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Radon Concentration and Annual Dose at S.Ind.Ai.R. Schools

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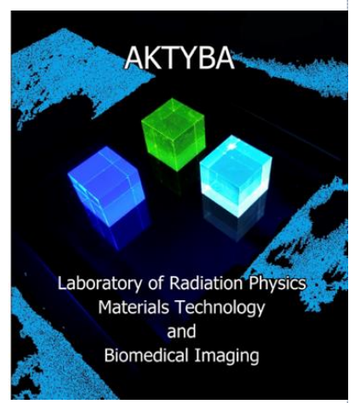
1. Background-Aim

- The air quality affects human health, safety, physiology, productivity. **S.Ind.Ai.R. (School Network for Indoor Air Quality and Radon** - https://sindair.blogspot.com/) conducts research and informs the community about Radon concentrations and air quality at schools.
- In **2023** we researched **Radon concentrations**, the first cause of lung cancer for never smokers. This research aims to contribute to the **National Action Plan for Radon Mitigation** (ΕΣΧΕΔΡΑ).
- Radon is an inert radioactive gas resulting from the underground decay of higher radionuclides and transcends pores and cracks all the way to the surface of the Earth and the water masses. It enters indoor spaces through building pores and cracks or from the building materials and accumulates. Radon itself leaves no residue to the respiratory system. However, **the radioactive products of its decay remain within the respiratory system and irradiate it, causing cancer**.
- The **WHO** recommends a **reference value (RV)** of **100 Bq/m³** for the average Indoor Radon concentration and a RV of **200 Bq/m³** for cost effective Radon mitigation. In the **EU** the RV for taking action is **300 Bq/m³**. In the **USA** the value is stricter, **148 Bq/m³**.



2. Materials & Methods

Measuring Radon at school classrooms

The usual way to measure the average indoor Radon concentration is through passive dosimeters, placed more than half a meter away from any wall and higher than one meter above the floor, for longer intervals (3 months to a year). But Radon monitoring can be done with inexpensive active instruments (Radon monitors).

Active measurements were conducted with the Radon monitor RadonEye BLE in 24 classrooms, in 12 schools of 3 regions during the four-month period between February and May 2023. Each classroom was measured for about 24 hours or more. All schools were of secondary education (adolescent population, mostly between 12 and 17 years of age).

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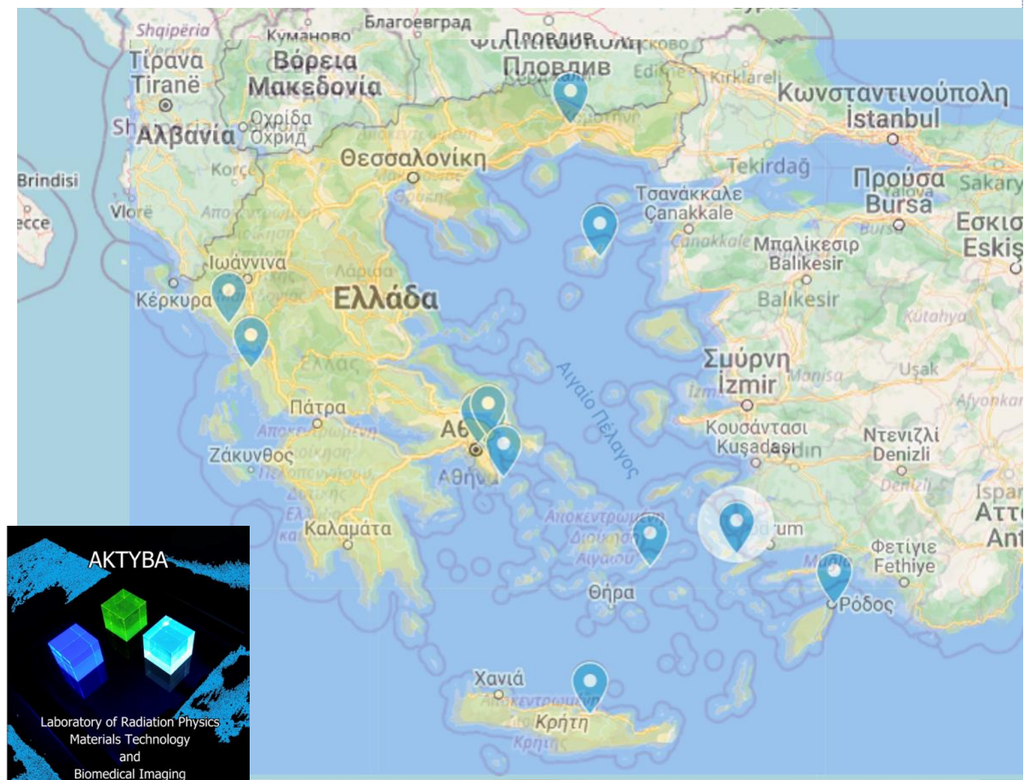
Annual dose to the lung

