An Assessment of Radioactivity and Heavy Metal Concentrations in Dust at Shak El-Thoban Industrial Zone

A.A. Taha; W. M. Abdellah

Abstract— **An investigation was conducted to examine the variation trend of some heavy metal and natural radionuclides concentrations in ambient air at cutting and polishing factories in Shack El-Thoban industrial area, Cairo, Egypt. The present work measures the concentration of some heavy metals such as (Nickel (Ni), Copper (Cu), Aluminium (Al), Cobalt (Co) and Sodium (Na)). The heavy metals were chosen based on the types pollution associated with the industry under this investigation. Natural radionuclides were determined in the dust attached to aerosol particles that collected on filters by a High-Volume Air Sampler after the desired collection period about 1 h. The activity of deposited dust was measured by γ-spectrometry for total activity and the trace and heavy metal determination on the collected dust filters by ICPMS. The data were compared to the air quality standards by the World Health Organization (WHO), United State Environmental Protection (USEPA) and Egyptian Regulation. The evaluated concentrations of trace and heavy metals in ambient air had low concentration compared to the standard. The radioactivity results indicated that most of the measured natural radionuclides fall within the worldwide averages identified by the United Nations Committee on the effects of atomic radiation. The obtained data could be used as reference data for any future use of modelling purposes for the determination of the Annual Limit on Intake (ALI) for long-lived radioisotopes associated with dust.**

Index Terms— **Radioactivity, Heavy metal, Industrial zone, Dust, Pollution**

I. INTRODUCTION

Natural radiation refers to ionizing radiation originating either from high energy cosmic rays entering the earth's atmosphere from outer space or from Naturally Occurring Radioactive Materials (NORM) present in the crust of the earth. This radiation is distinguished from artificial radiation produced through man-made nuclear or atomic transformations. The exposure of human beings to a background of natural radiation is a continuing and inescapable feature of life on earth. The effective dose due to this ionizing radiation for members of the public varies substantially depending on where they live, occupation, personal habits, diet, building type and house utilization pattern [1].

Primordial cosmogenic or anthropogenic radionuclides present in the ambient air are useful tracers for studying physical and health-related processes in the atmosphere [2]. Especially, the knowledge of the ^{222}Rn and ^{220}Rn daughters' Concentration in surface air is important as these radionuclides are responsible for a large fraction of the total public exposure to ionizing radiation. On the other hand, the activity ratios of radon daughters, ^{210}Bi/^{210}Pb or ^{210}Po/^{210}Pb are often used for calculation of aerosol residence times in the surface air and troposphere [3].

Mineral ores in the naturally undisturbed environments, the radionuclides in the decay series are more or less in radiological equilibrium. However, this equilibrium becomes disturbed through human activities such as mining and mineral processing [4].

The area of Shak El Thoban in Katameyya has become a conglomeration of around 400 factories constituting 60% to 70% of marble and granite factories in Egypt working in the marble and granite industry. More than two thousand workshops for complementary industries employ about 25 thousand workers other than 30 thousand workers indirect employment. Problems in these regions are outbreak of a group of diseases (e.g.: tinea, intestinal colic and chest disease) among workers in Shak El Thoban as a result of drinking water and food contamination. Marble and granite industry has stone waste in generally a highly polluting waste due to both its highly alkaline nature and its manufacturing and processing techniques, which impose a health threat to the surroundings. Shak El Thoban industrial cluster in Egypt is imposing an alarm threat to the surrounding communities, the new Maadi, Zahraa Elmaadi, residential area, and the ecology of the neighboring Wadi Degla protectorate [5].

The present study aims to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K eight filter samples collected from Shak El-Thoban industrial zone in Cairo, using HPGe detector in a low background configuration and ICPMS for some heavy metals. The obtained results are compared with the national and international standards for assess the potential toxic and radiological hazards associated with these dust filters.

II. EXPERIMENTAL WORK

A. Sampling and sample preparation for γ-spectroscopy:

The sampling sites are almost systematically distributed within the study area (sampling sites were randomly chosen in cases where the site was not easily accessed) and well distributed to get samples highly representative for the studied area. The filter samples are taken around the basin of the cutting machine and the drain pipes of water, and around the cutting and polishing marble and granite machines.

