Air dose rate analysis and its relation with temperature and humidity

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The research is based on gamma radiation background assessment of two different ecosystems for the period of seventeen consecutive months and its relation to air temperature and air humidity. The measurements of ambient dose equivalent rate (H*10), commonly referred to as “air dose rate” or gamma dose rate (GDR), at the eleven monitoring points in the two test fields –a river and a lake, located alongside the southern coastline of the Black Sea coast near Burgas, Bulgaria, were performed by a portable survey meter. At the same monitoring points air temperature and air humidity were measured. The research shows different correlations between the three variables at the lake and the river. For Karaagach river gamma air dose rate is negatively correlated with air temperature and positively correlated with air humidity while air temperature is positively correlated with air humidity. On the contrary, for Vaya lake gamma air dose rate is positively correlated with air temperature and positively correlated with air humidity, while air temperature is negatively correlated with air humidity. Gamma air dose rates are lower alongside the river banks, than alongside the lake because of the difference in water flow, depth, sediments development and anthropogenic impact.

Keywords: air dose rate, gamma background, ionizing radiation, Vaya lake, Karaagach river

INTRODUCTION

Gamma radiation is part of the environmental indicators, which form the area inhabited by the living organisms. Within the safe limits which usually describe a nature landscape distant from active ionizing radiation source, the gamma background could be also described as air dose rate building the so-called natural radiation background. Its name comes from the sources from which the natural radiation is emitted, which are mostly soil, rocks, cosmic radiation and elements naturally present in the environment. Terrestrial radiation comes from the radionuclides present in the earth's crust (primordial radionuclides), soil, rocks, water and air [1]. Primary radionuclides predominantly found in rock and soils are ^{238}U, ^{232}Th and ^{40}K. It is reported that contribution of radon is not significant for outdoor radiation [2], but for the present research, its presence defined by air temperature and air humidity is the main factor for the development of the gamma radiation levels. Excluding cosmic radiation from extraterrestrial sources, major radiation along the water objects’ bank comes from the nearby rocks at higher altitudes, river sediment and water whereas in plain areas the key radiation sources are soil, sediment and water [1].

The temperature and the humidity of the air are two of the air parameters, with most active influence on the physic-chemical processes in the environment. Their relation with the gamma radiation had been a subject of lots of measurements and analyses and it is a subject of the present research.

Gamma radiation and air temperature

Air temperature can cause fluctuations in gamma dose rate within the range of 0.018–0.0053 $\mu Sv.h^{-1}$ depending on the air temperature [3], but at the same time, higher temperatures might reduce radon levels, which could in turn decrease the dose rate [4]. The dose rate also tends to be lower in winter and higher in summer, which is attributed to changes in weather and soil conditions [5, 6].

Gamma radiation and air humidity

Relative humidity is usually positively correlated with gamma dose rate [3, 4], but could be also inversely correlated with air temperature, meaning that when the temperature rises, relative humidity typically decreases, and *vice versa* [3, 7]. Higher humidity levels are also associated with increased radon concentrations, which can contribute to higher dose rates [4].

The overall impact of meteorological parameters, including air temperature and air humidity, on natural radioactivity and dose rates is significant. These parameters can cause variations in the natural atmospheric radioactivity, which in turn affects the dose rates [4, 8].

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EXPERIMENTAL

The present study assesses the gamma radiation background values in two different ecosystems – a lake and a river for a period of seventeen consecutive months and seeks their relation with air humidity and air temperature values. The measurements of ambient dose equivalent rate (H*10) DER, commonly referred to as "air dose rate" were performed in two test fields – Lake Vaya and River Karaagach, located alongside the southern coastline of Black Sea coast. It is measured in μSv h^{-1}. A "Terra" dosimeter-radiometer MKS – 05 – a portable survey meter – Fig. 1, based on energy-compensated Geiger-Müller counter was used.

