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RADIOLOGICAL RISK OF THE URANIFEROUS COAL WASTE IN THE CASE OF THE LANDSCAPE ARCHITECTURE APPLICATION

RYZYKO RADIOLOGICZNE ZWIĄZANE Z ZASTOSOWANIEM ODPADÓW Z HAŁD URANONOŚNYCH WĘGLI W ELEMENTACH ARCHITEKTURY KRAJOBRAZU

Abstract: Gamma-spectrometric measurements of four (A, B, C, D) spoil tips, by means of portable gamma spectrometers RS230 have been performed in the Okrzeszyn area of the Intrasudetic Synclinorium, where uraniferous Permocarboniferous coal exploitation and uranium prospecting took place in the past. The obtained results of K, U, Th content were recalculated into activity indices f1 and f2. Acceptable limits according to Polish Law are f1 ≤ 1 and f2 ≤ 200 $Bq \cdot kg^{-1}$ for raw materials in buildings for people and livestock. Obtained results indicate that spoil tips material cannot be fully accepted as building material even for landscape architecture constructions in urban areas, where limits are less restrictive (f1 ≤ 2, f2 ≤ 400 $Bq \cdot kg^{-1}$).

Keywords: uranium, coal, gamma spectrometry, Sudetes

Introduction

Okrzeszyn, a small village located in the western part of the Intrasudetic Synclinorium close to its boundary with the Karkonosze-Izera Block has been the place of coal exploitation since the 18-th century. Coal seams intercalated with mudstones, sandstones and conglomerates represent the uppermost part of the Carboniferous and are overlain by the Early Permian conglomerates, sandstones and mudstones (black *Anthracosia* shale). Sedimentation of the above-mentioned rocks has been accompanied by bimodal volcanism (intermediate-trachyandesites and felsic-rhyolites) [1]. Sedimentary sequence represents the fossil record of climate change from relatively wet, with regular precipitation, when peat bogs were formed to dry, arid conditions with irregular, but intensive rainfalls of red conglomerate sedimentation [2, 3].

Due to this, periods of intensive chemical weathering were followed by dry seasons, when accumulated material stayed in oxygenating conditions. Even during Permian dry climate period, the buried peat layers maintained acid, reducing conditions, what combined with their absorption activity resulted in uranium precipitation from circulating oxygenated groundwater. Especially effective adsorbent systems were connected with thin layers of peat (slowly transforming to lignite and coal) surrounded by permeable sand (sandstones). Uranium in groundwater was derived from oxygenated weathering zones of sedimentary debris and massifs of acid igneous rocks (local felsic rhyolites and Karkonosze Granite) and maybe to some extent also from the late hydrothermal fluids. According to uranium prospecting reports of the mid XX-th century uranium concentration in thin coal seams reaches thousands of ppm, but low thickness make their exploitation uneconomic [3, 4].

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As a result of coal mining and uranium prospecting spoil tips - piles of rock waste material exist in this area [5]. Their main components are: black shales and mudstones with abundant organic matter, sandstones and conglomerates. Four spoil tips (A, B, C, D) has been studied, their composition varies from place to place and so does the radionuclides content.

Methods

Gamma-spectrometric measurements were performed by means of portable gamma spectrometers RS230 with BGO detectors and automatic gain stabilization based on thallium ^{208}Tl emission at 2615 keV. The results were registered as potassium content K [%], equivalent uranium content eU [ppm], equivalent thorium content eTh [ppm]. Later on the results were recalculated into activity indices f1 and f2.

Results and radiological risk assessment

Obtained results are summarized in the Table 1.

