Middle-East Journal of Scientific Research 24 (7): 2196-2203, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.24.07.23726

Evaluation of Radiation Hazard Indicesduo to Gamma Radiation in Hattin Complex at Babylon Government

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Abstract: This study has been carried out to measure the specific activates and radiation hazard indices in soil samples at Hattin complex in Babylon government.The measurements have been done using spectral analysis technique for gamma-rayspectroscopy with scintillation detector.Three radionuclides have been detected in the selected samples Which included: radionuclide (^{214}Bi) belonging to the uranium series ; radionuclide (^{208}TI) belonging to the thorium series and the natural radionuclide (^{40}K). The specific activity of radionuclides belonging to the uranium series(^{238}U) in samples ranged between 5.15 to35.74 Bq/kg, with an average 16.07±2.89 Bq/kg and the specific activity of radionuclides belonging to the thorium series (^{232}Th) ranged between5.95 to15.56 Bq/kg, with an average 9.60±0.954 Bq/kg. The nature radionuclide (^{40}K) is detected in all samples too with specific activity ranged between235.63 to 363.67 Bq/kg, with an average271.42±11.60 Bq/Kg. The radiation hazard indices have been calculated in the present work which include: (Radium Equivalent Activity (Raeq), Absorbed Gamma Dose Rate (Dγ), external hazard index (H_{ext}), internal hazard index (H_{int}), Representativegamma index (I_γ) and Annual effective dose equivalent (AEDE) which include indoor, outdoor and totaleffective dose rate,), in addition to calculated excess life cancer (ELCR) in all samples under study. The average values of Ra_{eq}, Dγ, H_{ex}, H_{in}, Iγ and $AEDE_{total}$ were 86.24 ±4.94 Bq/Kg, 26.47 ± 1.25 nGy/h, 0.144 ± 0.007, 0.188 ± 0.014, 0.408 ± 0.019 , 0.162 ±0.009 mSv/y respectively, while the values of ELCR were ranged between 0.438×10^{-3} to 0.700×10^{-3}, with an average0.568×10^{-3}±0.034. When comparing the results for the present work with Worldwide average, we found that the values were within the recommended values given by (UNSCEAR,1994 and UNSCEAR, 2008). In other words, The soil samples of Hattin complex were Safe for does and not constitute a danger or hazard to the citizens.

Key words: NORM in Soil · Gamma-ray · Hazard Indices · ELCR · Hattin complex

INTRODUCTION

Additionally, humans are susceptible to be exposed to the natural radiation owing to different external sources outside their bodies. These are mostly including cosmicrays, gamma ray emitters in soil, building materials, water, food and air [1]. Radionuclides, By definition, are the major source of radioactive decay which emit radiation that become part of human daily lives.The most common forms of ionizing radiation are alpha particles, beta particles and gamma rays [2]. Naturally occurring radionuclides of terrestrial origin (also called primordial radionuclides) are present in various degrees in the environment, including the human body itself. It should be noted that the radionuclides and their decay products that their half-lives comparable to earth's age are significantly existed in the aforementioned materials. Irradiation of the human body from external sources is mainly by gamma radiation from radionuclides in the U-238 and Th-232 series and from K-40. These radionuclides are also present in the body and irradiate the various organs with alpha and beta particles, as well as gamma rays [3]. Terrestrial radiation radionuclides are mainly derived from three separate decay chains, ^{232}Th, ^{238}U and ^{235}U, in addition to the single radioactive potassium (^{40}K) [4, 5]. The important main source for human exposure is to soil contamination which it is affected on human by incidental or ingestion. Since soil is one of the main contributors to background radiation, it is very interest to know the radioactivity content of the soil

