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Evaluation of the Biological Effects of Radiations on Pulmonary functions of NMA Employees in the Black Sand Project at Rashid and Abou-Khashaba Sites Year 2012

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Abstract:

Background: Almost all workers in the Black Sand Project at Rashid and Abou-Khashaba sites of NMA (Nuclear Materials Authority) are obligatorily exposed to ionizing radiations during their routine work. The most apparent harmful effects in Rasheed employees were reflected easily on pulmonary function tests which may occur due to increase registered dust radio activities than the accepted level for air concentration.

Objectives: This study was done mainly to evaluate the biological effects of ionizing radiations on lung and pulmonary functions of workers in the Black Sand Project at Rashid and Abou-Khashaba sites of NMA in the year 2012 and to start follow up of these workers

Measurements: This research was done on 30 male workers aging 25 - 56 years to measure pulmonary function tests. Certain radiological measurements were also performed to assess the levels of exposure to radiations

Results: Out of the 30 members; regarding the radiological measurements all levels measured were within the reference range accepted internationally, except radioactive dust levels were elevated mildly above the reference range accepted internationally this results in deterioration of pulmonary function of some workers.

Conclusions: Generally, workers of the Black Sand Project at Rashid and Abou-Khashaba sites were receiving a good radiological protection protocol. Radioactive dust levels were elevated mildly above the reference range accepted internationally this result in pulmonary function disorders in some workers.

Introduction:

The nuclear fuel cycle does not give rise to significant radiation exposure for members of the public. Radiation protection standards assume that any dose of radiation, no matter how small, involves a possible risk to human health.

Nuclear radiation arises from hundreds of different kinds of unstable atoms. While many exist in nature, the majority are created in nuclear reactions. Ionizing radiation which can damage living tissue is emitted as the unstable atoms (radionuclide) change (decay) spontaneously to become different kinds of atoms **(1)**.

Radiation to almost any organ can produce both acute and chronic adverse effects. Sources of exposure include industrial or medical radiation sources capable of producing high dose rates. Detrimental effects can occur due to radiation exposure, however they are dose dependent **(2)**.

On the lung, clinical and experimental data are used to describe the acute and late reactions of the lung to both external and internal radiation including pneumonitis, fibrosis and carcinogenesis **(3)**. In situations of accidental exposure, it was initially assumed that a whole-body dose exceeding 10 Gy was inevitably fatal; however, experience with nuclear accident victims suggests that when patients survive gastrointestinal and bone marrow syndromes, respiratory failure become the major cause of death. This effect is known as a delayed effect of acute radiation exposure **(4)**.

Pulmonary Function Testing (PFT) has been a major step forward in assessing the functional status of the lungs as it relates to how much air volume can be moved in and out of the lungs and how fast it moves, how stiff are the lungs and chest wall, the diffusion characteristics of the membrane through which the gas moves and how the lungs respond to chest physical therapy procedures. Pulmonary Function tests are used for different reasons as: screening for the presence of obstructive and restrictive diseases, evaluating the patient prior to surgery especially in old obese smoker patients with previous history of pulmonary disease as vital capacity is an important preoperative assessment tool. PFT is important also in evaluating the patient's condition for weaning from a ventilator, documenting the progression of pulmonary disease if restrictive or obstructive and documenting the effectiveness of therapeutic intervention. There is a systematic way to read the PFT and be able to evaluate it for the presence of obstructive or restrictive disease: First of all looking at the forced vital capacity (FVC) and the forced expiratory volume in one second (FEV_1) and determine if they are within normal limits. If both FVC and FEV_1 are normal, the patient has a normal PFT test, but if FVC and/or FEV_1 are low, then the presence of disease is highly likely, then we need to go to the %predicted for FEV_1/FVC. If the %predicted for FEV_1/FVC is 88%-90% or higher, then the patient has a restricted lung disease. If the %predicted for FEV_1/FVC is 69% or lower, then the patient has an obstructed lung disease **(5)**.

Fine particulate matter (PM2.5) is an air pollutant that is a concern for people's health when levels in air are high; it refers to tiny particles or droplets in the air that are two and one half microns or less in width. Particles in the PM2.5 size range are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose, and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease. Studies also suggest that long term exposure to fine particulate matter may be associated with increased rates of chronic bronchitis, reduced lung function and increased mortality from lung cancer and heart disease **(6)**.

