INTRODUCTION

In 2010, an industrial accident near Ajka city, Hungary led to a large quantity of red mud flooding the surrounding settlements, causing significant human, material and environmental damage. The area was remediated circa six months later, however, in order to avoid similar accidents, changes were implemented in red mud deposition. Storage was changed from wet technology to a dry procedure, there is no longer an alkali process solution above the red mud, which can lead to dehydration and dusting of the red mud. The resulting risk of higher particulate matter concentration in air could have also carried over an increased quantity of naturally occuring radioactive materials (NORM), and also provides the ability for the long-lived decay products of decomposing radon to adhere to aerosol. Monitoring is necessary for assessing airborne pollution to investigate the effect of technological change and to ensure the protection of the population and the environment. Biomonitoring by the tobacco plant seems to be suitable for this, tobacco is an annual plant, due to its nicotine content the tobacco plant is unlikely to be consumed by animals and it has large, hairy, sticky leaves that can accumulate falling aerosols. However, the uptake path of polonium and lead in the tobacco plant is not yet fully elucidated, as it is capable of uptake through its roots and leaves as well.

AIM

The aim of this work is to monitor the remediation, to monitor the migration of radionuclides, and to determine the applicability of the Po(Pb)-210 in tobacco plants for biomonitoring aerosol contaminant emitted from the red mud reservoir. To this end I investigated the natural radionuclide content in the soil around the reservoir at different distances at the same points and the temporal change of Po(Pb)-210 in the planted active biomonitor tobacco plants, their correlation with the Rn-222 content of the air, and the weather differences during the test period.

MATERIALS AND METHODS

During my work, I measured the activity concentration of Po(Pb)-210 in tobacco plants and in soil samples at red mud-contaminated areas and non-contaminated areas in the years 2011, 2012, and 2014. In 2012 and 2014, I determined the Rn-222 concentration in air using CR-39 detectors. Also in 2014, the concentration of Ra-226 in the soil samples was determined.

During the radiological analysis of the samples I utilized gamma-spectrometry by HPGe detector and alpha spectrometry by PIPS detector. After etching, the CR-39 print detectors were evaluated using a scanner.

RESULTS

Based on the results, it can be said that no significant radionuclide migration occurred in the areas affected by red mud. However, due to the change from wet to dry mud storage / deposition technology on 28 February 2011 and dry weather in 2012, air pollution exceeded the health limit, and the tobacco plant can be used as a bio-indicator for this air pollution. In addition, In addition, I found that there is no close relationship between the concentration of Rn-222 in the air and the concentration of Po(Pb)-210 activity on the leaf surface, or the soil Ra-226 and soil Po(Pb)-210 and the tobacco leaf Po(Pb)-210 concentrations. There is no close correlation, from this I conclude that a large portion of the elevated Po(Pb)-210 concentration on the leaf surface of the tobacco plant is due to an external source, red mud dusting. Therefore the tobacco plant can be used to monitor atmospheric (dust) pollution.

THESE OF THE (PhD) DISSERTATION

I. THESIS

The quasi linear characteristics curve observed at low activity concentrations (26,0-53,6 mBq/g) by the colleagues from the Institute of Radiochemistry and Radioecology at the University of Pannonia, suggesting a good correlation between Po(Pb)-210 activity concentrations in soil and tobacco leaves with a suggested indication range of 20-100 mBq/g is not present in the observed area, and it does not explain the activity concentrations observed in my study.

There is no good correlation between Ra-226 content in soil, Po(Pb)-210 content in soil or Rn-222 concentration in air and the activity concentration of Po(Pb)-210 in the tobacco leaves. The observed activity concentrations indicate that an aerosol with a different equilibrium state and a higher Po(Pb)-210 activity concentration than locally observable from an external source is increasing the Po(Pb)-210 activity concentration

measured in tobacco leaves. This external source is probably the dust coming from the red mud depository containing excess Po(Pb)-210.

II. THESIS

I have proven the usability of tobacco plants for the biomonitoring of Po(Pb)-210 aerosol based on the Po(Pb)-210 activity concentrations measured in tobacco plants grown in the vicinity of the red mud depository and settlements afflicted by the red mud.

