# Measurement of Individual Radon Progeny in Egyptian Under Ground Coal Mine and Related Lung Doses

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*Some trace elements in coal are naturally radioactive. These radioactive elements include uranium (U), thorium (Th) and their numerous decay products, including radium (Ra) and radon (Rn). So, the staff of underground coal mine can be exposed to $^{222}$Rn and its progeny ($^{218}$Po, $^{214}$Pb and $^{214}$Po). The present study has been done in El-Maghhara mine. It is located in the middle of Sinai desert about 250 km north-east of Cairo, where a coal-fired power plant is intended to be built in El-Maghhara mine. A filter method was used to measure the individual radon progeny concentrations ($^{218}$Po, $^{214}$Pb and $^{214}$Po). The mean value of activity concentrations of $^{218}$Po, $^{214}$Pb and $^{214}$Po were determined to be 75 ± 8, 49 ± 7 and 28 ± 5 Bq $m^{-3}$, respectively. With a dosimetric model calculation ICRP 66, the total deposition fractions and total effective doses have been evaluated considering the obtained experimental data in the present work [1]. At a total deposition fraction of about 21 ± 4 % the total effective doses to the lung were determined to be 6, 3.3 and 5.3 x $10^{-7}$ mSv$y^{-1}$ for $^{218}$Po, $^{214}$Pb and $^{214}$Po, respectively. The effect of static magnetic field on the biophysical properties of distilled water is investigated in this work. Magnetic field was applied in a direction perpendicular to distilled water drops coming from a burette (drop by drop), using a variable gap magnet, producing a magnetic field of strength varying from 0.2 up to 5 kG. Variations in the rate of flow of water, electric conductivity and dielectric constant were observed. Increasing the strength of magnetic field decreases the rate of flow, increasing both the electric conductivity and the dielectric constant of water.*

## 1. Introduction:

Radon is a naturally occurring radioactive gas. The highest concentrations of radon are recorded in uranium mines, due to its origin from the decay of uranium through radium. Trace amounts of uranium are associated with many minerals, such as iron, zinc-lead and coal mines. Wet mines tend to have relatively high levels of radon due to the dissolution in water and transport of the radon out of the rock into the mine where it vaporizes [2]. The radioactive decay of radon leads to a series of isotopes of polonium, bismuth and lead. These decay products are inhaled and deposited in the different regions of the respiratory tract, where they release alpha irradiation, which interacts with the respiratory epithelium. Alpha particles release high energy and cause intense local ionization, which damages tissue and increases subsequent risk of cancer [3]. The Main Safety and Health Administration (MSHA) regulate both uranium and nonuranium mines for air concentration of radon daughters. Epidemiological studies of health effects from exposures to radon daughters have been conducted in pyrite, phosphate, fluorspar and shale-clay mines. Although the concentration of radon daughters in nonmetal mines are usually lower than those in metal mines, radon daughters and the associated lung cancer risk should be considered when evaluating the health of any miner [3]. Epidemiological investigations of uranium and other underground miners have provided extensive and consistent data on the quantitative risk of lung cancer associated with exposure to radon progeny in [4-11]

Occupational exposures were reviewed in reference [12] in which also a number of recommendations were made with regard to data analyses to obtain much clearer indications of occupational exposure in all areas of work, not only to workers in uranium and coal mines. The staff of other underground workplaces, such as workers in caves, can be exposed to $^{222}Rn$ and its progeny. Radon and radon progeny concentrations were measured in four Hungarian caves. Based on the measured radon concentrations, cumulative WLM exposures, bronchial dose and effective dose equivalent values were calculated for the staff, patients and visitors. The effective dose equivalent values for the cave personnel did not exceed the 20 $mSvy^{-1}$ limit.

The dose for visitors and patients were one or two orders of magnitude lower than those of the personnel [13]. The radiation levels in some uranium mines in Egypt were investigated. In El-Missikat mine, during 1987, readings showed radon daughter concentration ranging from 0.12-1.5 WL (working level), while in 1988 the reading ranged form 1.4-5.6 WL. In Erediya mine, the radon daughters concentrations ranged from 0.084 – 2.4 WL in 1987, in 1988, these levels ranged from 2.26 – 6.22 WL [14]. During the period 1985-1990, the monitoring measurements of radon gas concentrations in (Bq $m^{-3}$) and radon daughters concentrations in (WL) are summarized for some galleries in the Eastern Desert of Egypt [15].