Fig. 1. "Terra" dosimeter-radiometer MKS – 05

It is designed to measure ambient dose equivalent and ambient dose equivalent rate of gamma radiation (or photon-ionizing radiation), with ±15 % accuracy in the gamma energy range from 0.05 MeV to 3 MeV –Fig. 1 [9]. It is designed for measurement of in the range of 0.001 to 9999 mSv. To measure the gamma/photon-ionizing radiation, the dosimeter was directed with its metrological mark "+" towards the examined area at the height of 1 m. The final values were obtained as an arithmetic mean of the five last measurements after the LCD of the survey meter stopped blinking. For the determination of gamma dose rate the monitoring area is determined roughly as a circle with radius of 1 meter and a center-the sampling point. Within the surveyed area around the sampling point, the radiological examination includes three points, for the operator to stop, to measure the background. The three locations (points) are placed approximately at the vertices of an equilateral triangle, with the center – the sampling point. The area thus formed is traversed at a speed of about 5-10 cm/s.

The gamma dose rate, the air temperature and air humidity were measured at the height of 1 m above the ground, at eleven monitoring points above land, lake and river banks within the two test fields. Six monitoring points were placed alongside the lake banks of the Vaya lake – Fig. 2a and five alongside Karaagach river – Fig. 2b.

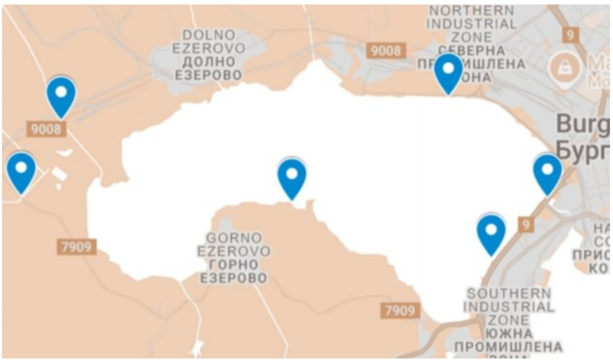

Fig. 2a. Monitoring points alongside the banks of the Vaya lake

On the same monitoring points air temperature (specified in units of degrees Celsius (°C) and air humidity (specified in %RH). were measured. Air temperature and air humidity were measured with Humidity &Temperature meter. The air dose rate measurements were performed by the "Terra" dosimeter-radiometer MKS – 05.

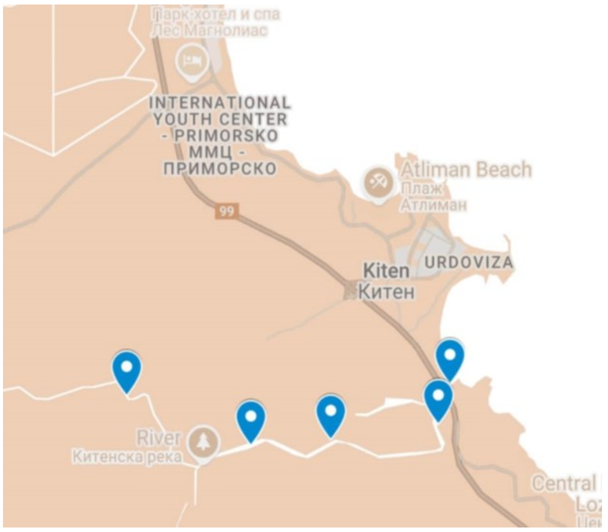

Fig. 2b. Monitoring points alongside Karaagach river

RESULTS AND DISCUSSION

Reliability of data

The reliability of the data gathered was analyzed and reported using Cronbach's α coefficient of an excellent value of 0.952, which indicates very high internal consistency among the measured items (gamma/air dose rate, air temperature and air humidity). Since some of the items have similar values (especially for gamma air dose rate), this value (α = 0.952) could also indicate that some items are very similar or overlapping in composition.

Mean values of gamma air dose rate

The mean values of gamma air dose rate of Karaagach river and Vaya lake are (MV Karaagach =0.1336, MV Vaya Lake=0.1538) – Fig. 3.

