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SHORT RESEARCH AND DISCUSSION ARTICLE

Gross beta and alpha activities in the selected commercial freshwater fish species in Vietnam

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Abstract
The baseline data of radioactivity levels in food is one of the main factors for the assessment of resident's health risk. Gross beta and alpha activity was identified for selected commercial freshwater fish species, including 29 types of fish species by a gas-flow proportional detector. The samples were collected from wholesale markets in Hanoi city, Vietnam. The highest gross alpha activity was recorded in blotched snakehead, a pelagic and carnivorous species, and the lowest one was recorded in common carp, a demersal and omnivorous species. Meanwhile, the gross beta activity was much higher than the gross alpha activity with the highest value of gross beta, observed in Wels catfish, a demersal and carnivorous species, and the lowest one found in Mudskipper a demersal, herbivores species. Regarding feeding types, the gross alpha activity was observed in the order of $Al_{carnivores} > Al_{omnivores} > Al_{herbivores}$ whereas the gross beta was non-distinction. In terms of living behavior, the gross alpha activity in pelagic species was much higher than that in demersal species ($Al_{pelagic} >> Al_{demersal}$) and indifferent for gross beta. There was an insignificant relationship between the trophic level with gross beta and alpha activities in freshwater fish species. The calculated annual effective dose ranged from 0.19 to 1.88 and 0.78 $mSv.y^{-1}$ on average, being within the limited dose for the public as reported by UNSCEAR in which gross beta activity has a strong correlation with the total annual effective dose.

Keywords Gross beta and alpha · Pollution · Ingestion dose · Freshwater fish · AED · Feeding types · Living behavior

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Introduction

The contemporary environment is perilously contaminated by natural components and human actions such as heavy metal contamination in soil, sediments, weathering slates, and microplastics (Hung et al. 2019; Hoang et al. 2020; Hoang et al. 2021; Mai et al. 2020; Dang et al. 2020; Ha et al. 2019; Doan Thi et al. 2021; Duong et al. 2020). Volcanism, recent tectonic activities, mineral resources, oil, and gas are also natural factors that pollute the environment (Liem et al. 2021, Trinh et al. 2012, Nguyen-Van et al. 2020, Chau et al. 2017, Duong et al. 2021, Nadezhda et al. 2021). Every day, humans are irradiated by cosmic rays, natural or artificial radionuclides from the surrounding environment. Even though the activity is high or low, it will more or less affect human health, especially it is much more dangerous if it enters to the human body through the digestive tract, drinking water, or respiratory tract. According to World Health Organisation (WHO) (2011) and Le et al. (2017), eight percent of radiation exposure is contributed from food ingestion. In general radionuclide characteristics in human foods and in freshwater fish in particular have been conducted for a long time. The radionuclide activity can range from low to very high, for example, the ^{210}Po activity in freshwater fish was reported with a high value of 3670 Bq. kg^{-1} (Skipperud et al. 2013). Many previous studies have reported the radionuclide contamination in tissues of freshwater fish (Hameed et al. 1997; Manav et al. 2016; Carvalho et al. 2017; Ishii et al. 2020). Therefore, radioactive characteristics in human food have been concerned especially on the radiation hazard assessment for solving the environmental problems and the public health protection.

Vietnam is a tropical country with dense rivers and lakes, so freshwater fish is one of the main foods of the Vietnamese people in daily meals. In addition, with favorable natural conditions, freshwater fish and fishing activities are particularly of interest for development (Vietnam Directorate of Fisheries 2021). As a developing country, the environmental issue here is considered as sensitive, seeking attention. Rivers and lakes could be polluted for many reasons. When the river and lake get contaminated due to industrial, agricultural, and other anthropogenic activities, fish species are prone to accumulate toxic chemicals from the aquatic environment. It is also to note that Vietnam is well-known for its rich natural resources, as it is bestowed with uranium, rare earth elements, and other rich radioactive element-bearing mines. This contributes to radionuclide contamination, with radionuclides getting released to surface and underground water, air-dust and high radioactive waste exploitation, and mineral extraction. Henceforth, radionuclides get accumulated in fish through direct absorption and indirect ingestion by feeding on biota harboring radionuclides.