Inhaled radon progeny are deposited in different regions of the human lung as functions of particle size and flow rate. In the case of internally deposited radionuclides, direct measurement of the energy absorbed from ionizing radiation emitted by the decaying radionuclides is rarely, if ever, possible. Therefore, one must rely on dosimetric models to obtain estimates of the spatial and temporal patterns of energy deposition in human lung. When the radionuclides are uniformly distributed throughout the volume of a tissue of homogeneous composition and when the size of the tissue is large compared to the range of particulate emission of the radionuclide, then the dose rate within the tissue is also uniform and the calculation of absorbed dose can proceed without complication. However, if uniformities in the spatial and temporal distributions of the radionuclide are coupled with heterogeneous tissue composition, then the calculation of absorbed dose becomes complex and uncertain. Such as the case with the dosimetry of inhaled radon progeny in the respiratory tract [16].

The dosimetric model of ICRP [1] considers the respiratory tract as four anatomical regions, the extrathoracic region (ET), comprising the anterior nose ($ET_1$) and the posterior nasal passage ($ET_2$), the bronchial region (BB), the bronchiolar region (bb) and the alveolar-interstitial region (Al). In this model each region of the respiratory tract is represented by an equivalent particle filter that acts in series and each breath is represented by a tidal flow of air that carries particles through each anatomical region, which is represented by one or more filters, in series. Each of these filters has two characteristic parameters: its volume and its overall efficiency for removing aerosol particles.

There are increasing demands to obtain a definitive explanation of the role of alpha particles emitted from radon daughters in the induction of lung cancer. Various authors have attempted to evaluate the dose to the respiratory tract due to the inhalation of radon daughters [17-21]

In this study, the individual radon progeny concentrations of $^{218}Po$, $^{214}Pb$ and $^{214}Po$ were measured in the Egyptian underground coal mine (El-Maghara mine). In addition, the annual effective and regional lung doses due to inhaled radon progeny for the worker in this mine were estimated.

## 2. Materials and method:

Maghara coal mine is located in the middle of Sinai about 250 Km East-North of Cairo. In this mine about 8 representative sampling sites were selected along the main gallery of the mine and at locations where the ore is mined, as shown in Fig. (1).

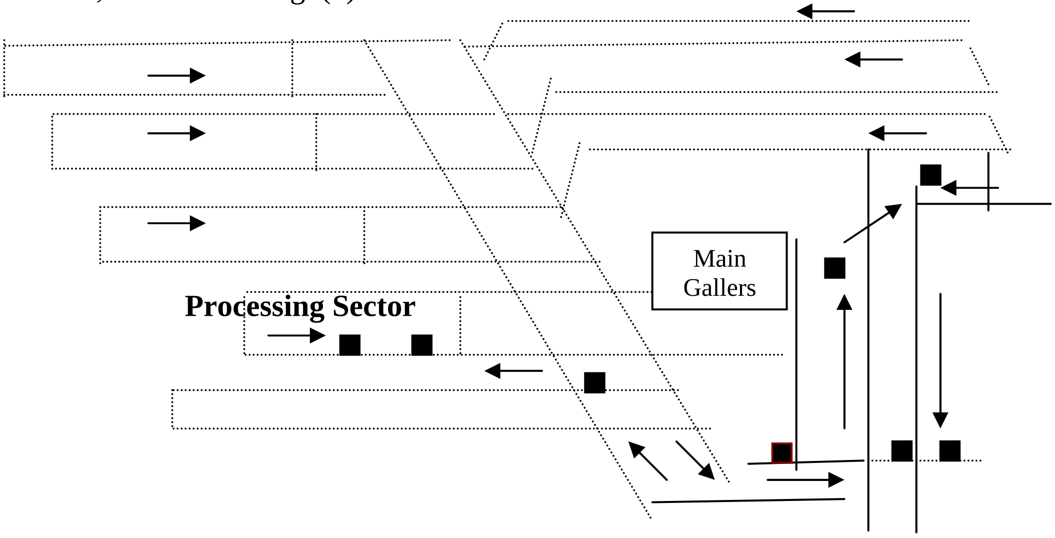


**Fig.(1)**: Sampling sites selected along the main gallery.

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In general, the tunnels were about 4.5 m wide and about 2.5 m high. At each sampling site always 5 measurements were made, 2 near the walls about 1 m above ground and 3 in the middle of the tunnel at 3 different positions.

