Risk assessment to natural radiation exposure from soil samples in the Jasmine rice cultivated area, Roi Et province, Thailand

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Abstract. Roi Et is one of the provinces with rice farming and exported to many countries around the world. In order to assess the radiation risk index from Jasmine rice cultivated soils, 175 samples in Roi Et province were measured using the gamma ray spectrometry technique for estimating the natural radioactivity levels. The specific activity of 226Ra, 232Th and 40K was found from 7.14 to 29.02 Bq/kg, 7.24 to 33.40 Bq/kg and 18.17 to 129.65 Bq/kg with a mean value of 16.92 ± 1.16 Bq/kg, 16.99 ± 2.24 Bq/kg and 46.95 ± 6.79 Bq/kg, respectively. However, the values of radium equivalent activity (Raeq), the external hazard index (Hex), the gamma-absorbed dose rate (D) and the annual effective dose equivalent (AEDEout) were also calculated to evaluate radiological hazards. The average values of Raeq, Hex, D and AEDEout were found to be 44.83 Bq/kg, 0.12, 20.03 nGy/h and 0.02 mSv/y, respectively. From the results can demonstrate that the natural radioactivity from soil are not affect to population in the area, which the natural radioactivity levels and the radiation risk values of Roi Et soil samples are lower than the UNSCEAR values.

1. Introduction

The radioactive elements are formed since the founding of the universe, which is caused by two sources: natural and man-made sources. The natural radioactive substances are contaminated in the environment around us, including water, sandstone, fruit, vegetables, even the air we use breathing with natural radioactive substances. 238U with half-life 4.47 × 109 years 232Th with half-life 1.40 × 1010 years and 40K with half-life 1.23 × 109 years [1]. These natural occurring radioactive materials are long-lived. The radioactive part is caused by human activity, which causes radioactive build up in an increasing environment, such as the accident of the Fukushima nuclear power plant in the year 2011, nuclear testing and mining will cause radioactive substances in the area [2-15]. Humans are exposed to radiation of natural origin, mainly up to 85% [5]. If humans are too much radiation in the body, it may cause damage to the tissues and the immune system. The consequences of this radiation are called syndrome or...
radiation sickness. Radiation can cause genetic changes in the body's genes. Causing development into various diseases later, such as cancer or causing changes to the offspring in the next generation.

In addition, there is a group of scientists in radiation safety, both in Thailand and abroad, interested in conducting research on the measurement and analysis of the natural radionuclides ($^{226}$Ra, $^{232}$Th and $^{40}$K) contained in the soil sample to monitor the exposure of natural radiation to people.

Roi Et is a major area for the cultivation of Khao Hom Mali, Thai fragrant jasmine rice. It is the most delicious and fragrant rice in Thailand. Also, the brand of Khao Hom Mali Thung Kula Ronghai, is well-known worldwide for its high quality. Roi Et is the province located in the middle part of northeast Thailand, which is situated in between the latitudes 15°24´ to 16°19´N and longitudes 103°17´ to 104°22´E, which measures 8,299.46 km² in total area. As far as we know, an investigation of radionuclide activity levels and radionuclide distributions in the soil of Roi Et Province has not been performed yet. Therefore, the aim of this study is estimation of $^{226}$Ra, $^{232}$Th and $^{40}$K specific activities and evaluated the radiation hazard indices in the surface soil samples in Roi Et province. This knowledge plays an important role in minimizing the expected health risks to the general public in Roi Et.