The filters papers were dried and weighted before taking

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samples, the air filter samples are from the inside work place and outside in the direction of the wind covering all the area of interest (A1:A8) as shown in fig 1. The method is based on the collection of aerosols, which are supposed to contain radioactive fractions attached to them. The method is standardized and relies on the use of an aspiration pump, type (Eberline), with a well determined air flow rate, 35-40 L/min. The aspiration is done within pre-established periods of time, usually one hour, the total volume of air varying between 2,100 and 2,400 L.

Preparation of the collected samples for γ-ray measurements were carried out by drying the sample in an oven at a temperature of 80ºC for 8h. The filters samples were weighed and packed in suitable polyethylene containers or will seal Petri dishes. All samples were closed tightly and left for 28 days to reach secular equilibrium between ^{226}Ra and ^{232}Th, and their respective progenies [6].

Fig. 1. Map illustrating the studied area with the locations of air samples collected from Shak El-Thoban

B. Experimental Method for Gamma Spectroscopy:

Gamma ray spectrometry is a powerful technique for determining qualitative and quantitative low-level natural and anthropogenic radioactivity in environmental and geological samples through their gamma-ray emission. The gamma spectrometric analysis of these samples enables many nuclides to be covered in a single analysis without radiochemical treatment. The large number of publications on radiation monitoring, all over the world, indicates the reliability of gamma ray spectrometry. The coarse and fine gain controls of the spectroscopy amplifier, it's differentiating and integrating time constants and all other controls were adjusted. It is necessary to obtain the best energy resolution and good linearity of the spectrometer over a wide band of the input voltages. After selecting the optimum set up, the resolving power [Full Width at Half Maximum (FWHM)] of the spectrometer was found to be 2.1 keV for the 1332 keV gamma ray line of ^{60}Co and relative efficiency 95.8% [6] (Finland).

C. Metals Concentration on the Filter Samples:

This procedure apples to the preparation and analysis of some potentially toxic heavy metals such as Na, Mg, Mn, Al, Co, Ni, Cu [7] and natural radioactivity (^{238}U & ^{232}Th) on filters. The present procedure describes the acid extraction and trace elemental analysis of ambient air samples using an Inductively Coupled Plasma-Mashs Spectrometer (ICP-MS) Agilent 7500CE/CX with ChemStation Software controlled by a personal computer in combination with the WinNt utility. The applied extraction procedures are suitable for low volume ambient air samples collected on quartz filter exposed to high volume ambient air sampling collected filters (47mm). The filters are extracted by 30 mL of the 10% nitric acid onto the filter conc. nitric acid for 3 hours flux gently for 30 minutes at 95 ºC, filter the extract then diluted to 4%. The extract is analyzed by ICP-MS. The ICP-MS analysis is completed using the manufacturer software following conditions established during calibration and quality control checks of instrument performance by Helsinki University.

III. RESULTS AND DISCUSSIONS

A. Activity Concentration on the Filter Samples:

The specific activity concentrations for the collected dust filter samples for the natural radionuclides, ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in the present study are determined. The results showed that the activity concentrations of all series are below the detection limits by gamma spectrometry except the relatively small concentrations of ^{210}Pb on the filters at some locations that may be attributed to the normal process of decay of ^{222}Rn which diffuses as a gas from soil and different materials such as granite and marble store in the area under this investigation. The calculated activities concentrations of (^{210}Pb) are shown in table 1. Good parameters obtained from a high-purity germanium detector and energy resolution of 1 keV for 47-keV photons. Due to the short range of 47 keV photons in germanium, essentially all photons striking the germanium crystal will be stopped.

The results of γ-spectrometry measurements according to the procedure applied [8] and the calculations for measured ^{210}Pb and other spectrum ^{234}Pa are shown in Figs. 2 & 3.