From the average Radon concentration during school hours the dose to the lung solely from school Radon was calculated and the annual dose to the lung was estimated, based on the assumption that the subjects remain in the classroom during school hours, or projected by including other source scenarios.

The calculation was done by assuming that 24-hour exposure to 200 Bq/m^3 results in annual dose of 1,2 mSv for adults, while respective doses for adolescents do not differ substantially (Kendall et al, 2005).

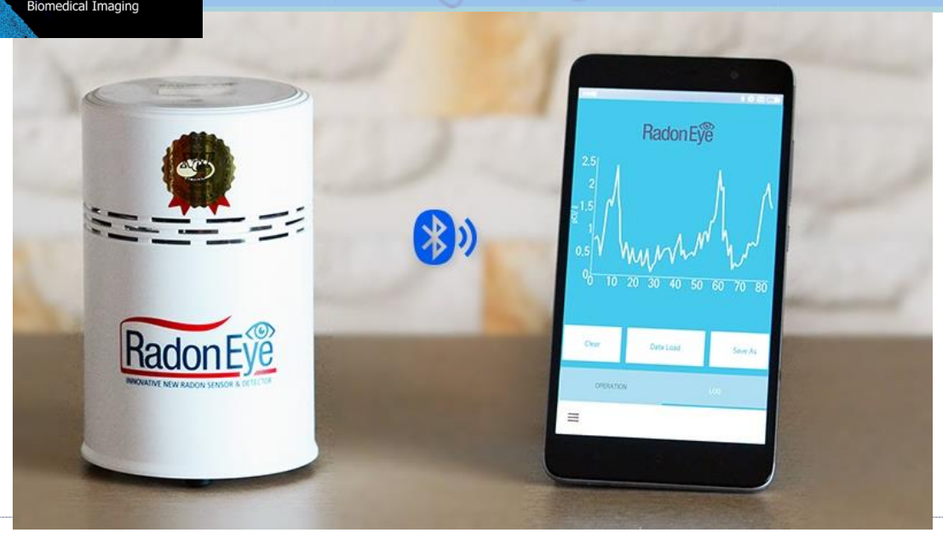
2. Materials & Methods

In general, Greece presents low Radon concentrations (yellow areas) and only some areas with somewhat higher concentration (orange areas) mainly in Northern Greece, vlose to radioactive deposits. The highest observed average value in the National Radon Map (depicted in the next picture) is 511 Bq/m^3, recorded in Northwestern Greece.



In April 2023 we sent the commercial Radon monitor RadonEye. It is small and handy and can be connected to smartphones via Bluetooth. It is inexpensive and considered as reliable as Radon alert. We chose 12 schools from the most densely populated areas as well as areas with high average concentrations and areas with fewer measurements, both in the mainland and in islands.

Due to the high variability of Radon concentration (Figure 1) through the day, we measured for a period of at least 24 hours in every classroom to obtain more reliable averages.