2. Experimental

2.1. Sample collection and preparation

Surface soil samples (175 samples) were collected (from a ground surface down to 10-15 cm in depth) from 20 districts of Roi Et Province, namely Pathum Rat district, Kaset Wisai district, Muang Suang district, Suwannaphum district, Phanom Phrai district, Phon Sai district, Nong Hee district, Chaturaphak Phiman district, At Samat district, Si Somdet district, Muang Roi Et district, Thung Khao Luang district, Chiang Khwan district, Thawatchaburi district, Selaphum district, Chang han district, Pho Chai district, Moeiwadi district, Phon Thong district and Nong Phok district as shown in figure 1. The geographical locations of the study areas were determined using the Global Positioning System (GPS; Garmin eTrex 30). After collection, each sample was dried up at room temperature and sieved through a 2 mm mesh-sized sieve to remove stones, pebbles and other macro-impurities. All samples were oven dried at a temperature of 100°C for 8 hours before the analysis to remove the moisture. The homogenized samples were placed in the cylindrical plastic container of uniform size (diameter 8.2 cm and height 7.5 cm), which is similar to the standard reference. The containers were sealed using adhesive tape and stored for one month to ensure equilibrium between $^{226}$Ra and its daughters before being taken for gamma spectrometric analysis [7].

2.2. Measurement of the samples

The specific activities of natural ($^{226}$Ra, $^{232}$Th and $^{40}$K) radionuclides in all surface soil samples were determined by a high-purity germanium detector, with relative efficiency of 30% and 2.1 keV energy resolution (FWHM) at 1.332 MeV of $^{60}$Co. The detector is connected to the multi-channel analyzers (MCA) and gamma-ray energy peak analysis by using the Genie 2000 program. The detector was shielded with 10 cm lead to reduce the gamma radiation from the environment into interference with the radiation metering system. Geometric efficiency for soil matrices in the container was determined by IAEA-RGU-1, IAEA-RGTh-1 and IAEA-RGK-1 reference materials (International Atomic Energy Agency, Vienna, Austria). The specific activities of $^{226}$Ra and $^{232}$Th were determined by their decay products, $^{214}$Bi (609.3) and $^{228}$Ac (911.2 keV), respectively. The specific activity of $^{40}$K was determined from its 1460.8 keV. The counting time interval was 12 hours. The background spectrum was recorded immediately before the sample counting.

The specific activities per unit mass (A) of natural radionuclides in each sample were calculated using the following equation (1)

$$A(Bq/kg) = \frac{C}{t.e.P_y^m}$$

(1)
Where C is the net peak area at energy, t is the counting time (s), P\textsubscript{\gamma} is the gamma emission probability, $\varepsilon$ is the absolute efficiency of the detector at particular gamma energy, m is the sample weight (kg).

2.3. Radiological Parameters

2.3.1. Radium equivalent activity (Ra\textsubscript{eq}). Ra\textsubscript{eq} is the most widely used as a radiation hazard index associated with the three radionuclides of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$. Ra\textsubscript{eq} is a weighted sum of activities of these radionuclides based on the estimation that 370 Bq/kg of $^{226}\text{Ra}$, 259 Bq/kg of $^{232}\text{Th}$, and 4810 Bq/kg of $^{40}\text{K}$ produce the same $\gamma$-ray dose rates. It can be expressed as equation (2) [12, 16]:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K}$$

where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in Bq/kg, respectively.

2.3.2. External and Internal Hazard Indices (H). The external hazard index (H\textsubscript{ex}) was used to assess the hazard of gamma radiation from natural radioactive nuclides in natural materials such as clay, sand, stones, bricks, etc. It was calculated according to the equation (3) [12]:

$$H_{ex} = (C_{Ra}/370) + (C_{Th}/259) + (C_{K}/4810) \leq 1$$

where $C_{Ra}$, $C_{Th}$, and $C_{K}$ are the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$, and $^{40}\text{K}$ in Bq/kg, respectively.

2.3.3. Absorbed Dose Rate (D). Gamma-absorbed dose rates in outdoor air at 1 m above the surface of the ground was calculated by equation (4) [5, 16]:

$$D = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K}$$

where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in Bq/kg, respectively.

