Assessment of the Radiological Impacts of Gypsum, Ferro-Manganese and Oil Industries

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ABSTRACT

This study aims to determine the concentrations of NORM in industries in Wadi-Nasieb, southwest Sinai. The area includes gypsum industry from quarries at Ras Malaab, Carbon ferro-manganese industry in Abu Zenima based on extracted Mn ore of Um Bogma and oil field on the Gulf of Suez shore of Abu-Rudeis. This investigation also included other raw materials; limestone, dolomite, carbon paste, coal, white sand, kaolin and locally produced petroleum products. The radionuclides present in all studied raw materials but the Egyptian Mn ore are neither a health hazard for the workers nor a threat to the general population. The associated wastes of these industries have been evaluated to guarantee the safety of the population and workers. Enhanced concentrations of NORM in the wastes was found only in the case of alloy production process, in such a way that the radiation exposure results in significant doses to the public.

1. Introduction

The raw materials formed in various geological environments are utilized in many industrial fields. The natural radioactivity concentrations of these raw materials depend on their mineralogy and geochemistry, and a few are occasionally found to have comparatively high concentrations of natural radioactivity. During the process to obtain the product, wastes and by-products containing technologically enhanced naturally occurring radioactive materials (TENORM) are generated. These wastes are produced in very large volumes with relatively low specific activities and must be disposed in a way that ensures they remain sufficiently isolated as long as necessary to protect the human health.

2. Materials and Methods

2.1 Study Area

The study area lies at the South-West part of Sinai Peninsula along the onshore of the eastern bank of Suez gulf (Fig. 1). The area includes gypsum industry from quarries at Ras Malaab, Carbon ferro-manganese industry in Abu Zenima based on extracted Mn ore of Um Bogma and oil field on the Gulf of Suez shore of Abu-Rudeis. This investigation also included other raw materials; limestone, dolomite, carbon paste, coal, white sand, kaolin and locally produced oil products.