There is a small but significant exposure-response relationship between prolonged exposure to low levels of dust, and lung function abnormalities (in the absence of radiologically diagnosed silicosis). The prevalence of chronic obstructive pulmonary disease (COPD) and small airways disease (SAD) was small but significantly higher in exposed workers. The risk of developing COPD was 2.7 times higher for exposed workers. The risk for non-smokers was small but significant. Peak expiratory flow rate (PEFR), and average flow rate between 25% and 75% of FVC ($FEF_{25\text{-}75\%}$) could be used as an early indicator of lung function impairment **(7)**.

Radon is formed during the radioactive decay of uranium-238, is present in the air, soil, and water, exposure to a combination of dust, radon progeny and smoking was associated with an increased risk of lung function abnormalities **(8)**. Heavy smokers with high smoking index are more susceptible. Smoking index is defined as the number of cigarette-years (or pack-years) smoked. Smoking Index is a way to measure the amount a person has smoked over a long period of time. It is calculated by multiplying the number of packs of cigarettes smoked per day by the number of years the person has smoked, so the greater the smoking index in workers the greater the risk of lung affection **(9)**.

Respiratory disease can be classified as obstructive or restrictive processes. Obstructive lung disease is a category of respiratory disease characterized by airway obstruction which is a respiratory problem caused by increased resistance in the bronchioles (usually from a decreased radius of the bronchioles) that reduces the amount of air inhaled in each breath and the oxygen that reaches the pulmonary arteries. The FEV_1 (forced expiratory volume in 1sec.) is the most widely used parameter to measure the mechanical properties of the lungs. The FEV_1 (forced expiratory volume 1) is the volume of air forcefully exhaled in 1 second, whereas the FVC (forced vital capacity) is the volume of air that can be maximally forcefully exhaled and therefore contains the FEV_1 within it. In normal persons, the FEV_1 accounts for the greatest part of the exhaled volume from a spirometric maneuver and reflects mechanical properties of the large and the medium-sized airways. In a normal flow-volume loop, the FEV_1 occurs at about 75% to 85% of the FVC (forced vital capacity). This parameter is reduced in obstructive and restrictive disorders. In obstructive diseases, FEV_1 is reduced disproportionately to the FVC, reducing the FEV_1/FVC ratio below the lower limit of normal and indicates airflow limitation. In restrictive disorders, the FEV_1, FVC, and total lung capacity are all reduced, and the FEV^1/FVC ratio is normal or even elevated **(10)**.

Obstructive disorders, such as emphysema or asthma, are characterized by airflow limitation, have increased lung volumes with air trapping, and have normal or increased compliance (based on pressure volume profile). Obstruction can be measured using spirometry. A decreased FEV_1/FVC ratio (versus the normal of about 80%) is indicative of an airway obstruction, as the normal amount of air can no longer be exhaled in the first second of expiration, so if the FEV_1/FVC ratio is $<80\%$, it indicates that an obstructive defect is present. Therefore, this ratio is the first number that should be assessed when interpreting spirometry. If the FEV_1/FVC ratio is less that 80%, the next question spirometry can answer is the severity of the obstructive defect. To do this we look at the FEV_1 percent predicted: > 80% = minimal obstructive defect, 65 - 80% = mild obstructive defect, 50 - 65% = moderate obstructive defect and < 50% = severe obstructive defect. These numbers are approximations, and should be interpreted in the appropriate clinical setting, when assessing if an obstructive defect is present **(11)**.