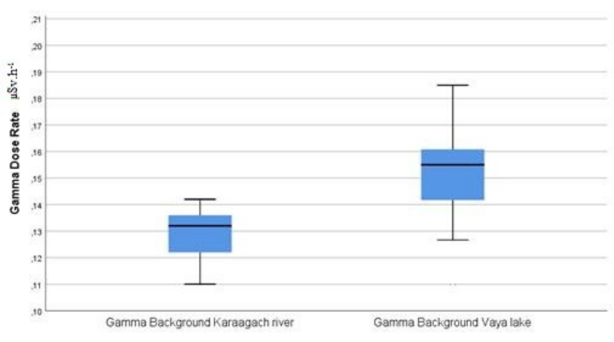

Fig. 3. Mean values of gamma air dose rate of Karaagach river and Vaya lake

It is seen that the average gamma dose rate alongside the river banks is by 15 % lower than that alongside the lake banks. Since we have only data on three environmental factors - gamma air dose rate, air humidity and air temperature, the possible explanation on that fact could be the radionuclide concentration at the monitoring points.

Vaya lake (also known as Burgas Lake), is the biggest natural lake in Bulgaria and the shallowest Black Sea costal lake. During the last decades Vaya lake has undergone significant changes due to different anthropogenic factors which disturb the water balance of the lake and lead to introduction of biogenic elements in the wetland with a negative effect on the chemical composition of the water with impacts on the flora and fauna of the aquatic ecosystem [10]. Its length is 9.6 km, its width is from 2.5 to 5 km, its area is 28 km^2, and its depth reaches 1.3 m. Vaya lake is located on the outskirts of the city of Burgas. It is subject to strong anthropogenic pressure due to its proximity to the densely populated city, large industrial facilities and complexes, as well as the unlimited and uncontrolled access of people outside the protected areas [11]. As an urban lake, Vaya lake's radionuclides may originate from atmospheric deposition, or anthropogenic sources. These radionuclides tend to settle in the still water, leading to higher concentrations near the lake bed and banks, which explains the higher mean values in gamma air dose rate.

Karaagach river, also known as Kitenska river, [12] is a 36 km long river in Burgas province in southeastern Bulgaria. Its maximum depth is 14 m and its basin size is 182 km^2. The depth, size, water flow and distance from direct anthropogenic sources makes Karaagach river different from Vaya lake. In that case, the lower gamma air dose rate could be a result of low radionuclide levels, more diluted due to the continuous river flow and the mobile nature of river sediments, which reduces their localized accumulation.

Correlation among items

The overall correlation between mean values of the items: (1.1) Gamma air dose rate Karaagach river, (1.2) Temperature Karaagach river, (1.3) Humidity Karaagach river, (2.1) Gamma air dose rate Vaya lake, (2.2) Temperature Vaya lake, (2.3) Humidity Vaya lake, assessed by Pearson correlation analysis (Table 1), shows that:

- *Eco system Karaagach River.* (1.1) Gamma air dose rate for Karaagach river is negatively correlated with (1.2) Temperature Karaagach and positively correlated with (1.3) Humidity Karaagach. (1.2) Temperature Karaagach is positively correlated with (1.3) Humidity Karaagach ($p<0.01$).
- *Eco system Vaya Lake.* (2.1) Gamma air dose rate Vaya lake is positively correlated with (2.2) Temperature Vaya lake and positively correlated with (2.3) Humidity Vaya lake, ($p<0.05$). (2.2) Temperature Vaya lake is negatively correlated with (2.3) Humidity Vaya lake.
- *Temperature and humidity.* The average air temperatures measured alongside the two water objects at the observed monitoring points are different. It could be seen from air temperatures' mean values, which are higher on the lake, than on the river (MV Vaya lake = 20.63°C and MV Karaagach river = 18.83 °C) – Fig. 4.