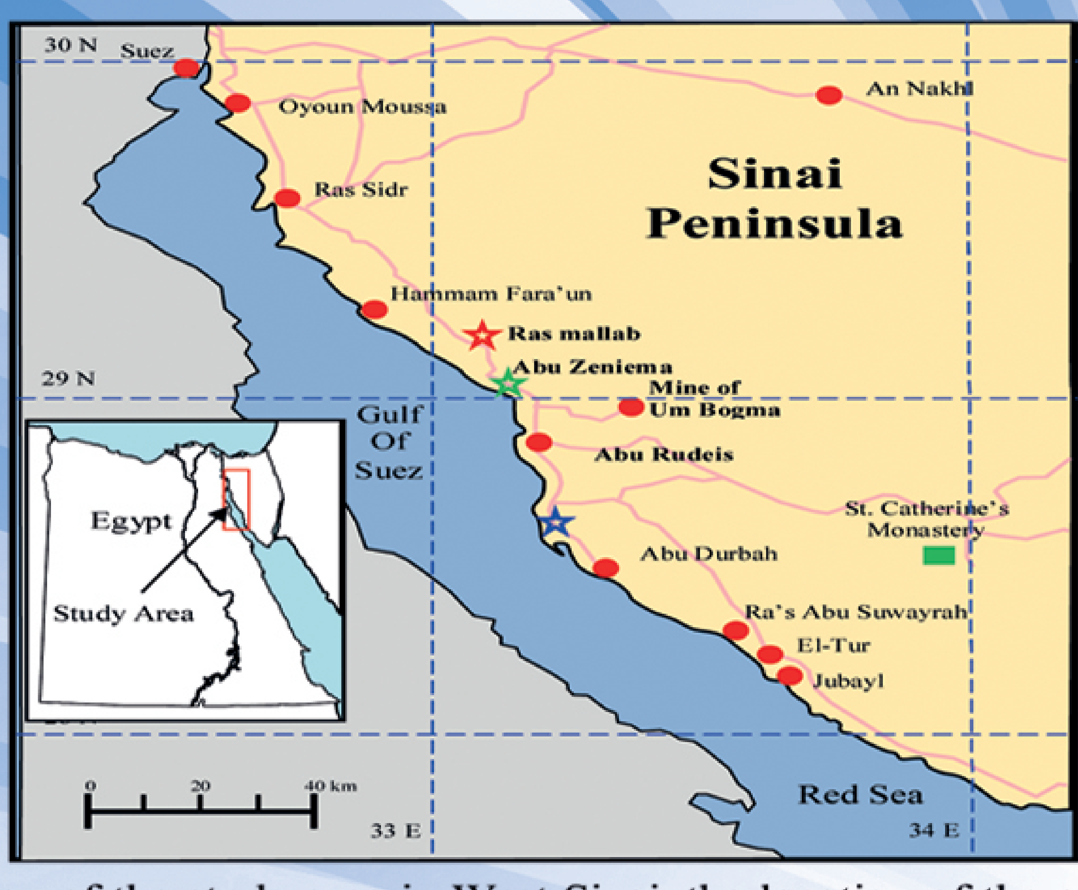

Fig. 1 The map of the study area in West Sinai, the location of the gypsum plant is marked with a red star, the high carbon Ferro-manganese alloy plant is marked with a green star, and the oil fields region is marked with a blue star. The cities are shown as red circles.

2.2 Sampling and Sample Preparation

Samples representing all raw materials, end products, products from Um Bogma mine, and gypsum samples were collected from the high carbon ferro-manganese alloy plant. Samples, representing the most popularly widely used oil products were also obtained from the local market. The collected samples were air dried and hand-cleaned. The samples were then oven dried at 90°C, homogenized, grinded and screened with 2 mm sieve. The prepared samples were placed in PVC cylindrical container. The sample containers were sealed tightly and stored for a minimum period of 4 weeks.

The activity concentration of radioisotopes in the studied samples was measured using a 50% p-type closed-end coaxial HPGe detector. The HPGe detector has an energy resolution (FWHM) of 1.98 keV for the 1332.5 keV ^{60}Co γ-line. The detector was shielded using a 10 cm thick low-background lead shield. The amplified signals of HPGe detector was acquired with 16 K ADC MCA.

3. Results and Discussion

3.1 Gypsum Plant

The Sinai Manganese Company (SMC) in Abu Zenima mines gypsum ore from quarries at Ras Malaab area in southwest Sinai which is used to produce calcined gypsum for construction purposes also it is used in cement industry, construction materials and in production of sulphoric acid.

Table 1 lists the activity concentrations of NORM in the samples collected from gypsum plant at Ras Malaab. The raw and calcined gypsum have nearly the same activity concentrations of ^{238}U, ^{226}Ra and ^{40}K. On the other hand the activity concentrations of ^{232}Th are higher in calcined gypsum. The radiation hazard indices (Ra_{eq}) the absorbed dose rate in outdoor air (D) and the external hazard index (H_{ex}) were calculated using NORM activity concentrations for all the studied samples (Table 2). The calculated values of radium equivalent, absorbed dose rate and external hazard indices are relatively low. To estimate the annual effective dose (AED), it was assumed that workers spend a total of 6048 h a^{-1} in working areas and that they work 50% of their time with the raw gypsum and 50% of their time with calcined gypsum. The calculated AED is 9.57 µSv.

Table 1 The activity concentrations (Bq kg^{-1}) of γ–ray emitting radioisotopes in gypsum samples.

Sample type	^{238}U	^{226}Ra	^{232}Th	^{40}K
Gypsum deposits	1.7±0.7	3.4±0.1	0.3±0.1	8.0±1.0
Calcined gypsum	1.8±0.8	3.7±0.1	1.5±0.9	6.0±1.0

Table 2 Radiation hazard indices of gypsum samples

Sample type	Ra_{eq} (Bq kg^{-1})	D (nG h^{-1})	H_{ex}
Gypsum deposits	5.65±0.21	1.97±0.10	0.012±0.001
Calcined gypsum	6.00±1.24	2.55±0.58	0.016±0.001