In contrast, Restrictive lung diseases (or restrictive ventilatory defects) are a category of extrapulmonary, pleural, or parenchymal respiratory diseases that restrict lung expansion, resulting in a decreased lung volume, an increased work of breathing, and inadequate ventilation and/or oxygenation. Pulmonary function test demonstrates a decrease in the forced vital capacity. Restrictive disease is a condition marked most obviously by a reduction in total lung capacity. A restrictive ventilatory defect may be caused by a pulmonary deficit, such as pulmonary fibrosis (abnormally stiff, non-compliant lungs), or by non-pulmonary deficits, including respiratory muscle weakness, paralysis, and deformity or rigidity of the chest wall. An airway restriction would not produce a reduced FEV_1/FVC ratio, would produce a reduced vital capacity. The ventilation is therefore affected leading to a ventilation perfusion mismatch and hypoxia **(12)**. In pulmonary tests, an individual with a restrictive ventilatory defect demonstrates a low total lung capacity, a low functional residual capacity, and a low residual volume. While his forced vital capacity (FVC) may be quite low, his forced expiratory volume in one second divided by the forced vital capacity (FEV_1/FVC) is often normal or greater than normal due to the increased elastic recoil pressure of the lung, restrictive disorders such as pulmonary fibrosis are characterized by reduced lung volumes and an increase in overall stiffness of the lungs (with reduced compliance) **(13)**.

Small airways disease is a spectrum of inflammatory and fibrotic pulmonary diseases centered on the small conducting airways. A variety of parameters selectively reflect small airways. These include measures of flow from a spirogram, such as forced expiratory flow at 25% to 75% vital capacity ($FEF_{25-75\%}$). $FEF_{25-75\%}$ is the average expired flow over the middle half of the FVC maneuver and is regarded as a more sensitive measure of small airways narrowing than FEV_1. $FEF_{25\%-75\%}$ describes the amount of air expelled from the lungs during the middle half of the forced vital capacity test. The $FEF_{25-75\%}$ has been found to be decreased prior to the FEV_1/FVC ratio falling below 80% in small airway obstructive disease as asthma. Therefore, many clinicians will interpret a $FEF_{25-75\%}$ of less than 50% predicted as indication that an early obstructive disease is present, even if the FEV_1/FVC is greater than 80% **(14)**.

Maximum voluntary ventilation (MVV) the greatest volume of gas that can be breathed per minute by voluntary effort. M VV is determined by having the patient breathe in and out as rapidly and fully as possible for 12 -15 seconds - the total volume of air moved during the test can be expressed as L/sec or L/min - this test parameter reflects the status of the respiratory muscles, compliance of the thorax-lung complex, and airway resistance **(15)**.

Uranium mining is strongly associated with obstructive lung disease and radiographic pneumoconiosis. Obstructive lung disease in miners is mostly related to cigarette smoking. Pulmonary function and mortality studies of U miners led us to suspect radiation-induced chronic diffuse interstitial fibrosis in miners who had inhaled excessive Rn progeny which is represented in pulmonary function as restrictive disorder. This disease, after a long latent period, usually results in pulmonary hypertension, shortness of breath, and death by cardiopulmonary failure. Many U miners have been disabled by and died of pulmonary fibrosis that was not recognized as an occupational disease. Smoking doesn't make a person more likely to develop pneumoconiosis but, because it also damages lung function, it may make the symptoms of the disease worse **(16)**.

Aim of work

This work is a preliminary attempt to evaluate the persisting health problems related to Uranium exploration ore handling with long term exposure to ionizing radiation in the work place in workers exposed to Uranium in the Black Sand Project at Rashid and Abou-Khashaba sites of NMA in the year 2012 with stress on evaluating the biological effects of radiation exposure on worker's lung and pulmonary functions and if they were receiving proper health protection and medical care. Also the levels of radiations in different sites of the work places were measured to determine whether these levels had effects on their lung functions by assessing their radiological exposure level, clinical examination results and pulmonary function tests.

Employees and environmental measurements:

This research was done on 30 male workers with age ranging from 25 - 53 years in the year 2012 at the Black Sand Project at Rashid and Abou-Khashaba sites of NMA.

Subjects and methods:

This research was done to examine the lung and measure the pulmonary functions of employees of the Black Sand Project at Rashid and Abou-Khashaba sites of NMA, also the following radiological measurements were taken: radon daughters levels, thoron daughters levels, radioactive dust levels, gamma ray levels, and film badge dosimeter readings.