The gross alpha and beta method is a cheap and fast method to determine the gross activity of beta- and alpha-emitting radioisotopes (Sáez-Muñoz et al. 2020). A few previous studies used this method to evaluate the radiation safety in water spinach (Le et al. 2017), in food crops and surface soil (Vu and Huynh, 2018), and in water (Phan and Le, 2014; Duong et al. 2020; Ho et al. 2020; Van et al. 2018). Investigations on radioactive activity in freshwater fish species were rarely reported in Vietnam. Very few studies have focused on ^{210}Po activity, gross beta, and alpha in marine species (Duong et al. 2020; Duong 2020); Nguyen et al (2021)). The aims of this study will provide a baseline data for gross beta and alpha activities and annual effective dose due to selected commercial freshwater fish species consumption from wholesale markets in Hanoi, Vietnam. In addition, those data provided primaries information about characteristics and behavior of gross alpha and beta activities regard of feeding types, living behavior, and trophic level of freshwater fish species in Vietnam.

Materials and methods

Sampling

Hanoi city, located in the Red River Delta, is one of the most populated city in Vietnam. This area has the advantages of natural conditions to develop freshwater fish, with fish output reaching 115,000 tons (Hanoi Department of Agriculture and Rural Development 2019). However, rapid economic development and urbanization have led to many environmental issues. A total of 29 commercial freshwater fish species (mature ones) that are most commonly consumed by Vietnamese people were collected from the Hanoi wholesale markets, Vietnam, for establishing the baseline data on gross alpha and beta activities and radioactive hazard assessment of the residents (Table 1). For discussion of characteristics of gross beta and alpha activities in study organisms, they were sampled for different kinds of living behaviors (pelagic and demersal), feeding types (herbivorous, carnivorous, and omnivorous), and trophic levels. One of the important tasks before sampling was to confirm whether all samples have been farmed and caught in the same local study area. For the purpose of addressing radioactive hazard assessment and concern on freshwater fish consumption, only the edible tissues of fishes were taken after cleaning with distilled water.

Method

The fish samples were transported to the laboratory with ultimate care, and edible tissues of it were separated, weighed, and dried at a temperature of 80 °C. The dry and wet weight ratios were determined for later calculation.

Table 1 Sampling information

English name	Scientific name	Living behavior	Trophic level	Type of feeding
Roho labeo	*Labeo rohita* (Hamilton 1822)	Pelagic	2.2	Herbivorous
Mrigal carp	*Cirrhinus cirrhosus* (Bloch 1795)	Pelagic	2.4	Herbivorous
Amazon sailfin catfish	*Pterygoplichthys pardalis* (Castelnau 1855)	Demersal	2.0	Herbivorous
Grass carp	*Ctenopharyngodon idella* (Valenciennes 1844)	Demersal	2.0	Herbivorous
Mudskipper	*Pseudapocryptes elongatus* (Cuvier 1816)	Demersal	2.6	Herbivorous
Pirapitinga	*Piaractus brachypomus* (Cuvier 1818)	Pelagic	2.5	Omnivorous
Silver carp	*Hypophthalmichthys harmandi* (Sauvage 1884)	Pelagic	2.5	Omnivorous
Barbel chub	*Squaliobarbus curriculus* (Richardson 1845)	Pelagic	2.7	Omnivorous
Bighead carp	*Hypophthalmichthys nobilis* (Richardson 1845)	Pelagic	2.8	Omnivorous
Nile tilapia	*Oreochromis niloticus* (Linnaeus 1758)	Pelagic	2.9	Omnivorous
Pilchard	*Konosirus punctatus* (Temminck & Schlegel 1846)	Pelagic	2.9	Omnivorous
Taiwan lesser-bream	*Metzia formosae* (Oshima 1920)	Pelagic	3.1	Omnivorous
Crucian carp	*Carassius auratus* (Linnaeus 1758)	Pelagic	3.1	Omnivorous
Asian swamp eel	*Monopterus albus* (Zuiew 1793)	Demersal	2.9	Omnivorous
Climbing perch	*Anabas testudineus* (Bloch 1792)	Demersal	3.0	Omnivorous
Common carp	*Cyprinus carpio* (Linnaeus 1758)	Demersal	3.1	Omnivorous
Pangas catfish	*Pangasius pangasius* (Hamilton 1822)	Demersal	3.4	Omnivorous
Black carp	*Mylopharyngodon piceus* (Richardson 1846)	Demersal	3.2	Omnivorous
Sharpbelly	*Hemiculter leucisculus* (Basilewsky 1855)	Pelagic	2.8	Carnivorous
Blotched snakehead	*Channa maculata* (Lacepède 1802)	Pelagic	3.7	Carnivorous
Paradisefish	*Macropodus opercularis* (Linnaeus 1788)	Pelagic	3.8	Carnivorous
Pond loach	*Misgurnus anguillicaudatus* (Cantor 1842)	Demersal	3.2	Carnivorous
Darkbarbel catfishcá	*Pseudobagrus vachellii* (Richardson 1846)	Demersal	3.5	Carnivorous
Armorhead catfishes	*Cranoglanis bouderius* (Richardson 1846)	Demersal	3.5	Carnivorous
Tank goby	*Glossogobius giuris* (Hamilton 1822)	Demersal	3.7	Carnivorous
Giant mottled eel	*Anguilla marmorata* (Quoy & Gaimard 1824)	Demersal	3.8	Carnivorous
Predatory carp	*Chanodichthys erythropterus* (Basilewsky 1855)	Demersal	4.4	Carnivorous
Amur catfish	*Silurus asotus* (Linnaeus 1758)	Demersal	4.4	Carnivorous
Wels catfish	*Silurus glanis* (Linnaeus 1758)	Demersal	4.4	Carnivorous