3.2 Ferro-Manganese Alloy Plant

The Um Bogma region (30 km southeast of Abu Zenima) is one of the chief manganiferous deposits in Egypt and is built of Paleozoic rocks (sandstones, siltstones, shales and dolomite), overlying igneous and metamorphic rocks (granite, diorite, gneiss) of Precambrian age. The SMC was founded in 1957 to exploit the manganese deposits in Sinai Peninsula, Egypt. In 1993, the production of high carbon ferro-manganese started in the plant built in Abu Zenima area. The company produces high carbon ferro-manganese alloy using a mixture of low-grade ore of Um Bogma and imported Norwegian high-grade ore. The mixture of manganese ore and other materials are smelted to enable reduction reactions and alloy formation. Limestone ($CaCO_3$) is the chief raw material for the manufacture of Portland cement. Dolomite is a sedimentary carbonate rock and a mineral, both composed of calcium magnesium carbonate $CaMg(CO_3)_2$ found in crystals. Dolomite is used as a source of magnesium oxide and in the Mn-metal production for the production of magnesium. A carbon paste consists of a mixture of conducting graphite powder and an organic binder, which is immiscible with water.

Table 3 The activity concentrations of NORM (Bq kg^{-1}) in raw, end products and waste samples from the ferro-manganese alloy plant. The activity concentrations of NORM in white sand and kaolin produced by the same company are also listed.

Sample type	^{238}U	^{226}Ra	^{232}Th	^{40}K
Manganese ors:				
Norwegian Mn	18.2±1.3	42.1±0.9	20.4±0.5	271±13
Egyptian Mn	204.3.0±11.2	201.4±3.8	23.3±0.6	85±5
Treated Mn-mixture	420.4±21.5	348.0±6.5	23.6±0.7	108±6
Other raw materials:				
Limestone	58.0±3.6	64.8±1.4	4.6±0.2	59±4
Dolomite	68.6±4.3	53.8±1.1	20.4±0.5	298±14
Carbon paste	9.9±2.1	5.7±0.2	5.9±0.2	29±2
Coal	51.9±5.2	46.0±1.2	32.5±0.9	168±10
Final products:				
Fe-Mn alloy	10.1±0.8	17.6±0.4	1.5±0.1	16±1
Smelting waste	231.4±12.0	435.9±8.1	32.6±0.9	334±16
Other products				
White sand	3.9±1.0	2.9±0.1	2.7±0.1	3±1
Kaolin	57.0±3.5	64.2±1.3	68.4±1.2	31±2

Table 3 gives the activity concentrations of NORMs in samples collected from ferro-manganese alloy plant including raw, end products and waste. While the concentrations of ^{238}U-series in the Egyptian ore is significantly higher than that in Norwegian ore, the concentration of ^{40}K in Norwegian ore is about three time that in Egyptian ore. The two ores have nearly the same concentrations of ^{232}Th. The Mn-mixture has much higher concentration of ^{238}U-series than both ores, about the same concentration of ^{232}Th and intermediate concentration of ^{40}K. The results indicate that most of the NORMs are associated with the waste while the alloy contains relatively low concentrations. The waste generated in the alloy production process is 500-1000 kg for every ton Mn-alloy the company produces. Since the company is producing 40,000 ton/year, the estimated range of the total activities of ^{226}Ra, ^{232}Th and ^{40}K in the wastes produced annually by the extraction process are 8.7–17.4, 0.7–1.3 and 6.7–13.4 GBq, respectively. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the other raw materials (limestone, dolomite, electrode paste and coal) ranged from 5.7 to 64.8 Bq kg^{-1}, from 5.9 to 32.5 Bq kg^{-1}, from 29 to 298 Bq kg^{-1}, respectively. Table 3 lists also the activity concentrations of the γ–ray emitting radioisotopes in sand and kaolin produced by the same company.

Table 4 Radium equivalent, absorbed dose, external hazard index and annual effective dose equivalent of samples collected from ferro-manganese alloy plant samples.