Table 1

Summary of radiometric results

Location	Statistical parameter	K [%]	eU [ppm]	eTh [ppm]	f1	f2 [$Bq \cdot kg^{-1}$]
SPOIL TIP A	max	4.4	29.1	23.9	1.9	361.77
	min	2.1	6.2	15.4	0.91	77.08
	mean	2.8	14.4	18.9	1.3	179.3
SPOIL TIP B	max	3.9	148.5	25	7.02	1846.14
	min	2.2	2.9	10.3	0.61	36.05
	mean	2.99	59.82	19.43	3.18	743.67
SPOIL TIP C	max	2.8	59.2	13.4	3.01	735.97
	min	2.2	3.3	10.1	0.58	41.03
	mean	2.5	24.5	11.4	1.5	304.4
SPOIL TIP D	max	2.5	158.8	13.6	7.07	1974.19
	min	2.1	23.5	8.8	1.37	292.15
	mean	2.27	65.6	10.33	3.16	815.53
OUTSIDE AREA	max	2.6	36.6	21.3	2.16	443.82
	min	0.8	2.5	7.1	0.39	31.08
	mean	1.73	18.1	9.86	1.13	225.02

Basic parameters of radiological risk assessment are according to Polish Law f1 and f2 indices. Index f1 is a weighted average of specific activities of ^{40}K isotope and radionuclides of uranium ^{238}U and thorium ^{232}Th decay series, described by the formula:

$$f1 = \frac{S_K}{3000\ \mathrm{Bq \cdot kg^{-1}}} + \frac{S_{Ra}}{300\ \mathrm{Bq \cdot kg^{-1}}} + \frac{S_{Th}}{200\ \mathrm{Bq \cdot kg^{-1}}}$$

where S_K, S_{Ra}, S_{Th} are specific activities of ^{40}K, ^{226}Ra and ^{228}Th in $Bq \cdot kg^{-1}$, respectively.

As visible from the formula above f1 value can be treated as a sum of three components connected with radiation of ^{40}K, ^{226}Ra and ^{228}Th, respectively.

Frequency distribution of the f1 index is presented in Figure 1.

Shares of the ^{40}K, ^{238}U and ^{232}Th components in the total f1 values are shown in the Figure 2. Each bar represents calculated value of f1 and is composed of three layers of different grey tone. The lowest layer corresponds to ^{40}K component of f1 value, the medium layer corresponds to ^{238}U component of f1 value and the uppermost layer corresponds to ^{232}Th component of f1 value. ^{238}U component is the most significant and the most variable one.

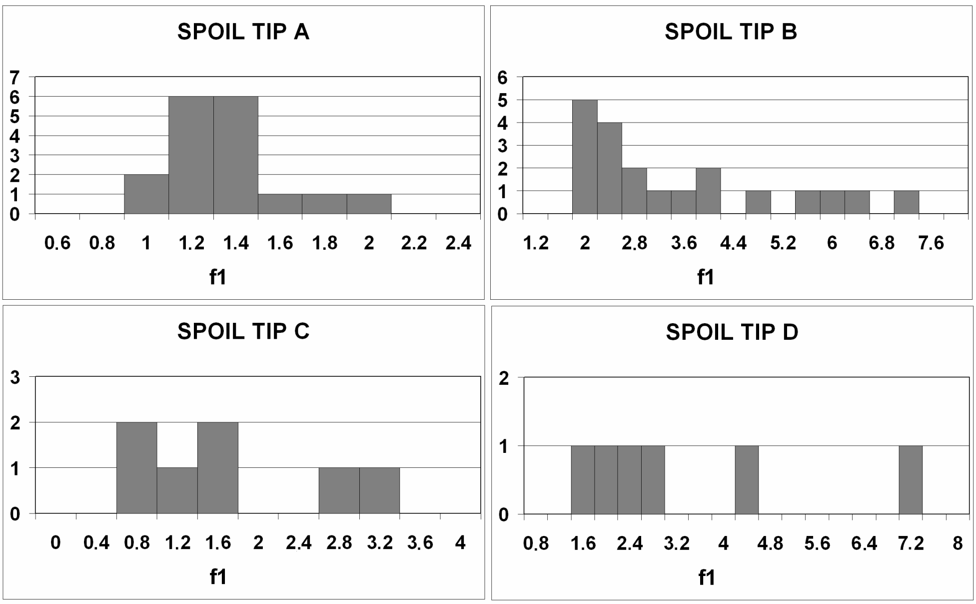

Fig. 1. Frequency distribution of f1 index

Index f2 is a measure of radon risk expressed as ^{226}Ra specific activity of the material. Frequency distribution of f2 index is presented in Figure 3.

