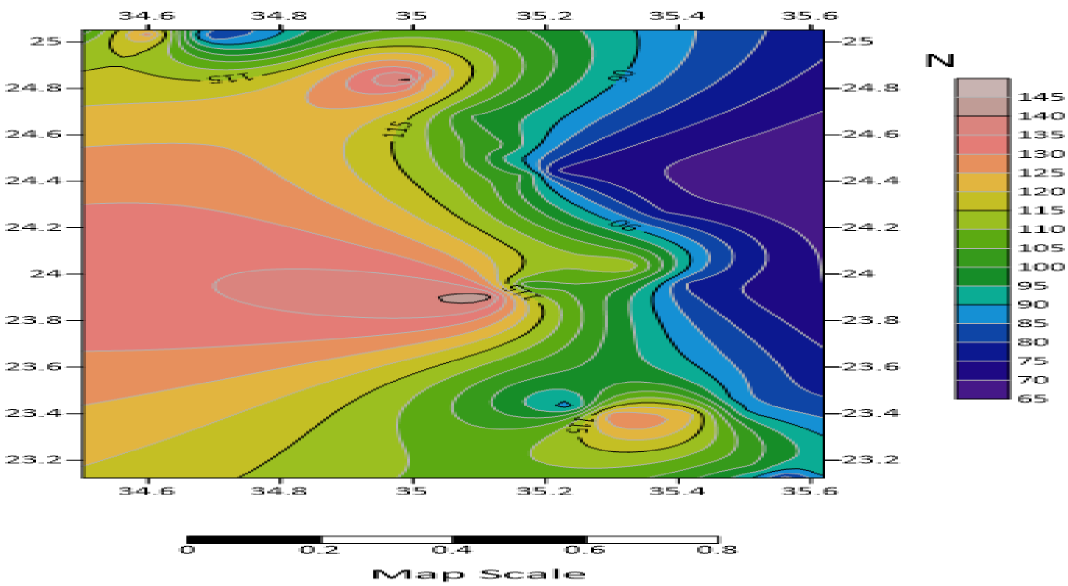

Figure 11: Contour map of outdoor D of Marsa Allam Shalteen (current study)

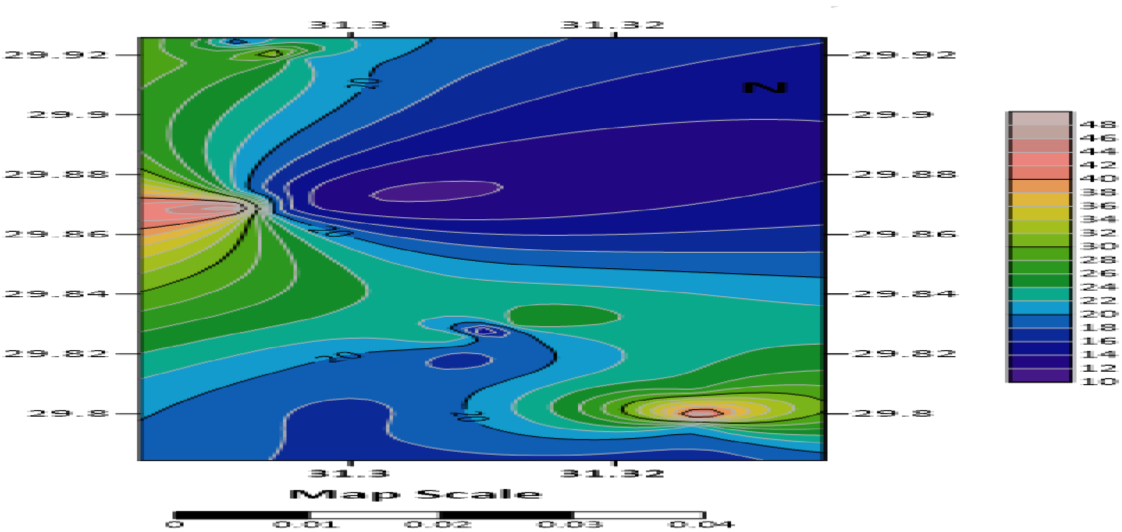

Figure 12: Contour map of outdoor D of Helwan (previous study)