2.3.4. Annual Effective Dose Equivalent (AEDE\textsubscript{out}). The annual effective dose equivalent was calculated from the absorbed dose by applying the dose conversion factor of 0.7 Sv Gy\textsuperscript{−1} and the opportunity to spend the time outdoor of 20% (0.2), 1 year (8,760 h). Therefore, the annual effective dose equivalent was calculated from relation following equation (5) [12]:

$$AEDE_{out} (\text{mSv} \cdot \text{y}^{-1}) = D (\text{nGy} \cdot \text{h}^{-1}) \times 8,760 (\text{h}) \times 0.2 \times 0.7 (\text{Sv} \cdot \text{Gy}^{-1}) \times 10^{-6}$$

3. Results and discussion

The specific activity of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ for 175 soil samples from 20 districts in Roi Et province as shown in table 1. The specific activity of $^{226}\text{Ra}$ ranged from 7.14 to 29.02 Bq/kg, with the average value of 16.92 ± 1.16 Bq/kg. The highest specific activity of $^{226}\text{Ra}$ was found to be 29.02 Bq/kg from the soil sample at Selaphum district. The specific activity of $^{232}\text{Th}$ ranged from 7.24 to 33.40 Bq/kg, with the average value of 16.99 ± 2.24 Bq/kg. The highest specific activity of $^{232}\text{Th}$ was 33.40 Bq/kg from the soil at Thung Khao Luang district and the specific activity of $^{40}\text{K}$ ranged from 18.17 to 129.65 Bq/kg, with the mean value of 46.95 ± 6.79 Bq/kg. The highest value of $^{40}\text{K}$ was found at Changhan district, with a value of 129.65 Bq/kg. The variations in activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in soil samples are based on the nature of its geological formations in the study area.

Comparison of the specific activities of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in this study with research data in Thailand from other research reports and the national and global radioactivity measurements was shown in table 2. The results show that the radioactivity in this study was not uniformly distributed in each area. These may be depending on the geological conditions, chemical and physical soil properties of each type of soil, while another factor is causes different activity concentrations values [1, 17].
Table 1. Specific activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in the soil samples, Roi Et province.

| District          | Sample | $^{226}$Ra Range (Bq/kg) | $^{232}$Th Mean (Bq/kg) | $^{40}$K Mean (Bq/kg) |
|-------------------|--------|--------------------------|-------------------------|-----------------------|
| Pathum Rat        | 6      | 10.02 - 16.02            | 8.42 - 13.95            | 33.21 - 45.89         |
|                   |        | range                    | range                   | range                 |
| Kaset Wisai       | 8      | 12.49 ± 0.64             | 10.85 ± 0.84            | 40.26 ± 3.33          |
|                   |        | mean                     | mean                    | mean                  |
| Muang Suang       | 5      | 9.94 - 21.5              | 9.08 - 18.33            | 32.54 - 75.2          |
|                   |        | mean                     | mean                    | mean                  |
| Suwannaphum       | 9      | 14.25 ± 0.63             | 12.43 ± 0.83            | 46.53 ± 3.63          |
|                   |        | mean                     | mean                    | mean                  |
| Phanom Phrai      | 8      | 10.21 - 22.05            | 8.52 - 17.01            | 35.59 - 61.02         |
|                   |        | mean                     | mean                    | mean                  |
| Phon Sai          | 5      | 13.38 ± 0.52             | 12.67 ± 0.78            | 43.14 ± 3.42          |
|                   |        | mean                     | mean                    | mean                  |
| Nong Hee          | 4      | 11.54 - 20.22            | 12.11 - 20.5            | 32.19 - 61.47         |
|                   |        | mean                     | mean                    | mean                  |
| Chaturaphak Phiman| 12     | 15.10 ± 0.62             | 16.53 ± 1.02            | 45.38 ± 3.62          |
|                   |        | mean                     | mean                    | mean                  |
| At Samat          | 10     | 7.14 - 23.17             | 7.24 - 16.91            | 30.88 - 70.08         |
|                   |        | range                    | range                   | range                 |
| Si Somdet         | 8      | 14.07 ± 0.59             | 12.74 ± 0.86            | 43.95 ± 3.75          |
|                   |        | mean                     | mean                    | mean                  |
| Muang Roi Et      | 15     | 12.31 - 26.34            | 9.41 - 17.44            | 33.23 - 54.06         |
|                   |        | mean                     | mean                    | mean                  |
| Thung Khao Luang  | 5      | 16.39 ± 0.62             | 13.27 ± 0.82            | 40.93 ± 3.41          |
|                   |        | mean                     | mean                    | mean                  |
| Chiang Khwan      | 6      | 10.65 - 12.18            | 9.36 - 14.94            | 33.07 - 46.12         |
|                   |        | mean                     | mean                    | mean                  |
| Thawatchaburi     | 12     | 11.35 - 24.47            | 10.41 - 20.44           | 18.88 - 45.65         |
|                   |        | mean                     | mean                    | mean                  |
| Selaphum          | 18     | 14.09 ± 23.6             | 10.94 - 23.15           | 21.26 - 62.8          |
|                   |        | mean                     | mean                    | mean                  |
| Chang han         | 8      | 18.50 ± 1.49             | 17.62 ± 2.16            | 38.05 ± 7.02          |
|                   |        | mean                     | mean                    | mean                  |
| Pho Chai          | 9      | 10.39 - 25.68            | 10.27 - 28.81           | 34.12 - 44.75         |
|                   |        | mean                     | mean                    | mean                  |
| Moeiwadi          | 4      | 18.55 ± 1.65             | 16.59 ± 2.40            | 39.53 ± 8.33          |
|                   |        | mean                     | mean                    | mean                  |
| Phon Thong        | 14     | 14.84 - 23.35            | 12.05 - 33.40           | 36.33 - 52.24         |
|                   |        | mean                     | mean                    | mean                  |
| Nong Phok         | 9      | 19.02 ± 1.48             | 21.30 ± 2.73            | 43.44 ± 8.06          |
|                   |        | mean                     | mean                    | mean                  |