Sampling point 6 shows that tobacco plants take up Po(Pb)-210 through their roots, however the elevated Ra-226 and Po(Pb)-210 content of soil did not increase the Po(Pb)- 210 concentration in the tobacco leaves to a similar extent as was observed in the areas afflicted by the resuspended red mud. On the other hand the distance from the depository and the Po(Pb)- 210 activity concentration measurable in the plants are correlated according to the

Pearson correlation coefficient, the plants located nearer, with the higher aerosol load, have higher concentrations. Based on the obtained data areas afflicted with dust fallout have tobacco leaves with activity concentrations elevated unproportionally compared to concentrations in soil.

III. THESIS

Based on the results it can be said that there is no significant radionuclide migration in the observed area, however the effects of the dust from the red mud deposition can be easily observed.

Comparing the weather data of the three years and the Po(Pb)-210 activity concentrations observed in the tobacco plants we can observe **that dry and windy weather will result in a significant dust load, which we can find in both the dust load measured at a nearby weather station and the increase in the increase of Po(Pb)-210 activity concentrations observed in the tobacco leaves.**

2012 was the hottest, the dryest and the windiest in the vegetation period, during which the aerosol concentration exceeded public health regulations multiple times. In this year the average Po(Pb)-210 activity concentration of the tobacco leaves was significantly higher than in 2011 and 2014.

On the other hand precipitation increases wet deposition, so the aerosol load from the red mud depository and the accompanying Po(Pb)-210 load was limited to the near vicinity of the depository. The year 2014 had the most precipitation and the lowest wind speed, increasing wet fallout and decreasing aerosol load. In 2014, the correlation between soil Po(Pb)-210 activity concentrations and the distance was moderate, but in the close vicinity of the depository Po(Pb)- 210 activity concentrations further increased in both soil and tobacco leaves compared to 2012.

ÉRTEKEZÉS ALAPJÁT KÉPEZŐ TUDOMÁNYOS KÖZLEMÉNYEK JEGYZÉKE / PUBLICATIONS THAT POSE THE BASE OF THE DISSERTATION

Nemzetközi referált folyóiratban megjelent idegen nyelvű publikációk / Publications in foreign languages

Kovács, T., Horváth, M., Csordás, A., Bátor, G., Tóth-Bodrogi, E,. **Tobacco plant as possible biomonitoring tool of red mud dust fallout and increased natural radioactivity.** Heliyon. 6: 3 p. e03455 Paper: e03455 (2020)

Horváth, M., Shahrokhi, A., Bátor, P., Tóth-Bodrogi, E., Kovács, T., **Determination of Po-210 content in cigarette smoke using a smoking machine: A case study of Iranian cigarettes.** Journal of Environmental Radioactivity. 174 pp. 66-70. 5 p. (2017)

Kovács, T., Horváth, M., Sas, Z., Dung, B.D., Minh T.K., **Determination of 210Po content of vietnamese tobacco samples.** Central European Journal of Chemistry. 12: 11 pp. 1127-1132. 6 p. (2014)

Máté, B., Horváth, M., Somlai, J., Kovács, T., **Using tobacco plants as biomonitors of contaminated norm areas.** Journal of Radilogical Protection. 33: 1 pp. 81-89. 9 p. (2013)

Egyéb, az értekezéshez nem szorosan kapcsolódó tudományos közlemények/ Other publications, not tightly connected to the dissertation

Nemzetközi referált folyóiratban megjelent idegen nyelvű publikációk / Publications in foreign languages

Konferencia kiadványok/ Conference publications

Jónás, J., Horváth, M., Bátor, G., Kovács, T., Somlai, J., **Radiological survey and monitoring of special remediated area in Hungary.** In: T, Kovács; E, Tóth-Bodrogi; G, Bátor (szerk.) V. Terrestrial Radioisotopes in Environment: International Conference on Environmental Protection, Veszprém, Magyarország: Social Organization for Radioecological Cleanliness p. 48. (2016)