The samples were then milled to a homogenous powder. Experimental procedures for preparing samples were referenced from the previous researches (Duong et al. 2020; Le et al. 2017).

To determine gross beta and alpha activity, samples were measured by Canberra LB4100 low ground gas rate counter with standard surface sources of ^{241}Am and ^{90}Sr. A low substrate count rate was 0.10 cpm for total alphas activity and < 0.93 cpm for total beta, with a gas to gas ratio counter of 10% methane + 90% argon. In this study, all samples were counted for 86,400 s, with an efficiency of 35% for gross alpha and 48% for gross beta.

Annual effective dose

The AED that an adult receives as a result of the consumption of a freshwater food was determined by Formula (1) (Tettey-Larbi et al. 2013; Le et al. 2017).

$$E_{(\alpha/\beta)} = \frac{I_m}{N_{R(\alpha/\beta)}} \sum_{i}^{R(\alpha/\beta)} A_{(\alpha/\beta)}.DCF_{ing}(\alpha/\beta) \quad (1)$$

where $E_{(\alpha/\beta)}$ is the gross alpha/beta average AED. I_m is the consumption intake rate (kg.y^{-1}, 18 kg.y^{-1} according to the recommendation of the National Institute of Nutrition Vietnam). Vietnamese usually consume freshwater fish species more than seafood. Thus, the 18 kg.y^{-1} could be used as a reference value of minimum freshwater fish consumption amount per year in this study. $N_{R(\alpha/\beta)}$ is the number of major alpha radionuclides (^{238}U, ^{235}U, ^{234}U, ^{226}Ra, ^{210}Po) or major beta (^{210}Pb, ^{40}K, ^{228}Ra) emitters. $A_{(\alpha/\beta)}$ is gross beta and alpha activities in study freshwater fish samples. $DCF_{ing\ (\alpha/\beta)}$ is the dose conversion factor (WHO 2017).