Legally accepted values of the above-mentioned indices are:

1) $f1 \leq 1$ and $f2 \leq 200$ Bq · kg^{-1} for raw materials and construction materials used in dwellings designed to accommodate people and livestock,
2) $f1 \leq 2$ and $f2 \leq 400$ Bq · kg^{-1} for industrial waste used in above-ground building constructions erected in the urban areas and leveling of the areas designed for urbanisation purposes in the local spatial plan,
3) $f1 \leq 3.5$ and $f2 \leq 1000$ Bq · kg^{-1} for industrial waste used in above-ground parts of buildings not listed in point 2, and the leveling of areas not listed in point 2,
4) $f1 \leq 7$, $f2 \leq 2000$ Bq · kg^{-1} for industrial waste for use in underground parts of buildings referred to in point 3, and underground structures, including rail and road tunnels, with the exception of industrial waste used in underground mining.

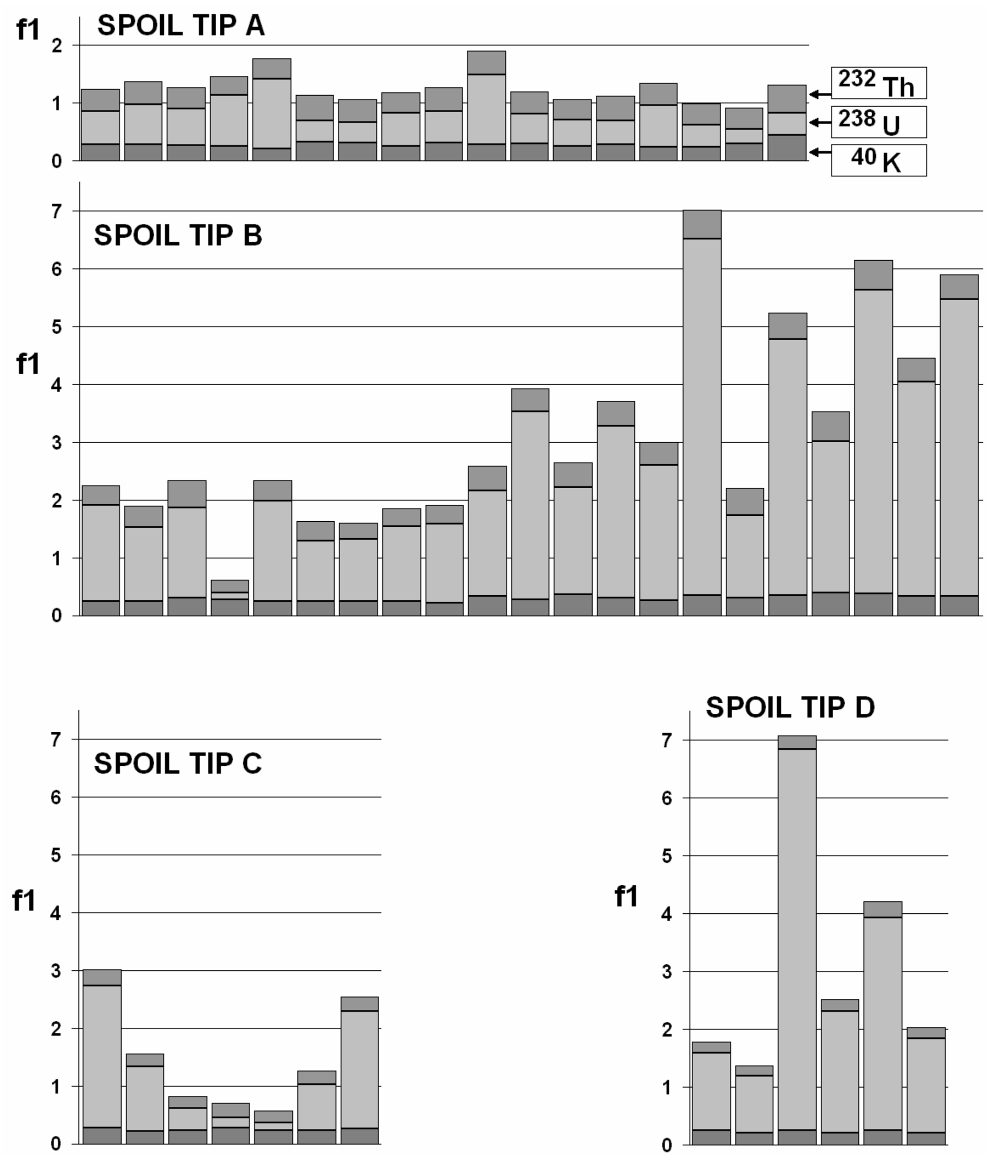

Fig. 2. Shares of the ^{40}K, ^{238}U and ^{232}Th components in the total f1 values