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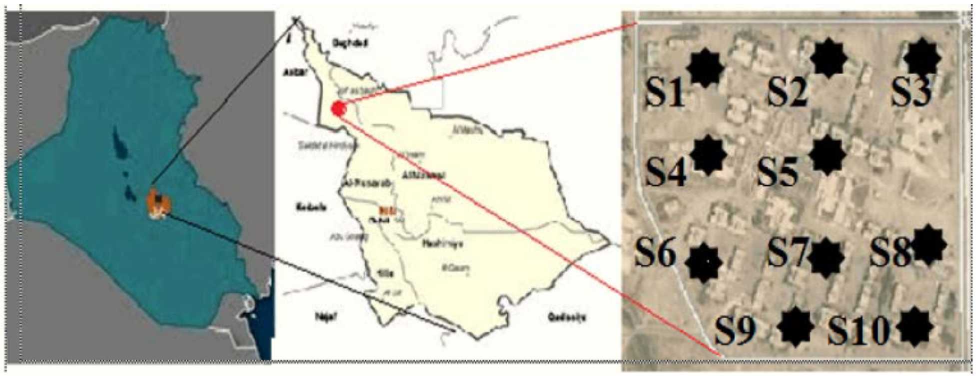

Fig. 1: Location area of Study.

over the world, natural radioactivity in the mainly soil comes from the ^{238}U, ^{232}Th series and ^{40}K during creation the earth [6]. The rate of natural gamma dose ground is an important contributor to the medium dose that the world's population receives [7, 8]. Therefore knowledge of natural radioactivity of important soil evaluation of radiation risks. Measurement of natural radioactivity in soil is of great importance to the majority of researchers throughout the world. This in turn has led to many worldwide national surveys in the last 2 decades. This is because such kind of measurement in soil would help in determination of change of the natural background activity throughout time [9]. There are many studies around word, study natural radioactivity and radiation hazard in soil [10-14]. The aims of the present study to measure the specific activity of gamma emitted due to natural radioactivity (uranium-238, thorium- 232 and potassium-40) in soil samples of Hattin complex in Babylongovernment, Iraq using gamma ray spectroscopy and compared these levels with the global radioactivity. Also in this research studying the radiological hazard index values and its influence.

Area of Study: Hattin Complex is a complex affiliated to Alexandria District in Babylon on the longitude 44° 20.200 east and latitude 32° 52.096 north. It houses 26 thousand people vertically having 174 buildings and 2088 apartments. It used to be a property for the Military Industries of the former Iraqi Army. The current study includes collecting samples from the soil of this area to examine the natural radioactivity to sketch a radiation map for it following the other international residential complexes and testing its radiation validity for living[15].

Methodology

Sample Collection and Preparation: Ten soil samples were collected to be studied in this research in Hattin complex Babylon government. Prior to final measurement in the laboratories, the samples were placed in a drying oven. Since the organic constituents are not considered in this study, the drying temperature was increased to (60°C) for 24 hours to ensure that any significant moisture was removed from the samples. To obtain uniform particle sizes, a 500ìm mesh was then used to sieve the samples which were then weighed and transferred to 1 labeled Marinelli beakers. The samples were stored for one month at normal laboratory conditions. The allowed time is required to reach to the radiological equilibrium of the given samples, prior to the concentration counting process of the natural radioactive material of the samples.

Gamma-Ray Spectroscopy: Gamma-ray spectroscopy was used in print study which it consists of NaI (Tl) detector (a scintillation detector) of (3"×3") crystal dimension coupled with MCA (multi-channel analyzer). MCA is contains a 4096 channel connecting with ADC (Analog to Digital Convertor) through interface. Gamma-ray spectroscopy measurements are analyzed by MAESTRO-32 software. Nay(Tl) was calibrated for energy by acquiring a spectrum from radioactive standard sources of known energies such as ^{137}Cs, ^{60}Co and ^{22}Na. Detector efficiency can be expressed as [6].

$$\varepsilon = \frac{C_p}{I_\gamma A} \times 100\% \qquad (1)$$

where ε, is photo peak efficiency, C_p is the net area per unit time under the photo peak (N/T), I_γ is transition probability of the specific gamma decay and A is the activity of the source at time of experiment. The relationship between the detector efficiency and the energy was obtained using the five energies that used in present study as shown in Figure (2).

From Figure (4), it can be found the efficiency in $Bi^{214}(U^{238})$, $Ti^{208}(th^{232})$ and ^{40}K as shown in Table (1).