Results and discussions

Characteristics of gross beta and alpha in freshwater fish species

The gross alpha and gross beta activities in freshwater fish species are shown in Table 2. The activities range from 1.29 ± 0.57 to 162 ± 81 and 13 ± 7 Bq.kg$^{-1}{}_{wet}$ in average for gross alpha and from 27 ± 4 to 228 ± 26 and 119 ± 19 Bq.kg$^{-1}{}_{wet}$ in average for gross beta (Table 2). The lowest gross alpha activity of 1.29 ± 0.57 Bq.kg$^{-1}{}_{wet}$ was recorded in common carp, a demersal and omnivorous species, while the highest level of 162 ± 81 Bq.kg$^{-1}{}_{wet}$ was recorded in blotched snakehead, a pelagic and carnivorous species. It is to note here that the gross beta activity is much higher than the gross alpha for all studied samples. The results are in accordance with the previous studies conducted in fish samples from Lake Van, Turkey, and in selected marine fish species in Vietnam (Erenturk et al. 2014; Duong et al. 2020). The lowest gross beta activity of 27 ± 4 Bq.kg$^{-1}{}_{wet}$ was recorded in mudskipper, a demersal, herbivores species, whereas the highest one of 228 ± 26 Bq.kg$^{-1}{}_{wet}$ was observed in Wels catfish, a demersal and carnivorous species.

Feeding type is one of the key factors influencing the radioactive accumulation in aquatic organisms (Carvalho and Fowler 1994 and Carvalho 2018). The feeding types of selected freshwater fish species were classified into three groups including herbivores, omnivorous, and carnivores.

Table 2 Gross beta and alpha activities in freshwater fishes

English	Activity concentration (Bq.kg^{-1}wet)		AED (mSv.y^{-1})		
	Gross alpha	Gross beta	Gross alpha	Gross beta	Total
Roho labeo	12.6 ± 7.1	125 ± 16	0.07	0.78	0.86
Mrigal carp	4.7 ± 2.6	140 ± 18	0.03	0.89	0.92
Amazon sailfin catfish	2.71 ± 1.6	107 ± 14	0.02	0.67	0.69
Grass carp	9.38 ± 5.4	218 ± 28	0.05	1.37	1.42
Mudskipper	3.8 ± 2.3	27 ± 4.7	0.02	0.17	0.19
Pirapitinga	9.45 ± 5.1	105 ± 13	0.06	0.66	0.71
Silver carp	4.63 ± 2.7	160 ± 20	0.03	1	1.03
Barbel chub	4.9 ± 2.7	57 ± 7.3	0.03	0.36	0.39
Bighead carp	10.1 ± 5.4	128 ± 16	0.06	0.8	0.86
Nile tilapia	1.26 ± 0.73	112 ± 14	0.01	0.7	0.71
Pilchard	17 ± 10	160 ± 20	0.1	1	1.1
Taiwan lesser-bream	11 ± 6.2	60 ± 8	0.07	0.38	0.44
Crucian carp	3.16 ± 1.9	105 ± 14	0.02	0.66	0.68
Asian swamp eel	4.28 ± 2.5	62 ± 8	0.02	0.39	0.41
Climbing perch	1.6 ± 1.1	112 ± 15	0.01	0.7	0.71
Common carp	1.29 ± 0.57	107 ± 14	0.01	0.67	0.68
Pangas catfish	16 ± 9.1	116 ± 13	0.09	0.73	0.82
Black carp	31 ± 16	77 ± 9	0.18	0.48	0.66
Sharpbelly	5.33 ± 2.9	84 ± 11	0.03	0.52	0.55
Blotched snakehead	162 ± 81	150 ± 19	0.94	0.94	1.88
Paradisefish	13 ± 7.4	99 ± 13	0.08	0.62	0.69
Pond loach	16 ± 9.3	135 ± 16	0.09	0.85	0.94
Darkbarbel catfishcá	2.62 ± 1.6	102 ± 13	0.02	0.64	0.66
Armorhead catfishes	18 ± 9.2	214 ± 24	0.1	1.34	1.44
Tank goby	1.34 ± 0.57	76 ± 10	0.01	0.48	0.48
Giant mottled eel	3.89 ± 2.4	78 ± 10	0.02	0.49	0.51
Predatory carp	12 ± 6.5	137 ± 17	0.07	0.86	0.93
Amur catfish	1.56 ± 0.85	131 ± 0.87	0.01	0.82	0.83
Wels catfish	16 ± 8.2	228 ± 26	0.09	1.43	1.52
Min	1.29 ± 0.57	27.4 ± 4.0	0.01	0.13	0.19
Max	162 ± 81	228 ± 26	0.94	1.43	1.88
Average	13 ± 7	119 ± 15	0.09	0.69	0.78