Regarding the employees (history intake, examination and pulmonary functions were done as follows:

1. At first, each worker received a code number (CN) opposite to his name, and each one was dealt with later by his CN for the security of the data and results, and also for simplicity.
2. Full case history sheets were taken from all workers to evaluate their general health and also to show if effects of ionizing radiations were present or not. The work sheet reviewed also some investigations whose results were done in the near past.
3. Complete physical examination was also done to all employees.
4. Spirometric lung function tests were done as follows: The mouth piece was put in the patient's mouth and from a high seal with his lips while the tongue was not blocking the mouth piece. The patient was asked to take deep breath and then blow the air out as fast as he could. The patient did three valid tests, which should be reproducible within 5% and the best was selected. The results were read on the display and printed.

The following tests were done: Forced vital capacity FVC (the total volume that can be forcefully expired from a maximum inspiratory effort (L), Forced expiratory volume at one second FEV_1 (volume of air forcibly expired from a maximum inspiratory effort in the first second (L), ratio of (FEV_1 / FVC), Peak expiratory flow rate PEFR and average flow rate between 25% and 75% of FVC, $FEF_{25-75\%}$ (the average expired flow over the middle half of the FVC maneuver) and Maximum voluntary ventilation MVV (the greatest volume of gas that can be breathed per minute by voluntary effort).

Regarding the environment (measurement of radiological exposure levels). The levels of radiations in different sites of the work places were measured to determine whether these levels were permissible internationally or not. Measurments were done by geologists in the field using the apparatus (Alpha GuardTm model PQ 2000 from Genitron Co. Ltd, Germany).

The following measurements were taken:

Radon daughters' levels [Working level (WL)], thoron daughters levels [picocurie per liter (pCi/L)], and radioactive dust levels [microcurie per cubic centimeter ($\mu Ci/cm^3$)] were measured by the RDA-200 alpha counter using the grab sampling technique (Rolle method).

Gamma ray levels were also measured by the RDS-100 survey meter in microsievert per hour (µSv/h). In addition, the personal dosimeters were read using densitometry in millisievert per year (mSv/y) for assessing the amount of every individual exposure to radiation.

<u>Degree of exposure to radiation:</u>

Radiation exposures of the employee were grouped into three groups according to the degree of exposure to radiation (according to their job natures and by direct questioning them about the duration of exposure to ionizing radiations at working places per month averagely). These groups are:

Group 1: Low exposures (L): Those who are present in the field with minimal contact with radiations (less than one hour daily).

Group 2: Medium exposures (M): Those who are dealing regularly with radioactive materials by any mean for shorter times (one to less than four hours daily).

Group 3: High exposures (H): Those who are dealing regularly with radioactive sources and for longer (but permissible) times i.e. four to eight hours daily, 5 days weekly, for fifteen weeks yearly **(17)**.

<u>Years of exposure to radiation</u>

Workers were classified according to the length of years they were exposed to radiation in NMA (coming from employment year in NMA) table (4) into:

Group 1: Those who were exposed to radiations less than 10 years.

Group 2: Those who were exposed to radiations 10 - 20 years.
Group 3: Those who were exposed to radiations more than 20 years.

Accepted international levels of exposure

-The radon daughters' levels accepted internationally is 0.3 WL according to **(18)**, the internationally accepted levels of radon daughter is 600 Bq m^{-3} **according to (19)**. WL = Rn conc. (Bq m^{-3}) x 0.00027 OR 1 Bq/m^3 at equilibrium is equivalent to 0.00027 WL **(20)**.

-The thoron daughters' levels accepted internationally is 20 pCi/L **(18)**, (19 pCi/L according to **(20)** or 30 WLM according to **(21)**.

-The gamma ray levels accepted internationally is 10 µSv/h **(22)** (150 mSv according to **(19)**.

-The radioactive dust levels accepted internationally is 3 x 10^{-11} µCi/cm^3 **(18)** or 500 Bq/g or less than 50 µBq/m3 according to **(21).**

-The dosimeter readings accepted internationally is 20 mSv/y **(22)**.

As regard pulmonary functions recommended for adult male, average values for FEV_1 in healthy people depend mainly on sex and age. Values of between 80% and 120% of the average value are considered normal. Predicted normal values for FEV_1 can be calculated online and depend on age, sex, height, weight and ethnicity as well as the research study that they are based upon **(23)**.

-FEV_1/FVC (FEV_1%) is the ratio of FEV_1 to FVC. In healthy adults this should be approximately 75–80%.