Horváth, M., Hegedűs, M., Csordás, A., Somlai, J., Kovács, T., **Preliminary study of polonium intake of tobacco plant: adsorption path**. In: Proceedings of the 3rd International Conference on Po and Radioactive Pb isotopes p. 141. (2015)

Kovács, T., Horváth, M., Csordás, A., Bátor, G., Tóth-Bodrogi, E., Somlai, J., **Po-210 and Pb-210 concentrations of tobacco plant grown on contaminated areas.** In: Proceedings of the 3rd International Conference on Po and Radioactive Pb isotopes (2015)

Egyéb publikációk/ Other publications:

Cikkek/ Article:

Ozden, B., Guler, E., Vaasma, T., Horvath, M., Kiisk, M., Kovacs, T., **Enrichment of naturally occurring radionuclides and trace elements in Yatagan and Yenikoy coal-red thermal power plants, Turkey.** Journal of Environmental Radioactivity. 188: 8 pp. 100-107., 8 p. (2018)

Horvath, M., Ipbuker, C., Hegedus, M., Kovacs, T., Tkaczyk, A.H., **Development of measurement system for adsorption of long-lived radon decay products on the leaf surface of tobacco plants.** Journal of Radioanalytical and Nuclear Chemistry. 313: 2 pp. 391-400., 10 p. (2017)

Csordás, A., Fábián, F., Horváth, M., Hegedűs, M., Somlai, J., Kovács, T., **Preparation and characterisation of ceramic-based thoron sources for thoron calibration chamber.** Radiation Protection Dosimetry. 167: 1-3 p. 151 (2015)

Kovács, T., Horváth, M., Tóth-Bodrogi, E., Somlai, J., **^{210}Po, ^{210}Pb, ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs Concentration of Medicinal Herbs.** Radiation Emergency Medicine. 4: 2 pp. 40-44., 5 p. (2015)

Gregorič, A., Vaupotič, J., Kardos, R., Horváth, M., Bujtor, T., Kovács, T., **Radon emanation of soils from diferent lithological units.** Carpathian Journal of Earth and Environmental Sciences. 8: 2 pp. 185-190. ,6 p. (2013)

Máté, B., Horváth, M., Somlai, J., Kovács, L., KovácsT., **^{210}Po activity concentration of blood samples after the radon inhalatoric therapy.** Radiation Emergency Medicine. 1: 1-2 pp. 121-126., 6 p. (2012)

Kovács, T., Somlai, J., Máté, B., Horváth, M., Csordás, A., **Növény- és gombaminták ^{210}Po és ^{210}Pb koncentrációjának meghatározása alfa-spektrometriai módszerrel**. Magyar Tudomány, 2012, Vol. 2 146 – 151.

Máté, B., Csordás, A., Horváth, M., Somlai, J., Kovács, T., **Pb(Po)-210 concentration of tobacco samples grown in the vicinity of a remedied uranium mine.** Radioprotection. 46: 6 pp. S161-S165. (2011)

Konferencia kiadványok/ Conference publications

Ozden, B., Guler, E., Vaasma, T., Horvath, M., Kiisk, M., Kovács, T., **The enrichment of NORM in Yatagan and Yenikoy coal-_red thermal power plants, Turkey.** In: 7th International Symposium on IN SItu NUclear MEtrology as a tool for redioecology - INSINUME 2017 : Book of Abtracts p. 52 (2017)

Horváth, M., Jónás, J., Szántó, J., Shahrokhi, A., Kelmen, Sz., Begy, R., Kovács, T., **Results of laboratory intercomparison of Ra-226 measurements in drinking water.** In: T, Kovács; E, Tóth-Bodrogi; G, Bátor (szerk.) V. Terrestrial Radioisotopes in Environment: International Conference on Environmental Protection, Veszprém, Magyarország: Social Organization for Radioecological Cleanliness p. 94 (2016)

Horváth, M., Bátor, P., Tóth-Bodrogi, E., **Kovács, T., Determination of Po-210 content in cigarette smoke using smoking machine.** In: Proceedings of the 3rd International Conference on Po and Radioactive Pb isotopes p. 63 (2015)