3. Results

24 classrooms in 12 schools

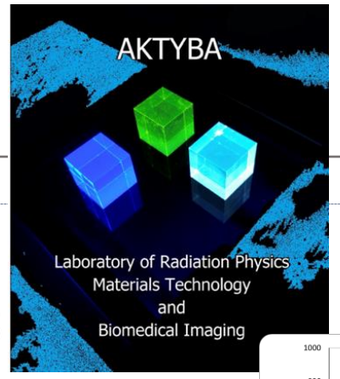
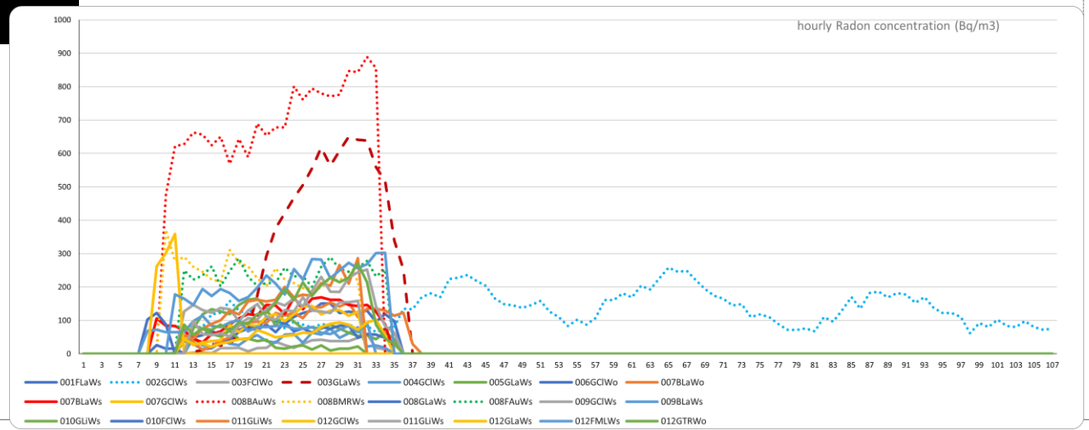
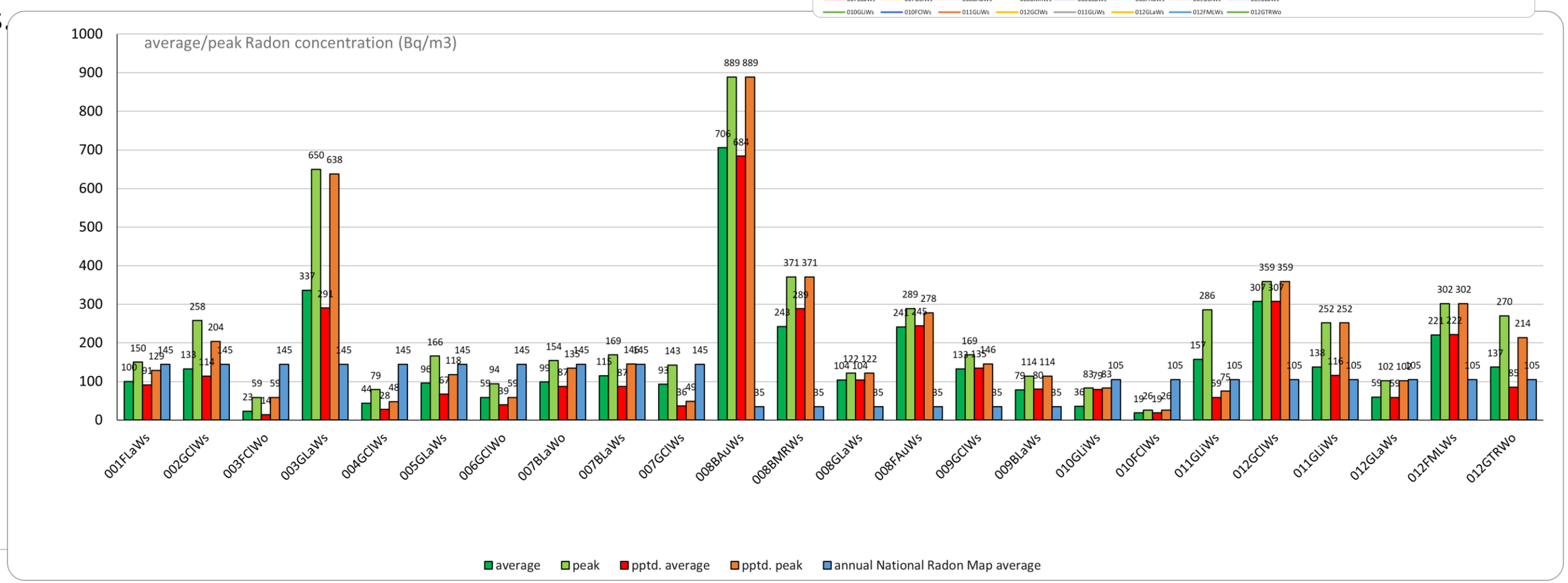