Ranges (175)    7.14 - 29.02 7.24 - 33.40 18.17 - 129.65
Mean (175)       16.92 ± 1.16 16.99 ± 2.24 46.95 ± 6.79
Table 2: Activity concentration of natural radionuclides with other published data.

| Locations | Activity concentration (Bq/kg) | References |
|-----------|--------------------------------|------------|
|           | $^{226}$Ra | $^{232}$Th | $^{40}$K   |
| Thailand  | 16.92      | 16.99      | 46.95      | Present study |
| Thailand  | 48         | 51         | 230        | [12]          |
| Malaysia  | 83.85      | 108.11     | 403.76     | [21]          |
| Syria     | 19         | 24         | 336        | [17]          |
| Camroon   | 14         | 30         | 103        | [18]          |
| Jordan    | 58         | 18         | 138        | [19]          |
| Turkey    | 27         | 34         | 371        | [20]          |
| Worldwide | 35         | 30         | 400        | [12]          |

Figure 1. The map of Roi Et province showing sampling sites.

Using the average specific radioactivity of $^{226}$Ra, $^{232}$Th and $^{40}$K as shown in table 1 to calculate the radiation risk index and presented in table 3. It was found that the calculated values of the radium equivalent activity (Ra$_{eq}$) vary from 20.12 (PhanomPhrai district) to 76.42 (Changhan district) Bq/kg, with an average of 44.83 Bq/kg. These values are lower than than the recommended maximum value of 370 Bq/kg.

The calculated values of external hazard index (H$_{ex}$) for the soil samples in the study area were in the range of 0.05–0.21, which is lower than unity, as is desired.

The gamma absorbed dose rates (D) in air were in the range of 9.10–34.35 nGy/h, with an arithmetic mean of 20.23 nGy/h. According to the report by UNSCEAR (2000), the dose rate in outdoor air from terrestrial gamma rays under normal conditions is approximately 60 nGy/h for a population–weighted value, and 51 nGy/h for a median value. The calculated mean value of 20.23 of nGy/h in the study area is thus lower than the worldwide average limit value (58 nGy/h).
The annual effective dose rates $AEDE_{out}$ were determined to be in the range of 0.01 - 0.04 mSv/y, with a mean value of 0.02 mSv/y. Thus, the average value is well below the world average annual effective dose rate value of 0.07 mSv/y [12].