Tóth-Bodrogi, E., Horváth, M., Csordás, A., Shahrokhi, A., Kovács, T., **Determination of Po-210 concentration of iranian cigarettes.** In: Proceedings of the 3rd International Conference on Po and Radioactive Pb isotopes p. 140 (2015)

Csordás, A., Fábián, F., Horváth, M., Hegedűs, M., Somlai, J., Kovács, T., **Preparation and characterization of ceramic based thoron sources for thoron calibration chamber.** The 9th International Symposium on the Natural Radiation Environment (NRE-IX) 22 – 26 September, 2014, Hirosaki, Japán (2014)

Horváth, M., Tóth-Bodrogi, E., Bátor, G., Ujhidy, A., **Kovács, T., Study of polonium content in cigarette smoke.** The 9th International Symposium on the Natural Radiation Environment (NRE-IX) 22 – 26 September, 2014, Hirosaki, Japán, Megjelenés: Japán (2014)

Horváth, M., Csordás, A., Hegedűs, M., Kovács, T., **Radionuklidok feldúsulása ipari termékekben és melléktermékekben és azok környezeti hatásai.** PhD hallgatók anyagtudományi napja XIV., 2014. november 24., Veszprém, Hungary

Csordás, A., Horváth, M., Hegedűs, M., Kovács, T., **Kerámia alapú toron források készítése és minősítése.** PhD hallgatók anyagtudományi napja XIV., 2014. november 24., Veszprém, Hungary

Hegedűs, M., Somlai, J., Kovács, T., Horváth, M., Csordás, A., **NORM anyagokból való kioldódási vizsgálatok a vörösiszap példáján.** PhD hallgatók anyagtudományi napja XIV., 2014. november 24., Veszprém, Hungary

Máté, B., Várhegyi, A., Horváth, M., Somlai, J., Kovács, T., **Study of uranium, radium and lead isotope migration on the Mecsek remediated uranium mine sites.** In: Tibor, Kovács; János, Somlai; Borbála, Máté (szerk.) III. Terrestrial Radioisotopes in Environment: International Conference on Environmental Protection, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 99-102., 4 p. (2012)

Máté, B., Horváth, M., Somlai, J., Kovács, T., **Using tobacco plant as bioindicator of the contaminated NORM areas.** In: Miroslaw, Janik; Masahiro, Hosoda; Atsuyuki, Sorimachi; Shinji, Tokonami (szerk.) International Symposium on Natural Radiation Exposures and Low Dose Radiation Epidemiological Studies, Hirosaki, Japán: Hirosaki University, pp. 113-113. Paper: P-79, 1 p. (2012)

Máté, M., Horváth, M., Somlai, J., Kovács, L., Kovács, T., **^{210}Po activity concentration of blood samples after the radon inhalatoric therapy.** In: Prof, Dr. Goran Ristic (szerk.) Proceedings of the First International Conference on Radiation and Dosimetry in Various Fields of Research Nis, Szerbia: University of Nis, Faculty of Electronic Engineering, pp. 153-156., 4 p. (2012)

Fábián, F., Kardos, R., Csordás, A., Horváth, M., Kovács, T., **Determination of uranium in human urine samples using alpha spectrimetry: A preliminarystudy.** In: Tibor, Kovács; János, Somlai; Borbála, Máté (szerk.) III. Terrestrial Radioisotopes in Environment: International Conference on Environmental Protection, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 149-152., 4 p. (2012)

Vaupotič, J., Gregorič, A., Kardos, R., Horváth, M., Bujtor, T., Kovács, T., **Radon emanation from soils of different lithological units.** In: Constantin, Cosma; Dan, Constantin Nita; Alexandra, Cucos Dinu (szerk.) First East European Radon Symposium Cluj-Napoca, Románia: Editura Risoprint, pp. 25-25., 1 p. (2012)

Horváth, M., Csordás, A., Máté, B., Fábián, F., Kardos, R., **Po-210/Pb-210 equilibrium measurements in tobacco samples.** In: Tibor, Kovács; János, Somlai; Borbála, Máté (szerk.) III. Terrestrial Radioisotopes in Environment : International Conference on Environmental Protection, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 153-156., 4 p. (2012)