Figure 1. Average and maximum (peak) value over 24hours, average of school hours (pptd. average), maximum of school hours (pptd. peak) and National Radon Map values.

Figure 2. Daily variation per hour (Hour 00:00 -> Value: 1)





3. Results

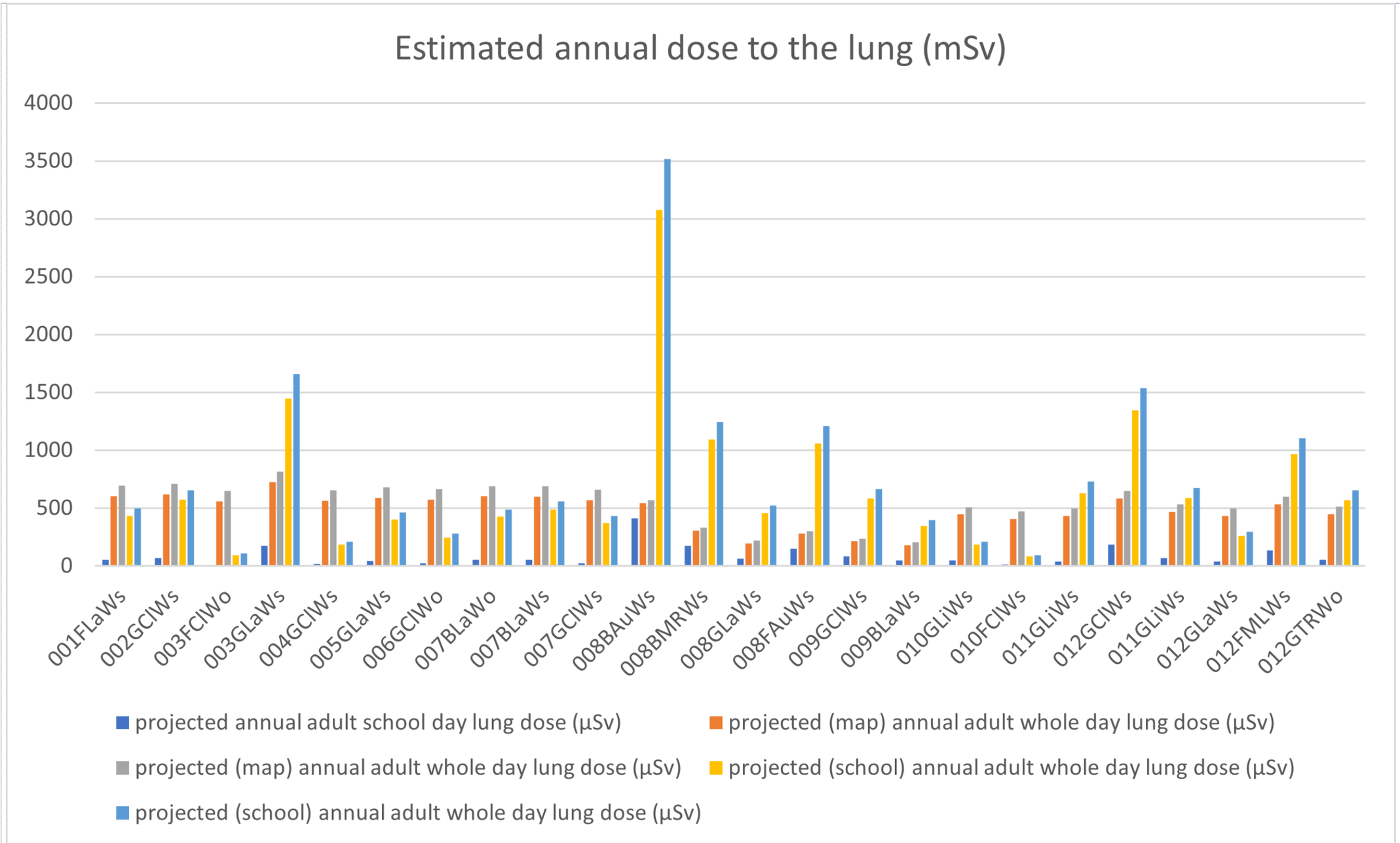


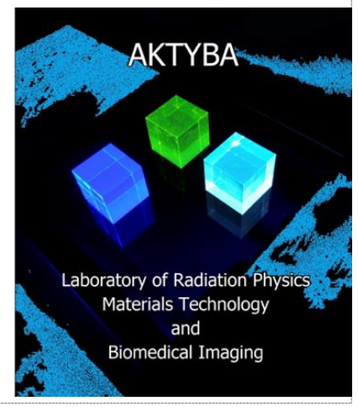
Figure 3. Estimated (projected) annual dose to the lung (mSv).

Annual dose to the lung estimation (projection)

The average Radon concentration in 60% of the classrooms exceeded the WHO recommended reference value (RV) of 100 Bq/m^3. In 25% of the classrooms, it exceeded 200 Bq/m^3, the WHO RV for cost effective Radon mitigation. In 12% of the classrooms, it exceeded 300 Bq/m^3, the EU action RV (Figure 2).

The annual dose to the lung (reference value 1000 mSv) from Radon was estimated (or projected) in three scenarios (Figure 3).

1. From Radon at school ***only***, it ranged from 9 to 412 mSv, average of all classrooms: 84 mSv (calculated estimation).
2. From all indoor Radon, including classrooms and indoor places with ***assumed*** Radon concentration similar to school, it ranged from 82 to 3515 mSv, average of all indoor sources: 700 mSv (calculated projection).