-A derived value of FEV_1% is FEV1% predicted, which is defined as FEV_1% of the patient divided by the average FEV_1% in the population for any person of similar age, sex and body composition.

- Peak expiratory flow rate (PEFR), and average flow rate between 25% and 75% of FVC ($FEF_{25-75\%}$) average ranges in the healthy population depend mainly on sex and age. Values ranging from 50-60% and up to 130% of the average are considered normal. Predicted normal values for FEF can be calculated online and depend on age, sex, height, weight and ethnicity as well as the research study that they are based upon.

-Maximum voluntary ventilation (MVV) for the comfort of the patient this is done over a 15 second time period before being extrapolated to a value for one minute expressed as liters/minute. Average values for males and females are 140–180 and 80–120 liters per minute respectively **(24)**.

Results:

Reports of the radiometric supervision division for radiological measurements of the working places of the Black Sand Project at Rashid and Abou-Khashaba sites of NMA were represented in **table (1)** and **(2)** respectively.

Abbreviations: CN: code number, µSv/h: microsievert per hour, WL: Working Level, pCi/L: picocuries per liter, µCi/cm^3: microcuries per cubic centimeter, R: Rashid, -----: Unmeasured value,

The registered dust radio activities were higher than the accepted level for air concentration in the left of the hall in the start, middle and the end i.e. more than
3×10^{-11} Dust µCi/cm^3 **(22)**. Meanwhile, the radon daughters' levels, thoron daughters levels, and gamma ray levels were less than the reference range accepted internationally i.e. less than 0.3 WL, less than 20pCi/L and less than 10 µSv/h respectively. In addition, the personal dosimeters for assessing the amount of every individual exposure to radiation were less than reference range accepted internationally i.e. less than 20 mSv/y.

Abbreviations: CN: code number, µSv/h: microsievert per hour, WL: Working Level , pCi/L: picocuries per liter , µCi/cm^3: microcuries per cubic centimeter,
-----: Unmeasured value , Kh: Abou-Khashaba.

The registered dust radio activities were higher than the accepted level for air concentration beside the oven and in the outer storage site i.e., more than 3×10^{-11} Dust µCi/cm^3 **(22)**. Meanwhile, the radon daughters' levels, thoron daughters levels, and gamma ray levels were less than the reference range accepted internationally. In addition, the personal dosimeters for assessing the amount of every individual exposure to radiation were less than reference range accepted internationally.

Discussion:

The safety of radiation workers in the NMA Employees in the Black Sand Project at Rashid and Abou-Khashaba requires close and continuous monitoring of their working conditions. As dust represents one of the most important sources of radiation exposure in the Black Sand Project at Rashid and Abou-Khashaba, external radiation surveillance and radioactive dust monitoring were performed for a sample of workers at their working sites.

The degree of dust exposure was variable in different sites. Areas with dust concentration exceeding the accepted levels might be related to clinical outcomes associated with dust exposure at this time in these individuals.

-Pulmonary function tests were determined in an attempt to correlate them with radiation exposure and health status of the workers.

In this study, the registered dust radio-activities in Rashid workers were higher than the accepted level at certain places. Intense and prolonged exposure to workplace dusts have been implicated in the development of airflow obstruction, even in nonsmokers. Workers who smoke and were exposed to dust even more likely to develop obstructive disorders. Intense dust exposure causes silicosis, a restrictive lung disease distinct from obstructive disorders. Chronic diffuse interstitial (Restrictive) diseases are a heterogeneous group of disorders characterized predominantly by inflammation and fibrosis of the pulmonary connective tissue, principally the most peripheral and delicate interstitium in the alveolar walls. The effect of occupational pollutants on the lungs appears to be substantially less important than the effect of cigarette smoking **(25)**.

An obstructive pulmonary disorder is a limitation of the amount of air exiting the lungs. This is termed "expiratory flow. Expiratory airflow problems are caused by diseases that lead to narrowing the airways by creating thick mucus and lung secretions. They also damage airway muscles and their ability to aid in the exhale process. They result in increased resistance in the bronchioles (usually from a decreased radius of the bronchioles). Restrictive pulmonary diseases cause lungs to lose their ability to hold as much air as usual. Lungs are either less elastic or are unable to expand properly causing incomplete lung expansion and increased lung stiffness. The total lung capacity becomes less even when resting and less oxygen is absorbed into the blood. Symptoms of restrictive pulmonary diseases include wheezing, chest pain and cough. So restrictive is difficulty getting air into the lungs and obstructive is difficulty getting air out of the lungs **(26)**.