The reported method [22] was used for measuring the concentrations of $^{218}$Po, $^{214}$Pb and $^{214}$Po. In this method, an air sample was collected for 5 minutes at a flow rate between 5 and 10 l/min on a high–efficiency filter paper Millipore (Type SM with 2.5 cm in diameter). The filter papers were counted using counting system type EDA by placing the filter paper on a scintillation tray coated by silver-activated zinc sulfide. The Pylon RN-190 radon daughter's standard source was used to determine the counting efficiency of the scintillation tray. It houses a dray $^{226}$ Ra source, which emanates radon gas into a sealed chamber. The radon gas decays into its daughters which deposit on the inner surface of the chamber and on an enclosed filter paper. The RN-190 is designed such that the radon daughters are deposited uniformly over the filter and the chamber surface where its activity deposited is 73.16 ± 4 % Bq $cm^{-2}$. The alpha count rate was measured at 5, 15 and 30 minutes. The concentrations of RaA, RaB and RaC were calculated in $Bqm^{-3}$ by the following equations [23]:

$$C_1 = \frac{37}{vE}\left(0.5945 A_5 + 0.8509 A_{30} - 1.347 A_{15}\right)$$

$$C_2 = \frac{37}{vE}\left(0.3598 A_{30} - 0.1485 A_{15} - 0.0448 A_5\right)$$

$$C_3 = \frac{37}{vE}\left(0.3997 A_{15} - 0.3246 A_{30} - 0.0293 A_5\right)$$

where,
$C_1$ = $^{218}$Po concentration
$C_2$ = $^{214}$Pb concentration
$C_3$ = $^{214}$Po concentration
E = counting efficiency
v = volumetric sampling rate in $l.min^{-1}$
$A_T$ = total alpha activity at time T after the end of sampling (in count $min^{-1}$)

### 2.1. Dose calculations

It can be estimated the annual effective dose through the different regions of the human lung due to the present measurements in the coal mine of interest as follow: based on the values of the activity median aerodynamic diameter 0.25 µm and standard deviation 2.5, which recommended in 1994 by ICRP-66 [1] and in 1991 by NRC [24], the total deposition has been carried out assuming that the tidal volume and respiratory frequency are give by 1920 ml and 26 $min^{-1}$, respectively. Consequently, the ventilation rate is taken as 3 $m^3$ $h^{-1}$. Moreover, the fraction 0.5 breathed through the nose was used. The obtained values of total deposition and the present measurement of activity concentrations of $^{218}$Po, $^{214}$Pb and $^{214}$Po have been used with a LUDEP 2.0 personal computer program NRPB-SR 264 [25] to calculate the annual effective dose through the human lung. It is assumed that the workers spent 2000 hours per year.

## 3. Results and discussion

The distributions of individual radon progeny concentrations among the different sampling sites in the considered mine are plotted in Fig. (2). Sampling site No.1 has the lowest "radon progeny concentration" values while the higher levels were found at sampling site No. 4. The activity concentrations of $^{218}$Po, $^{214}$Pb and $^{214}$Po ranged as (10-277), (7-167) and (4-80) with an average 75 ± 8, 49 ± 7 and 28 ±5 Bq m$^{-3}$, respectively. In general, the values of $^{218}$Po concentrations through the tunnel were higher than $^{214}$Pb and $^{214}$Po concentrations. The maximum values of the radon progeny concentrations don't exceed the action levels for working places as recommended in 1993 by ICRP 65 [26].