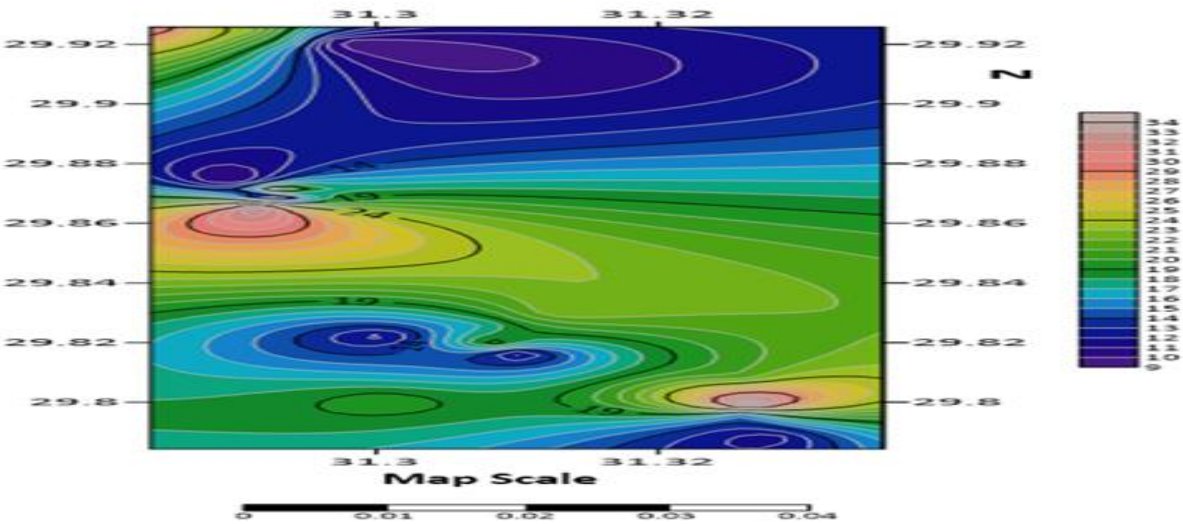

Figure 13: Contour map of outdoor D of Helwan (current study)

The outdoor D contour maps of the previous study and the current study for port said, Marsa Allam-Shalteen and Helwan areas are presented in figures 8 and 9, 10 and 11, 12 and 13 respectively.

The contour maps of the outdoor D of the previous study and the current study showed increase in the outdoor D from any direction into the center. And there are some similarities between these maps and the contour maps of ^{226}Ra, ^{228}Ra and ^{40}K of our pervious study for the same sites [25]. And that may be related to the dependence of the dose of the present study and the current study on the dose of the soil which depend on the soil content from ^{226}Ra, ^{228}Ra and ^{40}K.

The outdoor D of our previous and current studies of Marsa Alam-Shalten area tend to increase from west to the east as shown in figures 10 and 11. The outdoor D of Helwan area tend to increase from the south to the northeastern as shown in figure 12 for the previous study, while increases from south to east and north as shown in fig 13 for the current study.

4. CONCLUSION

In this study the outdoor D and outdoor AED are investigated in Port Said, Marsa Allam – Shalteen and Helwan areas.

1- In Port Said area,

- All outdoor D and outdoor AED values are lower than the average value recommended by UNSCEAR 2000.
- The residential area has average outdoor D and outdoor AED lower than the industrial area and the international coastal road.
- The highest values are around the industrial facilities in both cases of soil and shore sediment which is agreement with our pervious study [25].
- The outdoor absorbed dose rate (D) contour maps have similar trend with the contour maps of ^{226}Ra, ^{228}Ra and ^{40}K of our previous study of the same sites as a result of dependence the dose of the previous and current study on the dose of the soil which depend on the soil content from ^{226}Ra, ^{228}Ra and ^{40}K.

2- In Marsa Allam area,

- Soil and Shore Sediment sites of Marsa Allam Shalteen area has outdoor D and outdoor AED values ranged from 74.29 (nGy/h) and 91.104(μSv/y) to 142.85 (nGy/h) and 175.2(μSv/y) with averages 104.56 (nGy/h) and 127.36 (μSv/y) respectively. These values are higher than the worldwide average values recommended by UNSCEAR 2000.
- The cosmic rays contributed significally to both outdoor D and outdoor AED which is confirmed by the moderate correlation (R^2=0.45) between the outdoor AED and the elevation from sea surface.

3- Helwan area has absorbed dose rate and annual effective dose values lower than the worldwide average values recommended by UNSCEAR 2000.

4- Port Said, Marsa Allam Shalteen and Helwan areas have strong correlations between the current outdoor AED and outdoor ADE of our previous published data for the studied areas indicated that 79, 89 and 81 % of variation in measured outdoor AED values is due to the variation in calculated outdoor AED that is dependent on soil radioactivity only not include the cosmic rays or background components.

5- Port Said and Helwan areas have outdoor D and outdoor AED higher in previous work than current one, this may be related to impacts of human activities on soil heterogeneity in these areas.

6- Many sites in the study areas have same outdoor D and outdoor AED values where total doses from soil, cosmic rays and background are equal.

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