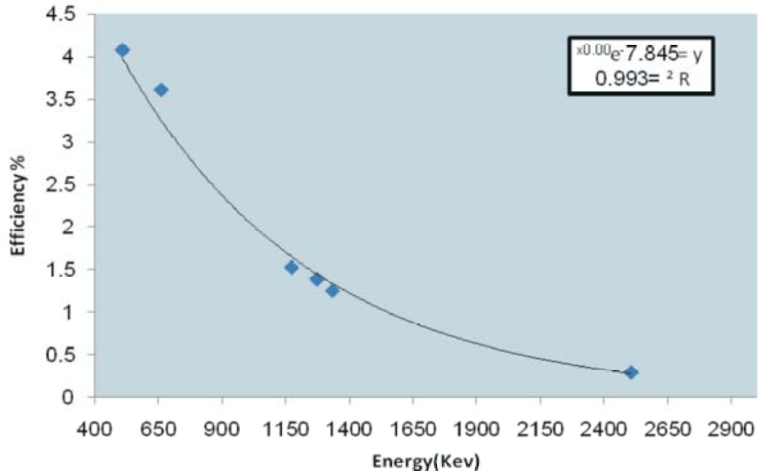

Fig. 2: The efficiency curve with six energies

Table 1: The efficiency values for U-238, Th-232 and K-40.

Isotopes	Energy (Kev)	ε%
U^{238} (Bi^{214})	1764	1.343
Th^{232} (Tl^{208})	2614	0.574
K^{40}	1460	1.821

The Measurements of Sample: The period time that used was about 18000 sec. To calculate the specific activity for every samples, net area underneath the corresponding peaks within the energy spectrum was computed by subtracting count because of background sources from net area of an exact peak by MAESTRO-32 information analysis package. The background spectrum measured by empty Marinelli beakers (i litter) on the detector and count underneath a similar time for the sample measurements. Due to the poor resolution of NaI(Tl) detector, at low gamma energies that haven't well-separated photo-peaks, therefore the measurement of the a ctivity concentrations is feasible at an honest separated photopeaks (at high energies) as that obtained in our results from the gamma rays emitted by the progenies of ^{238}U and ^{232}Th that square measure in secular equilibrium with them whereas, ^{40}K was calculable directly from gamma-line at1460 keV. while ^{238}U and ^{232}Th were determined by the gamma-lines 1765 keV (214Bi) and the gamma-ray lines 2614 keV (208Tl) respectively.

Specific Activity Measurement: The specific activity is defined as the activity per unit mass of the sample. It is measured in Becquerel (or Curies) per unit mass or volume. The specific activity of radionuclides in soil samples was obtained using the following equation [16, 17].

$$A_i(E_\gamma) = \frac{N}{t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M} \quad (2)$$

where, $A_i(E_\gamma)$ is the specific activity of radionuclide measured in (By/kg), N is the net peak area under the peak, t_c is the counting life time, $I_\gamma(E_\gamma)$ is the abundance at energy E_γ, $\varepsilon(E_\gamma)$: is the detection efficiency at energy E_γ and M is the mass of the soil sample (kg).

Radiation Hazard Indices Calculation: It is justifiable to exploit as many as possible the known radiation health hazard indices analysis to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and environment. To assess the radiation hazards associated with the soil samples, seven quantities have been defined [18].

Radium Equivalent Activity (Ra_{eq}): To represent the activity levels of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological Index has been introduced**.** This Index is called Radium equivalent (Ra_{eq}) activity and is mathematically defined by [19].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (3)$$

where A_{Ra},A_{Th} and A_K are the specific activities concentrations of ^{226}Ra,^{232}Th and ^{40}K in (Bq/kg) respectively.