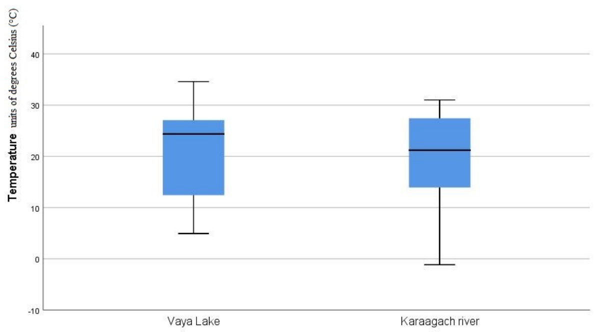

Fig. 4. Air temperature mean values alongside the lake and alongside the river

On the contrary, the difference in air humidity is reversed. According the mean values the air humidity values alongside the river are higher than the ones alongside the lake (MV Vaya lake = 51.33%RH and MV Karaagach river=54.17%RH) – Fig. 5.

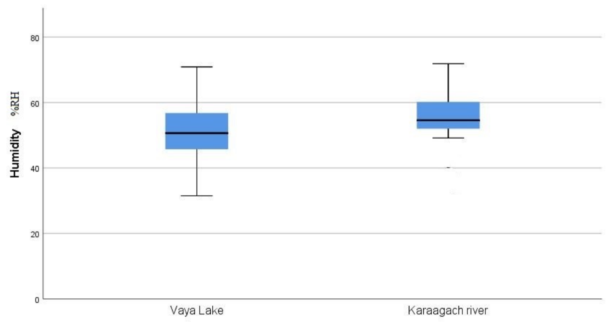

Fig. 5. Air humidity mean values alongside the river and the lake

That is seen by both the correlation analysis (Table 1) and the graphic depiction of the values in the observed months – Figs. 6a, 6b.

Table 1. Correlation amongst mean values of the items: (1.1) Air dose rate Karaagach river, (1.2) Temperature Karaagach, (1.3) Humidity Karaagach, (2.1) Air dose rate Vaya lake, (2.2) Temperature Vaya lake, (2.3) Humidity Vaya lake.

	1.1	1.2	1.3	2.1	2.2	2.3
1.1	1					
1.2.	–0.242	1				
1.3.	0.042	0.693**	1			
2.1.				1		
2.2.				0.019	1	
2.3.				0.484*	–0.039	1

*p<0.05, ** p<0.01

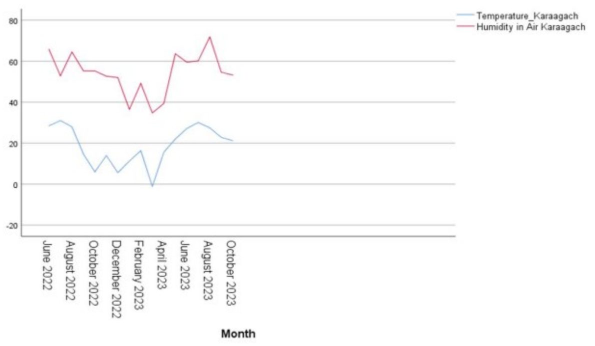

Fig. 6a. Temperature and air humidity values – Karaagach river for the period June 2022-October 2023 graphic view

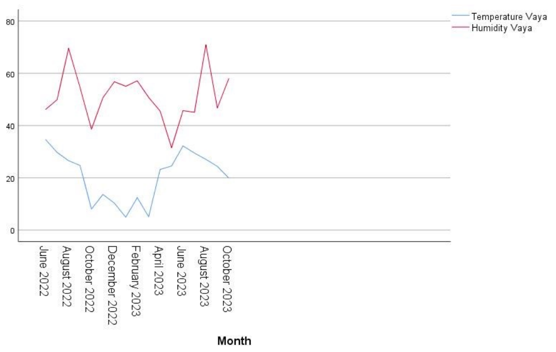

Fig. 6b. Temperature and air humidity values –Vaya lake for the period June 2022-October 2023 graphic view