Sample type	Ra_{eq} (Bq kg^{-1})	D (nGy h^{-1})	H_{ex}	AED (µSv)	
				M-I	M-II
Manganese ors:					
Norwegian Mn	92.2±1.5	43.2±0.7	0.25±0.01	60.96	–
Egyptian Mn	241.3±3.8	105.1±1.7	0.65±0.01	148.32	–
Treated Mn-mixture	390.2±6.6	168.9±2.8	1.05±0.02	238.35	–
Total AED for workers in manganese ore treatment				447.63	
Other raw materials and components:					
Limestone	75.9±1.4	33.2±0.6	0.21±0.004		
Dolomite	105.9±1.6	49.3±0.8	0.28±0.004		
Carbon paste	16.4±0.4	7.6±0.2	0.04±0.001		
Coal	105.5±1.8	48.5±0.9	0.28±0.005		
Final products and waste:					
Fe-Mn alloy	20.9±0.4	9.2±0.2	0.06±0.001	–	19.47
Smelting waste	508.2±8.3	222.1±3.6	1.37±0.023	–	470.14
Total AED for workers dealing with alloy and waste					489.62
Other products:					
White sand	7.0±0.2	3.2±0.1	0.02±0.001		
Kaolin	164.4±2.2	74.0±2.1	0.44±0.006		

The ranges for Ra_{eq}, D and H_{ex} are 7.0–508.2 Bq kg^{-1}, 7.6–222.1 nGy h^{-1} and 0.02–1.37, respectively (Table 4). The Mn-mixture and the waste have Ra_{eq} values higher than the recommended maximum value of 370 Bq kg^{-1} and H_{ex} higher than 1. Otherwise, all other samples have low values. The waste should be considered hazardous to health as they contain high concentrations of both heavy metals and radioactive isotopes. Special consideration needs to be given to its disposal. In addition, the use of this waste as filling materials in areas where houses may be built on is not recommended.

For the calculation of AED, two categories of workers were assumed: workers who work with the mixing process of the Egyptian and Norwegian Mn (M-I) and workers who work with the final Fe-Mn alloy and the waste (M-II). Workers in groups M-I and M-II spend 6048 h a^{-1}. M-I workers are assumed to be subjected to each of Egyptian, Norwegian and mixture Mn one-third of their total working time. Likewise, M-II workers are assumed to be subjected to each of Fe-Mn alloy and waste one-half of their total working time. The AED values were 447.63 and 489.62 µSv for the two groups M-I and M-II, respectively. The effective doses are higher than that of the world average value 410 µSv a^{-1} for public but below the 20 mSv a^{-1} for workers.

Table 5 The activity concentration of NORM (Bq kg^{-1}) in crude oil, petroleum products and waste samples.

	^{238}U	^{226}Ra	^{232}Th	^{40}K
Oil	23.41±2.24	18.0±0.4	14.0±0.3	388.0±13.0
Liquid waste	14.45±1.49	17.0±0.4	11.0±0.3	243.0±8.8
Solid waste	20.31±2.01	19.0±0.4	14.0±0.4	218.0±8.0
Bitumen	4.53±0.81	5.0±0.2	4.0±0.1	61.0±2.5
Heavy fuel	4.88±1.09	6.0±0.2	2.0±0.1	<5.0
Grease	<2.26	<0.25	<0.3	<5.0
Gasoline	2.63±2.20	0.3±0.1	2.0±0.4	7.0±1.0
Kerosene	3.68±2.36	0.5±0.1	<0.3	7.0±1.4
Benzine	4.06±2.70	0.4±0.1	0.5±0.2	6.0±1.6
Mean	3.67	2.0	1.52	15.17
Range	<2.26-4.88	<0.25–6.00	0.3–4.00	<5.0–61.0

3.3 Measurements of the oil and petroleum products

Over half of the Egyptian's oil reserves are offshore reserves. The most important oil fields in the Sinai are in Abu Rudeis and Ra's Sudr. Crude oil is processed and refined into more useful petroleum products, such as bitumen, heavy fuel, grease, gasoline, kerosene and benzine. Table 5 gives the activity concentrations of NORM in crude oil samples, petroleum products and wastes. The crude oil and wastes have comparable contents of all γ–ray emitting radioisotopes except ^{40}K. The petroleum products have narrow ranges of NORM and much lower activities than the corresponding ones in the crude oil. The calculated radium equivalent, absorbed dose and external hazard index of oil samples, petroleum products and wastes are listed in Table 6. All values are comparable and represent no hazard.