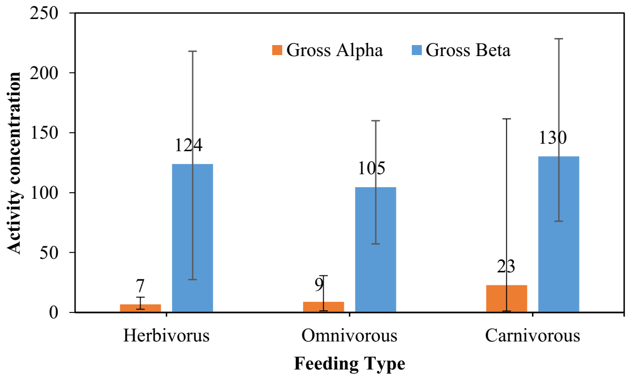

Fig. 1 The average and detected gross beta and alpha activities in freshwater fish species for different feeding types

The highest average gross alpha activity of 23 ± 12 Bq.kg^{-1}$_{wet}$ was recorded in carnivorous species. The lower average of (8.9 ± 4.9 Bq.kg^{-1}$_{wet}$) was observed in omnivorous, and 6.67 ± 3.82 Bq.kg^{-1}$_{wet}$ was recorded in herbivorous species (Fig. 1). Previous studies showed a similar trending that the carnivorous and omnivorous types harbor relatively higher radioactivity than herbivores fish species (Uddin et al. 2012; Deiaa et al. 2020; Nguyen et al. 2021).

There was an insignificant difference in gross beta of study samples between feeding type species ($p > 0.05$). In general, the maximum average gross beta activity was observed in a carnivorous species, the lower level was recorded in herbivorous species, and the lowest was recorded in omnivorous species. A beta decay of ^{210}Pb isotope with activity was reported higher in carnivore sin comparison with other fish species (Kılıç et al. 2018). However, other previous reports showed that the ratio of ^{210}Pb/^{210}Powas usually less than 1 (Aközcan and Uğur, 2013; Musthafa and Krishnamoorthy 2012; Štrok and Smodiš, 2011; Kılıç et al. 2018). Some previous studies in fish showed that the activity of beta decay of ^{40} K was greater than other isotopes (Alam et al. 1995; Yu et al. 1997; Ghose et al. 2000; Görür et al. 2012; Chen et al. 2015; Kabir et al. 2017; Ozmen and Yilmaz 2020; Biswas et al. 2021). Therefore, the major constituent in the gross beta activity could come from ^{40} K isotope, a light and mobile element (Prajapati and Modi 2012, Duong et al. 2020). The highest average gross beta and alpha activity was recorded in carnivores feeding type species, the feeding type species with large size and nutrient levels, which tend to accumulate a great amount of toxicity and radiation contamination (Milenkovic et al. 2019). The average gross alpha activity in feeding types follows the order $Al_{carnivores} > Al_{omnivores} > Al_{herbivores}$, while for gross beta, it is not so different and in general with order $Bt_{carnivores} > Bt_{herbivores} > Bt_{omnivores}$.

The living behavior could also be one of factors which were related to the level of the gross beta and alpha activities in study samples. In this study, the average value of gross alpha in pelagic species was 20 ± 11 Bq.kg^{-1}$_{wet}$, and the average lower value was recorded in demersal species. The average gross beta activity changed insignificantly between pelagic and demersal species. Specifically for the pelagic species, 114 ± 14 Bq.kg^{-1} $_{wet}$ was recorded, and 120 ± 15 Bq.kg^{-1}$_{wet}$ recorded in demersal species was slightly higher than the earlier. One of the main alpha-emitting isotopes that exist in fish species is ^{210}Po. Carvalho et al. (2011) showed that ^{210}Po isotope occopied ~ 80% of the alpha-particle-emitting isotope in fish. The previous studies of (^{210}Po) reported that the popular alpha-particle-emitting radioactive isotopes in pelagic species was higher than that in demersal species (Štrok and Smodiš, 2011; Çatal et al. 2012; Kılıç et al. 2018; Deiaa et al. 2020). This could be the reason why the gross alpha activity in pelagic species was higher than that in demersal species. The gross alpha activity in pelagic species was significantly higher than that in demersal species ($Al_{pelagic} > Al_{demersal}$) (Fig. 2). However, this tendency does not seem to affect and is different for the gross beta activity.