We see that higher levels of humidity are related to lower gamma radiation values in Karaagach river. This could be explained by the absorption and attenuation of gamma rays by the water molecules in humid air. This attenuation results in lower measured gamma radiation levels. Near a river, when air temperature increases, the water temperature also often rises leading to increased evaporation. Higher evaporation adds moisture to the air, raising humidity levels. A lake, being smaller or more isolated, may experience different dynamics. During hot periods, the lake's water might quickly evaporate initially, increasing local humidity, but if the water level significantly drops, the surface area decreases, reducing ongoing evaporation.

Along the Karaagach river, as a larger water body, the continuous moisture source leads to a positive correlation between temperature and humidity. Along Vaya lake, the smaller or more isolated water body and moisture source leads to a negative correlation due to the higher air temperature and the rapid drying of air they cause.

CONCLUSIONS

The observed correlations between the items air dose rates and environmental factors (air temperature and air humidity) at different locations—river and lake—are influenced by a combination of physical and environmental factors, as well as by the sensitivity of the used dose rate meter.

The observed differences in gamma radiation dose rates alongside lake and river banks could be related with the different sediment accumulation patterns, water flow dynamics, anthropogenic impact, etc. Vaya lake's higher gamma dose rate might be due to the localized radionuclide concentrations alongside its banks because of sediment settling, leading to elevated gamma dose rates, whereas rivers' flowing waters of Karaagach river tend to disperse radionuclides, resulting in generally lower localized dose rates along its banks.

Higher levels of humidity are related to lower gamma radiation values in our research. This could be explained by the absorption and attenuation of gamma rays by the water molecules in humid air. This attenuation results in lower measured gamma radiation levels. Along the Karaagach river as a larger water body, the continuous moisture source leads to a positive correlation between temperature and humidity. Along Vaya lake, the smaller or more isolated water body and moisture source leads to a negative correlation due to the higher air temperature and the rapid drying of air, they cause.

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REFERENCES

1. Sh. Prerna, K. Meher Prabodha, P. Mishra Kaushala, *Journal of Radiation Research and Applied Sciences*, **7**, 595 (2014).
2. N. Kavasi, J. Somlai, G. Szeiler, B. Szab I. Schafer, T. Kovacs, *Radiation Measurements*, **45**, 1068 e1071 (2010).
3. Y. Jung, Z. Shang-Guan, F. Zhao, M. Lin, X. Sha, D. Luo, Q. Chen, K. Peng, *Journal of Environmental Radioactivity*, **192**, 467 (2022).
4. R. Rabi, L. Oufni, *Radiation Physics and Chemistry* **139**, 40 (2017).
5. C. A. Baciu, *Journal of Radioanalytical and Nuclear Chemistry,* **268** (1), 3 (2006).
6. K. Kossert, S. Pommé, U. Stolzenberg, *Applied Radiation and Isotopes*, **210**, 18 (2024).
7. L. V. Allen Jr., R. McKenzie, A. Ron, E. S. Kastango, R. Kaestner, A. Rebelo, P. Burnside, G. Schultz, *International Journal of Pharmaceutical Compounding*, **14** (4), 284 (2010).
8. E. Simion, I. Mihalcea, F. Simion, C. Pacurar, *Revista de Chimie*, **63** (12), 1251 (2012).
9. Operating manual, MKS-05 "TERRA" dosimeter-radiometer (2020)
10. R. Dimitrova, E. Nenova, B. Uzunov, M. Shishiniova, M. Stoyneva, *Bulgarian Journal of Agricultural Science*, **20**, 165 (2014).
11. The birds in Bulgaria, website approached June 18th 2025, https://www.birdsinbulgaria.org/ovm.php?l=en&pageNum_Ovm_All=0&totalRows_Ovm_All=113&id=35
12. Scientific Information Center "Bulgarian Encyclopedia", 113 (2015).