Absorbed Gamma Dose Rate (D_γ): The absorbed dose rates in outdoor (D_γ) due to gamma radiations in air at (1m) above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra,^{232}Th and ^{40}K) were calculated based on guidelines provided by [19]. The conversion factors used to compute absorbed gamma-dose rate (D_γ) in air per unit activity concentration in Bq/kg (dry-weight) corresponds to 0.462 nG/hr for ^{226}Ra (of U- series), 0.621 nG/hr for ^{232}Th and 0.0417 nG/h for ^{40}K [19, 20].

$$D_r = 0.462\, A_{Ra} + 0.621 A_{Th} + 0.0417 A_K \quad (4)$$

Representative Gamma Index ($I_{\gamma r}$): Another radiation hazard index used for the estimation of gamma radiation associated with the natural radionuclides called the representative level gamma index($I_{\gamma r}$)defined according to [20, 21].

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \le 1 \quad (5)$$

The safety value for this index is ≤ 1

Annual Effective Dose Equivalent (Aede): The annual effective dose equivalent received outdoor by a member is calculated from the absorbed dose rate by applying dose conversion factor of (0.7Sv/Gy) and the occupancy factor for outdoor and indoor was 0.2(5/24) and 0.8(19/24), respectively [22]. AEDE is determined using the following equations [22]:

$$(AEDE)_{in} = D_r \times 8760 \times 0.7 \times 0.8 \times 10^{-6} \quad (6)$$

$$(AEDE)_{out} = D_r \times 8760 \times 0.7 \times 0.2 \times 10^{-6} \quad (7)$$

External Hazard Index (H_{ext}): The external hazard index (H_{ext}) is given by the following Equation [23].

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (8)$$

Internal Hazard Index (H_{int}): The internal hazard index (H_{int}) is given by the following equation [24].

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (9)$$

The values of the indices (H_{int}, H_{ext})must be less than unity for the radiation hazard to be negligible [19].

Excess Lifetime Cancer Risk: The excess lifetime cancer risk (ELCR) can be calculated by following equation [25]:

$$ELCR = AEDE \times DL \times RF \quad (10)$$

where, ELCR is Excess Lifetime Cancer Risk, DL is the average life of human and RF is the risk factor (sv^{-1}).

RESULTS AND DISCUSSION

The specific activity for ten soil samples collected from different sites from Hattin complex at Babylon government had been measured for, families and using equation (2). The Table (2) shows that the specific activities values for U-238 ranged from 4.56±0.11 Bq/kg to 15.45±0.19 Bq/kg with an average value of 9.01±0.15 Bq/kg. The minimum value had been found in samples S6 while the maximum value in sample S8, see Figure (3). The average value of the current work is less than the worldwide average value (35 Bq/kg) calculated by UNSCEAR 2008 [26]. The specific activities of in soil samples for Th-232 were estimated to be on range from 6.35±0.18 Bq/kg to 20.71±0.27 Bq/kg with average value of 12.16±0.22 Bq/kg as it is clear from the Table (2). The minimum value had been found in sample S2 and the maximum value in sample S3, see Figure (4). The average value of the current work is less than those mentioned in UNSCERA 2008 (45 Bq/kg) [1]. The specific activities obtained in selected samples for K-40, were listed in Table (2). It which in turn shows the minimum value of 20.22±2.28 Bq/kg in sample S2 and the maximum value of 221.35±3.33 Bq/kg sample S3, see Figure (5). The average value was found to be 133.22±2.91 Bq/kg which is less than the average world-wide concentration of UNSCEAR 2008 (412 Bq/kg). The specific activities values for all samples are compared with those of other some countries as in Table (3). The radium equivalent activity were calculated using equation (2) and listed also in Table (1). The results show that the values lie between 20.75±0.6 Bq/kg and 61.43±0.82 Bq/kg with an average value of 36.65±0.69 Bq/kg. Since the acceptable value is 370 Bq/kg [27], therefore, the maximum value in this study lies in the acceptable level. The equation (3) has been used to calculate the absorbed dose rate in air, the values obtained are listed in the Table (2). The values ranged from 9.16±0.28 nGy/h to 28.55±0.38 nGy/h with an average value of 17.06±0.32 nGy/h. The population-weighted value of the absorbed dose rate in outdoor that calculated by UNSCEAR 2000 [19] was 57 nGy/h which is higher than our average value.