It is considered in mind that, all workers, whatever their jobs, were exposed to radiation by any mean (because all are working in a radioactive field).

According to Clinical classification of severity of obstructive disease by **Yawn (11)**, 5 (16.7) workers had severe obstructive and restrictive airway disease, with FEV_1/FVC ratio or $FEV_1\%$ is less than 60% of the predicted values for normal person in the same age, sex, weight and length, and their FVC is less than 70% of the predicted value, all workers were exposed to dust and the degree of obstruction depends on duration of dust exposure and smoking history. Common factors in these workers, all of them were exposed to dust for a long period of time in addition to very high smoking index; the summation of these two factors had a great effect on their lung function.

The condition can be explained by the combined effects of high levels of dust exposure for long duration which leads to inflammation and fibrosis of the pulmonary connective tissue, principally the most peripheral and delicate interstitium in the alveolar walls, together with increased smoking index which is the number of cigarette/years (or pack/years) smoked, so the greater the smoking index in workers the greater the risk of lung affection, heavy smokers were more susceptible and goza smoking is more dangerous than cigarette smoking **(9)**.

These cases are highly recommended to stop smoking, use the protective measures properly (wearing the protective measures as masks, gloves, and protective shoes), checking proper ventilation at the work place and decrease days of exposure to dust, chest X ray is recommended to detect fibrosis in the lung parenchyma when a worker starts to complain and physical examination should be done for these workers to detect occurrence of dyspnea, crackles, chest pain or any other pulmonary symptoms and proper management for workers who started to complain. Follow up of these workers is recommended annually by physical examination and pulmonary function testing.

9 cases (30%) have small airway disease which always precedes obstructive disorder as it is consider obstruction in the smaller bronchioles prior to reaching the larger airways. A variety of parameters selectively reflect small airways, these include measures of flow from a spirogram, such as forced expiratory flow at 25% to 75% vital capacity ($FEF_{25-75\%}$), it is used as an early indicator of

lung function impairment and it is regarded as a more sensitive measure of small airways narrowing than FEV_1, because it is an early indicator of obstructive disease. The FEF **25-75%** has been found to be decreased prior to the FEV_1/FVC ratio falling below 80% in small airway obstructive disease. FEF **25-75%** of less than 50% predicted is an indication that an early obstructive disease is present, even if the FEV_1/FVC ratio is greater than 80% **(14).** Those cases had to take care of them selves by continuous follow up for lung functions, follow the protective measures and quite smoking so that the disease arrested at this stage. In between the two groups there was a group of 4 (13.3) workers had single obstructive disease with FEV_1% is less than predicted values, no restrictive defect in those employee as FVC levels were normal, 2 of these cases were sever obstructive (FEV_1% less than 60%) and 2 cases were moderate obstructive with FEV_1% between 60% and 80%) according to clinical classification of severity by **Yawn (11),** these cases also correlate with the duration of dust exposure and smoking index. A single worker had a single restrictive disorder with FEV_1% is more than 70%, this worker should make X ray chest to detect the possibility of occurrence of pulmonary fibrosis and clinical examination of the lung to diagnose signs of fibrosis.

The remaining 10 workers got normal pulmonary functions, most of them were non smokers and young with short duration of exposure to dust.

While the obstructive disorders indicate narrowing of the large airways by inflammation, secretions and mucous secondary to dust inhalation, the restrictive disorder denotes deposition of dust in the lung parenchyma which leads to pneumoconiosis and leads to fibrosis of the lung tissue and affects inflation of the lung this condition is more dangerous than obstruction **(25)**. The duration of exposure to dust has great effects on pulmonary function of workers the greater the exposure the more deterioration in functions, in our employees the summation of high smoking index and increased years of exposure results in great impairment in lung function. It seems that smoking index is more deleterious than duration of dust exposure as there is number of non smoking workers has normal lung functions despite of long duration of exposure.