Trophic level is also one of the factors which can be used to evaluate the contamination affection. This value varies from low to high in accordance with the position of the species in the food chain. As per the observation in this study, there is an insignificant correlation between gross beta and alpha with trophic level $R^2 < < 0.1$.

Annual effective dose

Table 2 summarizes the results of AED from gross beta and alpha activities in fish and their total annual effective doses. The results showed that the AED of gross alpha ranged widely and was within the recommended permitted limits of UNSCEAR (2008) while the AED of the gross beta for some fish species exceeded the recommended value of 1 mSv.y^{-1}. The authors further recommend in-depth studies on effective dose contribution by beta-emitting isotopes. If the principal

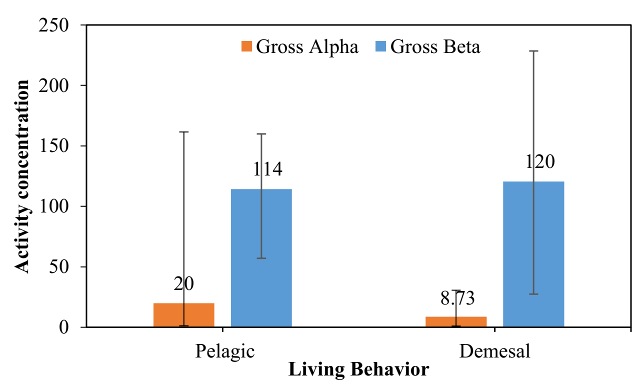

Fig. 2 The average and detected gross beta and alpha activities in freshwater fish species for different living behavior

contribution is by ^{40} K, the effective dose will come down so much. Therein, the total AED ranged from 0.19 to 1.88 mSv. $y^{-1}$and 0.78 mSv.y^{-1}in average. There exists a strong correlation between the total AED and gross beta activity with $R^2 = 0.98$ ($p < 0.01$), correlation being significant at the 0.01 level (2-tailed)) (Fig. 3a) which revealed highest values of total AED. In contrast, the total AED and the gross alpha activity had almost no correlation with $R^2 < 0.3$ (Fig. 3b). It indicated that the beta-particle-emitting isotopes contributed as a principal contribution to the total AED.

Conclusion

Based on the results, the following conclusions can be drawn:

The results showed a wide range for both gross beta and alpha activities in freshwater fishes in Hanoi, Vietnam. Therein, the lowest gross alpha was recorded in common carp, a demersal and omnivorous species, while the highest one was observed in blotched snakehead, a pelagic and carnivorous species. For gross beta activity, the lowest activity was found in mudskipper, a demersal, herbivores species, whereas the highest one was observed in Wels catfish, a demersal and carnivorous species.

With regard to feeding types and living behaviors, there was a trending for gross alpha activity but non-distinct for gross beta activity. Therein, the trending of gross alpha activity in study freshwater fish species was in the order $Al_{carnivores} > Al_{omnivores} > Al_{herbivores}$ for feeding types and $Al_{pelagic} > Al_{demersal}$ for living behaviors.