Also Table (3) shows that the values of H_{ex}, H_{in} and $I\gamma$varied from 0.056±0.002 to 0.166±0.002 with mean value of 0.099±0.002, 0.056±0.002 to 0.166±0.002 with mean value of 0.099±0.002 and 0.056±0.002 to 0.166±0.002 with mean value of 0.099±0.002 respectively, this gives us good indicator that no significant radiological hazards for all soil samples under study areaaccording to the radiation protection report [28]. while the $(AEDE)_{in}$, $(AEDE)_{out}$ and $(AEDE)_{total}$ values (as shown in Table (4)) were less than

Table 2: Results of natural radioactivity and Ra_{eq} in Hattincomplex

No.	Sample Code	Specific activity in (Bq/m^3) U-238	Th-232	K-40	Ra_{eq} (Bq/kg)
1	S1	15.68±0.738	8.25±0.31	235.63±2.96	72.91
2	S2	9.24±0.877	12.2±0.35	277±3.29	72.54
3	S3	5.15±0.881	8.74±0.37	288.79±3.48	63.16
4	S4	15.88±0.81	5.95±0.30	305.53±3.21	81.24
5	S5	7.94±0.765	15.56±0.32	338.71±3.26	83.57
6	S6	13.93±0.77	12.04±0.30	335.96±3.21	89.54
7	S7	15.08±0.72	6.89±0.31	363.67±3.32	89.79
8	S8	35.74±0.74	8.8±0.33	267.73±3.59	113.52
9	S9	22.35±0.66	8.36±0.27	335.27±3.26	99.89
10	S10	19.77±0.82	9.22±0.29	334.14±3.44	96.20
Average±S.D		16.07±2.89	9.60±0.95	308.24±11.06	86.24±4.94