Conclusions:

Almost all the Black Sand Project at Rashid and Abou-Khashaba workers were receiving a good medical and radiological protection program. This is evidenced by:

1. All medical conditions listed in table (3) do not include ionizing radiation exposure hazards such as malignant tumors or radiation cataract cases (except for 3 cases of bronchial asthma that may be due to dust exposure rather than radiation exposure).
2. The registered dust radio activities were higher than the accepted level for air concentration beside the oven and in the outer storage site i.e., more than 3×10^{-11} Dust $\mu Ci/cm^3$, as a result 5 (16.7) workers suffered from obstructive and restrictive airway disease, 4(13.3%)workers suffered from single obstructive disorder, 9 (30%) cases had small airway disease and one case suffered from single restrictive disease (3.3), the remaining 10 (33.3) cases had normal pulmonary functions and a single case didn't do the test because of contraindication.

Recommendations:

1-Proper protective measures have to be taken in work place with continous monitoring of our employees by periodic examinations with stress on smoking cessation and explaining the hazards of smoking on their lung in addition to radiation exposure.

2-Annual follow up by chest X-Rays is not recommended to avoid further exposure of the workers to radiation in addition to their occupational exposure to radiation hazards, chest X ray is recommended only if the worker had actual disease or suspected to have lung fibrosis.

3- Follow up of all employees at all sites of NMA (at least every six months) for early radiological exposure manifestations. This is especially done by: history collection, physical examination and laboratory investigations (mainly by CBCs) and pulmonary function test.

4-Performing urinary uranium analyses (uranium levels in urine) for discovering internal contamination by radioactive uranium isotopes.

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Table (1): Radiological measurements for the working Places of the Black Sand Project at Rashid site of NMA.

Area	CN	Gamma Rays Levels µSv/h		Radon Daughters Levels WL	Thoron Daughters Levels pCi/L	Radioactive Dust Levels µCi/cm^3	Total dosimeter
		Average	Higher				
Right of the hall, start	R1	0.23	0.28	0.00642	0.675	-------	**Less than 20 mSv/y**
Right of the hall, middle	R2	1.47	4.52	0.00614	1.04	-------	
Right of the hall, end	R3	0.81	2.01	0.00306	0.661	-------	
Left of the hall, start	R4	0.06	0.09	0.00558	1.02	**8.68×10^{-11}**	
Left of the hall, middle	R5	0.49	0.78	0.00642	0.219	**7.23×10^{-11}**	
Left of the hall, end	R6	1.45	2	0.00670	0.219	**5.78×10^{-11}**	
Behind the hall	R7	2.07	3.4	0.00558	0.653	-------	
Front of the hall	R8	0.89	1.52	0.00782	0.787	1.91×10^{-11}	
End of the store	R9	30.86	95.1	0.00482	0.853	-------	
Start of the store	R10	13.95	27.3	0.00474	0.421	-------	

Table (2): Radiological measurements for the working places of the Black Sand Project at Abou-Khashaba site of NMA.

Area	CN	Gamma Rays Levels µSv/h		Radon Daughters Levels WL	Thoron Daughters Levels pCi/L	Radioactive Dust Levels µCi/cm^3	Total dosimeter
		Average	Higher				
Site of storage of ore, start	Kh1	2.52	2.62	0.01816	0.48798	1.15×10^{-11}	**Less than 20 mSv/y**
Site of storage of ore, middle	Kh2	1.98	2.07	0.01984	0.54658	-------	
Site of storage of ore, end	Kh3	0.64	0.74	0.02124	0.54303	1.44×10^{-11}	
Beside the oven	Kh4	1.51	5.88	0.02012	0.35695	5.78	
Hydrostatic separation machine	Kh5	0.59	0.72	0.01509	0.41463	-------	
Electrostatic separation machine	Kh6	0.24	0.25	0.01509	0.58913	2.89×10^{-11}	
Inner room for separation	Kh7	2.08	4	0.02067	0.48797	-------	
Outer storage site	Kh8	1.78	1.92	0.01537	0.57835	5.78×10^{-11}	

Table (3) shows collection of the main data of NMA employees of the Black Sand Project at Rashid and Abou-Khashaba sites in the year 2012. Each employee first takes a code number opposite to his name (CN) then Radiological exposure (RE) representing the levels of exposure to radiation doses column: low (L), medium (M) and high (H), followed by Pulmonary function tests (PFT), in addition, smoking history were also represented and other diseases, employment years in NMA, and birth date were also represented.