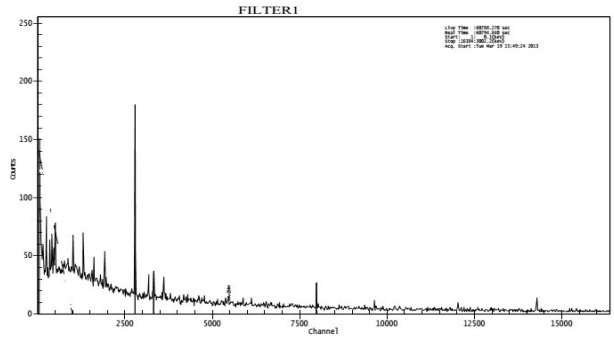

Fig 2. Gamma ray spectra detected on filter 1 by gamma spectrometry.

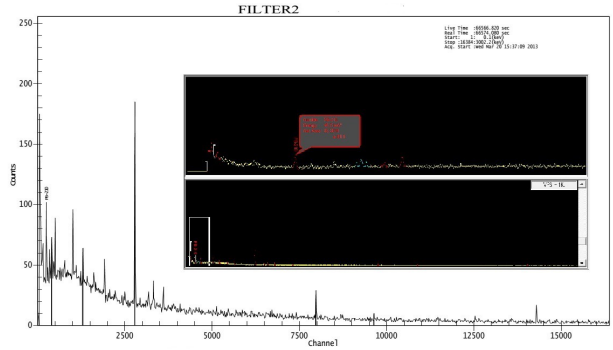

Fig 3. Gamma ray spectra detected on filter 2 by gamma spectrometry

Table 1: Specific activities (Bq/filter) of ^{210}Pb in the collected samples (dry weight) collected from Shak EL-Thoban zone using γ-spectrometry.

Sample Code	Bq/filter	Activity (Bq/m^3) (2250 L Volume)
A1	2.43 ± 0.54	1.10±0.34
A2	0.11 ± 0.07	0.05±0.03
A3	1.10 ± 0.80	0.5±0.35
A4	<DL	<DL
A5	0.53 ± 0.24	0.24±0.1
A6	<DL	<DL
A7	<DL	<DL
A8	0.15± 0.1	0.068±0.04
Average	**0.86±0.35**	**0.38±0.15**

Table 2: Concentration (ng gm^{-1}) of ^{238}U, ^{232}Th and some heavy metals in filter samples (dry weight) using ICPMS represent the origin of the collected samples collected from the work place.

Sample Code	Concentration (ng/g) ppb										
	Metal	**^{238}U**	**^{232}Th**	**Na**	**Mg**	**K**	**Mn**	**Al**	**Co**	**Ni**	**Cu**
A1		1.23	0.75	1868.79	1238.69	638.91	34.73	196.370	2.40	17.93	31.27
A2		0.56	0.07	1139.17	515.82	471.68	20.09	116.969	2.29	21.63	37.11
A3		0.50	0.35	900.60	610.40	319.45	16.90	97.080	1.4	8.10	17.7
A4		--	--	300.70	120.01	160.22	6.69	38.090	--	8.1	12.50
A5		0.55	0.08	1200.01	500.90	470.97	22.10	1260.1	2.1	21.5	35.10
A6		--	--	370.20	171.90	151.27	6.77	40.189	--	--	10.37
A7		0.19	--	389.72	166.14	150.23	7.00	39.989	--	7.21	12.00
A8		0.6	0.1	1140.5	560.02	466.67	25.00	11.7059	2.30	22.05	35.81
Average		**0.61**	**0.27**	**913.71**	**485.50**	**353.67**	**17.41**	**96.470**	**2.1**	**15.22**	**23.98**
WHO	**Maximum Acceptable Value (µg/l)**	30* 810 (10Bq/l)	246 (1Bq/l)	50000	--	--	--	--	--	70	2000
USEPA Secondary	**Maximum Acceptable Value (µg/l)**	30	5 pCi/l				50	200			1000

*The provisional guideline value for uranium in drinking-water is 30 µg/l based on its chemical toxicity for the kidney
1 Bq ^{238}U/kg = 81 ppb
1 Bq ^{232}Th/kg = 246 ppb
1ppb = 1µg/L

The radionuclide concentrations observed vary widely depending on weather conditions (rain, wind directions, humidity…etc.). Relatively low activities of the ^{222}Rn and ^{220}Rn daughters in the ambient air result from the low concentrations of their mother radionuclides, ^{226}Ra and ^{232}Th, in the soil from the Shake El-Thoban zone [9].