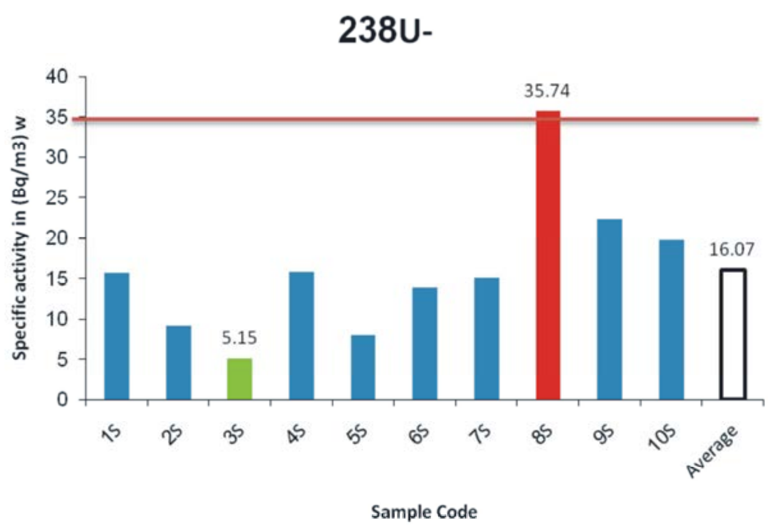

Fig. 3: The specific activities of U-238 of the samples

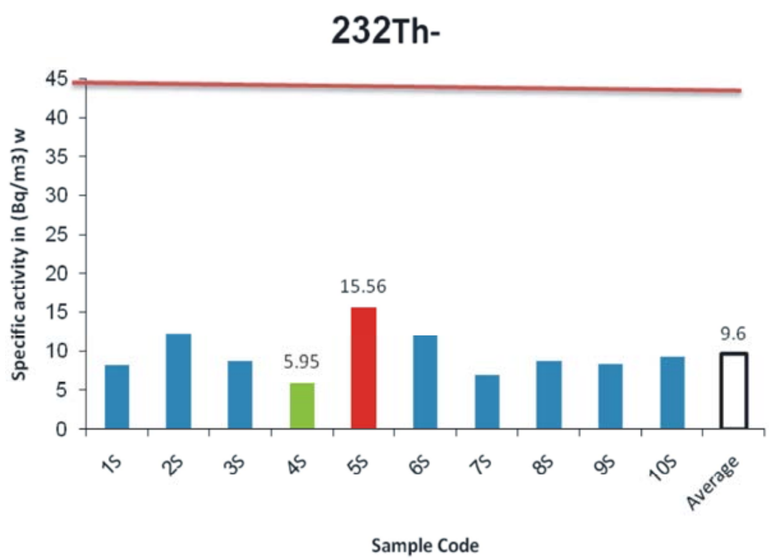

Fig. 4: The specific activities of Th-232 of the samples

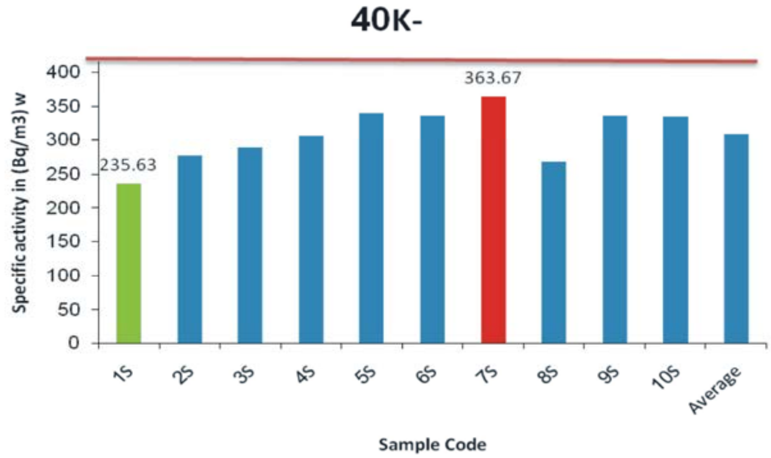

Fig. 5: The specific activities of K-40 of the samples

Table 3: Results D_r, H_{ex}, H_{in} and Iγ in Hattin Complex

No.	Sample Code	D_r (nGy/h)	H_{ex}	H_{in}	I_γ
1	H1	22.28	0.123	0.165	0.344
2	H2	23.93	0.129	0.154	0.368
3	H3	20.40	0.107	0.121	0.314
4	H4	23.85	0.129	0.172	0.369
5	H5	28.25	0.151	0.173	0.434
6	H6	28.36	0.153	0.191	0.437
7	H7	26.63	0.142	0.183	0.411
8	H8	32.59	0.186	0.282	0.504
9	H9	29.49	0.162	0.222	0.456
10	H10	28.91	0.158	0.211	0.446
Average±S.D		26.47±1.25	0.144±0.07	0.188±0.01	0.408±0.01

Table 4: Results of $(AEDE)_{in}$, $(AEDE)_{out}$, AEDE and ELCR in Hattin Complex

No.	Sample Code	$(AEDE)_{in}$(mSv/y)	$(AEDE)_{out}$ (mSv/y)	$(AEDE)_{total}$(mSv/y)	ELCRX10^{-3}
1	H1	0.109	0.027	0.136	0.478
2	H2	0.117	0.029	0.146	0.513
3	H3	0.100	0.025	0.125	0.438
4	H4	0.117	0.029	0.146	0.512
5	H5	0.138	0.034	0.173	0.606
6	H6	0.139	0.034	0.174	0.609
7	H7	0.130	0.032	0.163	0.572
8	H8	0.160	0.040	0.200	0.700
9	H9	0.144	0.036	0.180	0.633
10	H10	0.141	0.035	0.177	0.620
Average±S.D		0.129± 0.008	0.032 ±0.001	0.162 ±0.009	0.568±0.034

the corresponding worldwide values of 0.42, 0.08 and 0.50 mSv/y respectively [29] and at last the values of ELCR are very littleγ therefore, it may be decided that the risk of cancer in negligible.

CONCLUSION

From the results of research and compare them with the higher limit of natural radiation level, We can be concluded the Radiation Hazard indices duo to Gamma Radiation in Hattin Complex at Babylon government measured Within the allowed limit live conditions at the buildings. Our gamma spectroscopic investigations allow us to confirm that the soil samples under study were safe.

ACKNOWLEDGEMENT

I would like to express my deep thanks and appreciation to the dean of College of Education For Pure Science and the head of the department of physics for their help.

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