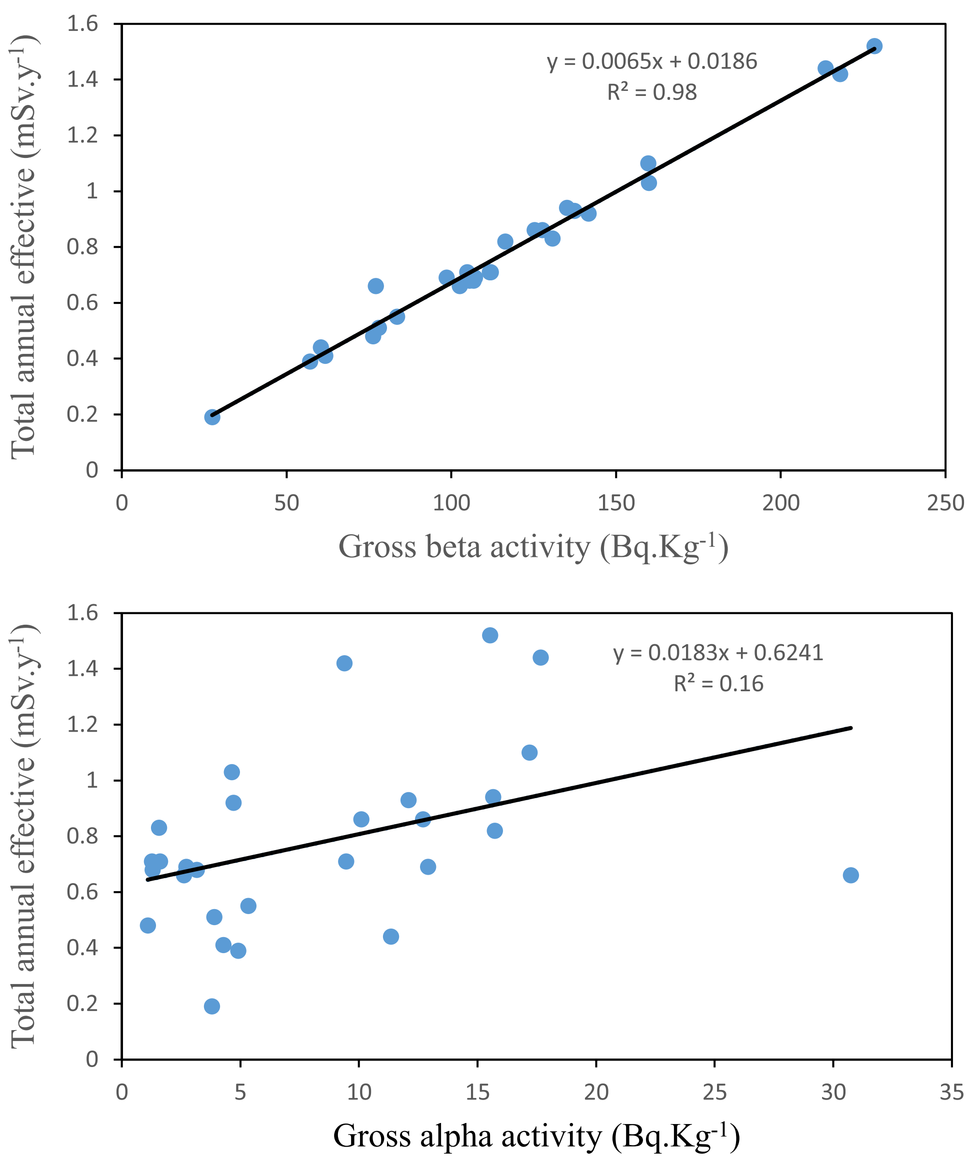

Fig. 3 **a, b** Correlation between gross beta and alpha activities with total AED

With respect to the trophic levels, there was an insignificant relation between gross beta and alpha activities, $R^2 << 0.1$.

The total AED from gross beta and alpha activities was significantly high and ranges from 0.19 to 1.88 $mSv.y^{-1}$ and 0.78 $mSv.y^{-1}$ on average. There was a strong correlation between the AED and gross beta activity with $R^2 = 0.84$ ($p < 0.01$).

The results of this study provide a planning further studies in each of the beta and alpha decay isotopes in freshwater fish and the target of environmental pollution in study areas also.

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c. Acquisition and collation of data: Van-Hao Duong, Tien Chu Trung.

d. Analysis, interpretation of data: Van-Hao Duong, Tien Chu Trung, Cuong Le Dinh, Thanh-Nam Nguyen, Duc-Thang Duong, Huyen-Trang Nguyen.

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f. Critical revision of paper: Van-Hao Duong, Thanh-Nam Nguyen, Luan Thanh Pham, Quan Nguyen Tien, Muhammad Yaseen, M. Saiyad Musthafa.

Data availability Not applicable.

Declarations

Ethics approval The authors further confirm that any aspect of the work covered in this manuscript that has involved human patients or animals has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

Consent to participate The authors confirm that the manuscript has been read and approved by the named authors. The authors confirm that the order of authors listed in the manuscript has been approved by the named authors.

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Competing interests The authors declare no competing interests.

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