The short collection time of 1 h, the identification of ^{218}Po in the continuous part of the low energy spectrum is impossible because of the remarkable decrease in the detection efficiency below 1%, caused by a severe absorption of the alpha radioactivity by the resolution improving metal net collimator. Therefore, for a short filtration period of between 1 to 3 h, ^{218}Po was determinate using the PIPS detector.

The total specific activities ranged from 0.11±0.07 to 2.43±0.54 Bq filter^{-1} with an average value of 0.86±0.35 Bq filter^{-1}. The obtained results for indicate that the activity concentrations of the main naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were lower limits of detection and lower than the world average, which are 12(10-50), 3 (7-50) and 81(100-700) Bq kg^{-1} for ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, respectively [9]. The validation of the method was tested using IAEA the reference material number IAEA-CU-2008-02 (Air filters) [10]. The values obtained were in good agreements with the reference values reported by IAEA indicating validity of our procedure.

B. Metals concentration on the Filter Samples:

Air pollution and its impacts have become one of the most challenging global issues for public health and environmental quality [11]. In recent decades, air pollution has been much focused on atmospheric particles because of its potential adverse health effects and the subsequent need to have a better control or regulate these pollutants [12].

The concentrations of the trace elements that were measured by ICPMS such as ^{238}U, ^{232}Th, K, Na, Mg, Al,

Co, Ni and Cu are illustrated in Table 2. The concentration ranged from 0.19 to 1.23 ppb with an average value of 0.61 ppb. The specific concentration ranged from 0.07 to 0.75 ppb with an average value of 0.27 ppb. The total concentration of K ranged from 150 to 638.91 with an average value of 353.67 ppb. The other metals under this investigation recorded average concentrations for Na, Mg, Mn, Al, Co, Ni and Cu were 913.71, 485.50, 17.41, 964.70, 2.1, 15.22 and 23.98 ppb respectively. The concentration obtained for trace elements associated with dust that collected in the present work were lower than the maximum permissible limits in air / drinking water quality standard recommended by WHO [13] and USEPA [14] guidelines as illustrated in Table 2.

WHO was used as a guideline for heavy metal standard and reference in the dust fall due to the dust fall samples collected in the form of rainwater because there is no suitable standard can be used to determine the concentration of heavy metals in the dust fall due to the polishing and cutting of ore treating plant in the industries area. The obtained concentrations at (sites A1 and A2) for Ni, Cu and Al were found to be relatively higher than the concentrations at the other industrial locations under the present study. The results illustrated in table (2) indicate that filter papers were slightly contaminated by some determined metals and the levels of contamination were variable depending on the position of the filter and work load in the sampling location and this agree with the explanation by Voutsa and Samara (2002) [15].

The calculated total suspended particulates for the collected samples ranged from 4.3 to 9.5 (micrograms/m^3) which lower than the limits set by the Egyptian regulation [16] about the maximum permissible limits of outdoor air pollutants (230 micrograms/m^3 for the exposure period 24h) and this agree with other author Pandey et al.,2008 [17] who determine the dust fall rate and its chemical compositions are important to understand dust pollution.

IV. Conclusion

Determination of radioactivity in non-nuclear industries is a part of the regular environmental monitoring programme. Variation of the measured natural radionuclides and heavy metals fall within the worldwide averages identified by WHO and the United Nations Committee on the Effects of Atomic Radiation [18]. The air filter samples were under the detection limit for activity concentration of ^{226}Ra, ^{232}Th and ^{40}K. the relatively small activity concentration on the filters related to ^{210}Pb.

The filter paper used to determine the trace metal in suspended air (Dust) the trace metals concentrations under this investigation recorded their highest mean values at locations A1 and A2 depending on the work load and the type of the activities of the small factories.

Finally, the obtained data could be used as reference for any future use of modeling purposes for the determination of the Annual Limit of Intake (ALI) for Long-Lived Radioactive Dust (LLRD) that may be associated with polishing and cutting process.

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