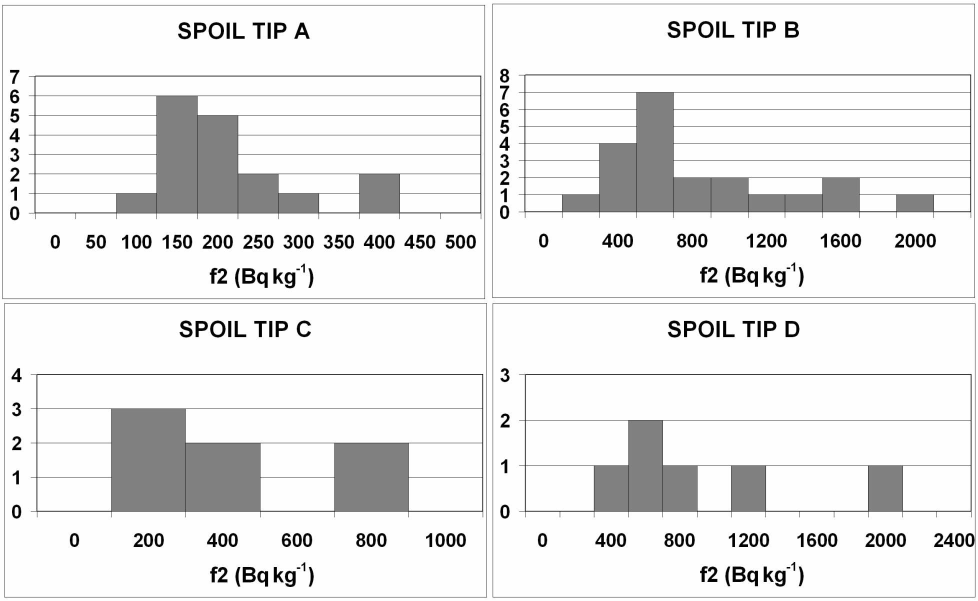

Fig. 3. Frequency distribution of f2 index [Bq · kg^{-1}]

Conclusions

Obtained results indicate that spoil tips material cannot be fully accepted as building material even for above-ground landscape architecture constructions in urban areas, where limits are less restrictive ($f1 \leq 2$, $f2 \leq 400$ Bq · kg^{-1}). It can be used after radiological control in limited range for road construction outside urban areas ($f1 \leq 3.5$ and $f2 \leq 1000$ Bq · kg^{-1}). There are no restrictions for application in the underground parts of buildings, and underground structures, including rail and road tunnels outside urban areas.

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Abstrakt: Zostały przeprowadzone pomiary za pomocą gamma spektrometrów RS230 na czterech (A, B, C, D) hałdach odpadów górniczych w rejonie Okrzeszyna (niecka śródsudecka), gdzie w przeszłości miała miejsce eksploatacja permokarbońskich uranonośnych węgli i poszukiwanie rud uranu. Uzyskane wyniki zawartości K, U, Th zostały przeliczone na wskaźniki aktywności f1 i f2. Zgodnie z Rozporządzeniem RM z dnia 2 stycznia 2007 r., dopuszczalne wartości wynoszą $f1 \leq 1$ i $f2 \leq 200$ Bq · kg^{-1} w przypadku materiałów stosowanych w budynkach mieszkalnych. Uzyskane wyniki wskazują, że zgromadzony na hałdach materiał nie może być w całości dopuszczony nawet do budowy elementów architektury krajobrazu w obszarach zabudowanych, gdzie dopuszczalne wartości wskaźników aktywności są większe ($f1 \leq 2$, $f2 \leq 400$ Bq · kg^{-1}).

Słowa kluczowe: uran, węgiel, gamma spektrometria, Sudety