**Table 3: Radiological hazard index.**

| Sampling areas     | Ra$_{eq}$(Bq/kg) | H$_{eq}$ | D (nGy/h) | $AEDE_{out}$ (mSv/y) |
|--------------------|------------------|----------|-----------|-----------------------|
| Pathum Rat         | 26.21 - 36.52    | 0.07 - 0.10 | 11.77 - 16.47 | 0.01 - 0.02          |
|                    | (31.11)          | (0.08)   | (14.00)   | (0.02)               |
| Kaset Wisai        | 29.17 - 51.00    | 0.08 - 0.14 | 13.32 - 22.78 | 0.02 - 0.03          |
|                    | (35.61)          | (0.10)   | (16.03)   | (0.02)               |
| Muang Suang        | 25.26 - 49.40    | 0.07 - 0.13 | 11.41 - 22.10 | 0.01 - 0.03          |
|                    | (34.82)          | (0.09)   | (15.63)   | (0.02)               |
| Suwannaphum        | 35.38 - 47.24    | 0.10 - 0.13 | 15.89 - 21.03 | 0.02 - 0.03          |
|                    | (42.24)          | (0.11)   | (18.85)   | (0.02)               |
| Phanom Phrai       | 20.12 - 50.02    | 0.05 - 0.14 | 9.10 - 22.42  | 0.01 - 0.03          |
|                    | (35.67)          | (0.10)   | (16.03)   | (0.02)               |
| Phon Sai           | 29.21 - 54.10    | 0.08 - 0.15 | 13.24 - 24.23 | 0.02 - 0.03          |
|                    | (38.51)          | (0.10)   | (17.29)   | (0.02)               |
| Nong Hee           | 28.61 - 35.10    | 0.08 - 0.09 | 12.93 - 15.57 | 0.02 - 0.02          |
|                    | (32.70)          | (0.09)   | (14.63)   | (0.02)               |
| Chaturaphak        | 30.47 - 56.59    | 0.08 - 0.15 | 13.63 - 25.22 | 0.02 - 0.03          |
|                    | (39.33)          | (0.11)   | (17.57)   | (0.02)               |
| Phiman             | 30.99 - 52.73    | 0.08 - 0.14 | 13.82 - 23.52 | 0.02 - 0.03          |
|                    | (41.00)          | (0.11)   | (18.31)   | (0.02)               |
| Si Somdet          | 33.22 - 59.00    | 0.09 - 0.16 | 15.00 - 26.20 | 0.02 - 0.03          |
|                    | (46.62)          | (0.13)   | (20.77)   | (0.03)               |
| Muang Roi Et       | 33.17 - 64.92    | 0.09 - 0.18 | 14.83 - 28.58 | 0.02 - 0.04          |
|                    | (45.32)          | (0.12)   | (20.24)   | (0.02)               |
| Thung Khao         | 38.52 - 73.78    | 0.10 - 0.20 | 17.37 - 32.51 | 0.02 - 0.04          |
|                    | (52.83)          | (0.14)   | (23.46)   | (0.03)               |
| Luang              | 44.29 - 59.89    | 0.12 - 0.16 | 19.82 - 26.79 | 0.02 - 0.03          |
|                    | (52.54)          | (0.14)   | (23.53)   | (0.03)               |
| Chiang Khwan       | 35.15 - 64.92    | 0.09 - 0.18 | 15.89 - 28.58 | 0.02 - 0.04          |
|                    | (47.01)          | (0.13)   | (20.97)   | (0.03)               |
| Thawatchaburi      | 43.61 - 75.61    | 0.12 - 0.20 | 19.45 - 33.77 | 0.02 - 0.04          |
|                    | (61.99)          | (0.17)   | (27.61)   | (0.03)               |
| Selaphum           | 45.17 - 76.42    | 0.12 - 0.21 | 19.96 - 34.35 | 0.02 - 0.04          |
|                    | (60.20)          | (0.16)   | (26.82)   | (0.03)               |
| Chang han          | 33.02 - 59.64    | 0.09 - 0.16 | 14.76 - 26.51 | 0.02 - 0.03          |
|                    | (47.96)          | (0.13)   | (21.40)   | (0.03)               |
| Moeiwadi           | 40.75 - 76.12    | 0.11 - 0.21 | 18.19 - 34.15 | 0.02 - 0.04          |
|                    | (52.41)          | (0.14)   | (23.36)   | (0.03)               |
| Phon Thong         | 40.04 - 69.86    | 0.11 - 0.19 | 17.98 - 30.99 | 0.02 - 0.04          |
|                    | (50.54)          | (0.14)   | (22.66)   | (0.03)               |
| Nong Phok          | 35.08 - 64.31    | 0.09 - 0.17 | 15.77 - 28.33 | 0.02 - 0.03          |
|                    | (48.12)          | (0.13)   | (21.50)   | (0.03)               |
| **Ranges**         | 20.12 - 76.42    | 0.05 - 0.21 | 9.10 - 34.35 | 0.01 - 0.04          |
| **Average**        | 44.83            | 0.12     | 20.03     | 0.02                 |
4. Conclusions
The average specific activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples from Roi Et province determined in this study were generally lower than average values from around the world. From the results can demonstrate that the natural radioactivity from soil are not affect to population in the study area. Moreover, the data in this research can be used as the basis information of natural background radiation from soil in Roi Et provides and also can be the guideline of environmental radiation in daily life of people in the area.