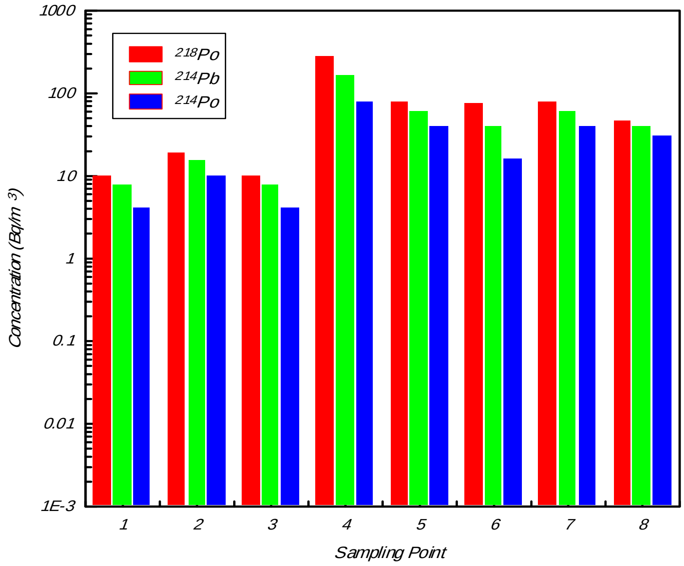


**Fig. (2)**: Individual radon progeny concentrations ($^{218}$Po, $^{214}$Pb and $^{214}$Po) in Maghara coal mine.

On the other hand, the measurement of radon progeny concentrations in underground phosphate mine, which was given previously [27], are higher than the present value. The radon progeny in that mine significantly exceeded the action level for working places which is recommended in1993 by ICRP 65 [26]. The efficient mechanical ventilation system which installed in the present mine is considered to be the main reason for the low radon progeny concentration.

The total deposition fractions and effective doses have been evaluated considering the obtained data in the present work. At a total deposition fraction of about 21±4 % the total effective doses to the lung were determined to be 6, 3.3 and 5.3 x $10^{-7}$ $mSvy^{-1}$ for $^{218}Po$, $^{214}Pb$ and $^{214}Po$, respectively.

The annual effective doses for bronchial (BB), bronchioles (bb) and alveolar regions of the respiratory tract as well as the total lung doses due to inhaled radon progeny ($^{218}Po$, $^{214}Pb$ and $^{214}Po$) in El-Maghara coal mine are shown in Table (1). It can be seen that the annual effective doses for $^{218}Po$ were higher than those for $^{214}Pb$ and $^{214}Po$ in all galleries. Also, the BB region has higher doses values than other regions.

Table (1): The annual effective doses of the lung for workers in El-Maghara coal mine due to inhaled radon progeny ( $^{218}Po$, $^{214}Pb$ and $^{214}Po$).

| **Region** | **Annual Effective Dose (mSv/y)** | | |
|---|---|---|---|
| | **$^{218}$Po** | **$^{214}$Pb** | **$^{214}$Po** |
| **Bronchial (BB)** | 4.0 | 2.098 | 3.432 x $10^{-7}$ |
| **Bronchioles (bb)** | 1.8 | 1.063 | 1.718 x $10^{-7}$ |
| **Alveolar (Al)** | 0.18 | 0.098 | 0.156 x $10^{-7}$ |
| **Total** | 5.98 | 3.259 | 5.306 x $10^{-7}$ |

In general, the total lung annual effective dose due to inhaled radon progeny in El-Maghara coal mine was not exceed the dose limits 20 mSv $y^{-1}$ (averaged over a period of 5 year with the proviso that the effective dose should not exceed 50 mSv in any single year) for workers, which recommended in 1991 by ICRP 60 [28].

The present value of lung doses are less than the other which was calculated [27]. This is due to the low radon progeny concentrations in under ground coal mine because of the ventilation system, which was installed in this mine.

## 4. Conclusions

From the radon progeny measurements in El-Maghara coal mine, it can be concluded that: all of the maximum values of individual radon progeny concentrations were within the action level for working places recommended in 1993 by ICRP 65 [26] (500-1500 Bqm$^{-3}$). The calculated annual effective dose for workers in the gallery under investigation is within the recommended dose limit. The efficient mechanical ventilation system, which installed in this mine, is considered to be the main reason for the low radon progeny concentration.

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