3. From all indoor Radon, including classrooms and indoor places with ***assumed*** Radon concentration as in the corresponding local values of the National Radon Map of Greece, it ranged from 180 to 813 mSv, average of all indoor sources: 510 mSv (calculated projection).



4. Conclusions

OBSERVATIONS

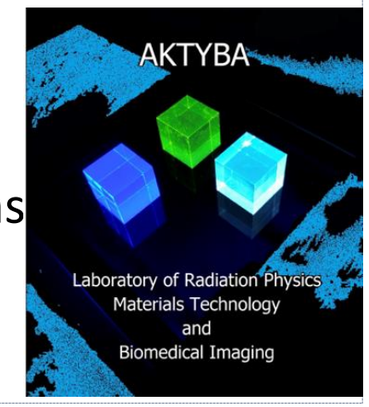
- Few classrooms exceed the EU reference value (300 Bq/m^3).
- Many classrooms are close to the USA reference value (148 Bq/m^3).
- Values decrease substantially when ventilation is introduced.
- The deviation between school hour averages and 24hour averages is small.
- The deviation from the values of the National Radon Map is small, except from island schools, where the deviation is consistently large.

MAIN CONCLUSIONS

- As the indoor Radon concentration increases in the winter, the annual dose may be higher than estimated in this study.
- The estimated total annual dose from the classroom and other sources outside schools may exceed the reference value of 1000 μSv for some cases. These classrooms contribute the most part of the increased dose.

SUGGESTIONS

- Update of the National Radon Map may be commendable in islands.
- Ventilation is recommended also during the winter in ground and underground classrooms
- Thorough Radon measurements at schools may be a necessary basis for further epidemiological studies of carcinogenesis.



5. References

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