5. References
[1] Al-Hassan A A, Abdel-Salam A M and El-Taheer A 2014 *Life. Sci. J.* 11 829-36
[2] Malain D, Regan P H, Bradley D A, Matthews M, Al-Sulaiti H A and Santawamaitre T 2012 *Appl. Radiat. Isot.* 70 1467-74
[3] Saeed M A, Wahab N A, Hossain I, Ahmed R, Abdullah H Y, Ramli A T and Tahir B A 2011 *Int. J. Phys. Sci.* 6 7335-40
[4] Jankovic M, Todorovic D and Savanovic M 2008 *Radiat. Meas.* 43 1448-52
[5] UNSCEAR 2008 *United Nations* New York
[6] Bajoga A D, Alazemi N, Regan P H and Bradley D A 2015 *Radiat. Phys. Chem.* 116 305-11
[7] Ahmad N, Jaafar M S, Bakhsh M and Rahim M 2015 *J. Radiat. Res. Appl. Sci.* 8 136-41
[8] Rani A, Mittal S, Mehra R and Ramola R C 2015 *Appl. Radiat. Isot.* 101 122-6
[9] Almayahi B A, Tajuddin A A and Jaafar M S 2012 *Appl. Radiat. Isot.* 70 2652-60
[10] Turhan, S et al. 2012 *Geoderma.* 117-124
[11] Singh J, Singh H, Singh S, Bajwa B S and Sonkawade R G 2009 *J. Environ. Radioact.* 100 94-8
[12] UNSCEAR 2000 *United Nations* New York
[13] Benjakul S, Ngumpein J, Uthaikwankeaw H and Kessaratikoon P 2009 *Thaksin J.* 12 38-51
[14] Kritsanawanwat R, Arae H, Fukushima M, Sahoo S K and Chanyotha S 2015 *J. Radioanal. Nucl. Chem.* 305 487-99
[15] Santawamaitre T, Malain D, Al-Sulaiti H A, Matthews M, Bradley D A and Regan P H 2011 *Nucl. Instrum. Methods. Phys. Res. Sect. A.* 652 920-4
[16] Beretka J and Mathew P J 1985 *Health. Phys.* 48 87-95
[17] Al-Marsi MS, Amin Y, Hassan M and Ibrahim S 2006 *J. Radioanal. Nucl. Chem.* 267 337-43
[18] Ngachin M, Garavaglia M, Giovani C, KwatoNjock M G and Nourreddine A 2008 *J. Environ. Radioact.* 99 1056-60
[19] Saleh H and Abu Shayeb M 2014 *Anal. Nucl. Energy.* 65 184-9
[20] Karatash M, Turhan S, Varinioglu A and Yeğinil Z 2016 *Environ. Earth. Sci.* 75 424
[21] Alsaffar M S, Jaafar M S, Kabir N A and Ahmad N 2015 *J. Radiat. Res. Appl. Sci.* 8 300-10

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