Kardos, R., Máté, B., Horváth, M., Csordás, A., Gyöngyösi, Cs., Kovács, T., **Survey of uranium in spring waters from Budapest, Bátaapáti waters (industrial area) and Torna, Stream (disaster affected surface water)**. In: Tibor, Kovács; János, Somlai; Borbála, Máté (szerk.) III. Terrestrial Radioisotopes in Environment: International Conference on Environmental Protection, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 45-49., 5 p. (2012)

Máté, B., Csordás, A., Horváth, M., Somlai, J., Kovács, T., **Pb(Po)-210 concentration of tobacco samples grown in the vicinities of a remedied uranium mine.** ICRER2011, Hamilton, Canada, 19-24. 06. 2011., (2011)

Máté, B., Horváth, M., Csordás, M., Somlai, J., Kovács, T., **Pb(Po)-210 levels of tobacco and soil samples at remedied uranium mine.** In: Dumitru, Ristoiu; Melinda-Haydee, Kovacs; Adrian, Piticar; Andreea, Dragus (szerk.) International Conference Environment & Progress : Environment - Research, Protection and Management Cluj-Napoca, Románia: Babes-Bolyai University, Faculty of Environmental Science and Engineering, pp. 79-79., 1 p. (2011)

Csordás, A., Horváth, M., Máté, B., Somlai, J., Kovács, T., **A déli-bakonyból származó ehető gombafajok Po-210 koncentrációjának meghatározása**. In: Kovács, Tibor; Somlai, János (szerk.) II. Földkérgi radioizotópok a környezetünkben : Környezetvédelmi Konferencia, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 115-123., 9 p. (2011)

Kardos, R., Horváth, M., Bujtor, T., Vaupotic, J., Kovács, T., **Radon emanation of slovenian soil samples.** In: Kovács, Tibor; Somlai, János; Szabó, Csaba (szerk.) VI. Magyar Radon Fórum: A Radon a Környezetben Nemzetközi Workshop, Veszprém, Magyarország : Pannon Egyetemi Kiadó, pp. 249-254., 6 p. (2011)

Horváth, M., Csordás, A., Máté, B., **Dohánynövény alkalmazása remediált uránbánya területek vizsgálatában.** In: Üveges, Viktória (szerk.) Pannon Egyetem, Mérnöki Kar Bagoly Almanach (CD), Veszprém, Magyarország : Pannon Egyetem, pp. 54-59. (2011)

Horváth, M., Csordás, A., Máté, B., Somlai, J., Kovács, T., **Dohánynövény alkalmazása remediált uránbánya területek vizsgálatában.** In: Kovács, Tibor; Somlai, János (szerk.) II. Földkérgi radioizotópok a környezetünkben: Környezetvédelmi Konferencia, Veszprém, Magyarország: Pannon Egyetemi Kiadó, pp. 125-132., 8 p. (2011)

Kovács, T., Somlai, J., Máté, B., Horváth, M., Csordás, A., **Növény- és gombaminták ^{210}Po és ^{210}Pb koncentrációjának meghatározása alfa-spektrometriai módszerrel.** MTA Tudományos Ülés, 2011. május 04., MTA székház, Budapest (2011)

Máté, B., Horváth, M., Somlai, J., Kovács, T., **A mecseki uránbánya rekultivációjának ellenőrzése bioindikációs módszerrel.** In: Szentmiklósi, L (szerk.) Őszi Radiokémiai Napok 2011, Budapest, Magyarország: Magyar Kémikusok Egyesülete (MKE), pp. 65-70. , 6 p. (2011)

Máté, B., Csordás, A., Horváth, M., Somlai, J., Kovács, T., **Remediált uránbánya környékén termesztett dohányminták Po-210 koncentrációja.** In: Szentmiklósi, L (szerk.) Őszi Radiokémiai Napok 2010: A konferencia programja és előadás kivonatai, Budapest, Magyarország : Magyar Kémikusok Egyesülete (MKE), pp. 69-69., 1 p. (2010)