CN	**RE**	**PFT**	**Smoking history**	**Other Diseases**	**Work Year**	**Birth Date**
R01	**L**	Normal Pulmonary Functions	Smoker and Goza smoking (SG),	Dental extraction	2002	1973
R02	**M**	Obstructive Airway Disease (Moderate)	SG (28 y)		1994	1974
R03	**L**	Normal Pulmonary Functions	Non smoker (NS),	Hernia Operation, Hypotension	1996	1974
R04	**M**	Small Obstructive Airway Disease	NS		1997	1976
R05	**H**	Small Obstructive Airway Disease	SG (15y) & Exsmoker(ES)(5y),	Dental extraction, Hypotension	1997	1974
R06	**L**	Obstructive Airway Disease (Severe) & Restrictive Airway Disease (Severe)	Smoker (S) (10)25y		1997	1971
R07	**H**	Small Obstructive Airway Disease	NS	Hydrocoele operation	1995	1959
R08	**H**	Obstructive Airway Disease (Severe) & Restrictive Airway Disease (Severe)	S (10) 20 y		1998	1978
R09	**M**	Small Obstructive Airway Disease (Mild)	NS	Perfume seller	2005	1977
R10	**L**	Obstructive Airway Disease (Severe) & Restrictive Airway Disease (Severe)	SG (15 y)	Hypotension	1996	1969
R11	**L**	Restrictive Airway Disease & Small Obstructive Airway Disease	SG (3 m)	L5/S1 disc lesion, DM	1996	1970
R12	**L**	Obstructive Airway Disease (Severe)	S (10) 17 y	Hernia, Dental extraction, chronic calcular cholecystitis	1999	1972
R13	**H**	Small Obstructive Airway Disease	NS		2005	1975
R14	**L**	Normal Pulmonary Functions	NS	DVT, Varicose veins	2002	1972
R15	**L**	Obstructive Airway Disease (Severe) & Restrictive Airway Disease (Mild)	S & SG (30 y),	Hypermetropi a, Colitis	1990	1961

R16	**L**	Small Obstructive Airway Disease	NS	Hypotension	1989	1965
R17	**H**	Normal Pulmonary Functions	NS	Lt leg operation	2005	1987
R18	**L**	Normal Pulmonary Functions	NS	Dental extraction	1997	1967
R19	**L**	Normal Pulmonary Functions	NS	Splenectomy, Oesophageal varices Grade III, Dental extraction	1989	1962
R20	**L**	Normal Pulmonary Functions	NS	Hypertension	1995	1970
R21	**L**	Obstructive Airway Disease (Severe) & Restrictive Airway Disease (Mild)	SG (15 y) Bronchial asthma	Hyperlipidemia, Fatty liver, Sciatica, Hypertension, Bronchial asthma	1993	1966
R22	**L**	Normal Pulmonary Functions	NS	Hypertension	1995	1968
R23	**L**	Small Obstructive Airway Disease	S (10) & ES (10),	Dental extraction	1996	1969
R24	**H**	Obstructive Airway Disease (Severe)	NS, Bronchial asthma,	Bronchial asthma, Hyperlipidemia, DM	1997	1967
R25	**H**	Small Obstructive Airway Disease	S (20) 3 y		2005	1976
R26	**L**	Normal Pulmonary Functions	S (15 y)	Ear diseases	2001	1983
R27	**M**	Small Obstructive Airway Disease	SG (5 y), Bronchial asthma	Bronchial asthma, Perfume seller	2005	1984
R28	**L**	Normal Pulmonary Functions	NS	Rt.Nephrectomy, Error of vision, Pelvic bone operation	2012	1972
R29	**M**	Obstructive Airway Disease (Moderate)	NS		1997	1974

Table (4): Shows the classification of employees according to years of dust exposure

levels of exposure	**Number of workers**
Low	18 employees
Medium	5 employees
High	7 employees