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Calculation and Evaluation of Radiation Doses for Workers in Phosphate Fields

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Abstract: The phosphate fertilizer industry is considered one of the effective industries in improving the economic reality at the country level in general and at the level of areas rich in phosphate in particular, which requires laborers from the same region or from others. Phosphates are from Naturally Occurring Radioactive Materials (NORM), Three important sites were chosen at the General Phosphate Company in Al-Qaim due to the long period of time for the presence of its employees (work requirements) and continuously for five days a week, and these sites are (the main silo, phosphate fertilizer store Sp, nitrogen fertilizer store Np). The readings of the radionuclide radiation dose were recorded in the above-mentioned sites, and other important information required for the purpose of entering it into the (RESRAD) program. The (RESRAD ONSITE) program was used to calculate and evaluate radiation doses for workers, and it is one of the family of (RESRAD) software packages and The results and measurements showed that the total radioactive dose rate at the site is within the permissible limits for the general public according to the relevant safety standards contained in the publications of the International Atomic Energy Agency in its publication Part 3 of the General Safety Requirements (GSR Parte 3).

Key points: Radiation dose, phosphate fertilizers, NORM, RESRAD program, radon.

Introduction:

Phosphate compounds are inorganic compounds and a salt of phosphoric acid, and organophosphates are esters of phosphorous acid, There are phosphate mines in Iraq and in many countries of the world[1]. In Iraq, Akashat is considered one of the areas rich in phosphate. It is an Iraqi city located in western Iraq between the city of Al-Rutba and the city of Al-Qaim. This area is one of the areas rich in phosphate and other minerals such as quartzite, dolomite, and glass sand and heavy sand. , which is characterized by the presence of a number of important minerals such as zircon, tourmaline, monazite and porcelainlite[2].

The presence of phosphate in Iraq is limited to the Western Desert, especially in the Akashat region. Iraq is the second country in the world in terms of reserves, but its quality is medium and it needs treatment and concentration to become suitable for industry. The industrial reserve was calculated in two areas, the first near the H-3 plant and the second in Akashat, which is invested in financing the phosphate plant for the purpose of manufacturing phosphate fertilizers, with a capacity of more than one million tons annually. The labor force in the phosphate fertilizer industry has a high technical skill[3]. The number of workers in the Akashat / Phosphate complex in 2013 reached (3250) male and female workers, most of whom are residents of Al-Qaim district, and the rest are distributed among their housing, according to Figure (1) (relative distribution of the housing of the workforce in The General Phosphate Company for the year 2013) according to the planning and follow-up records of the General Phosphate Company[4].

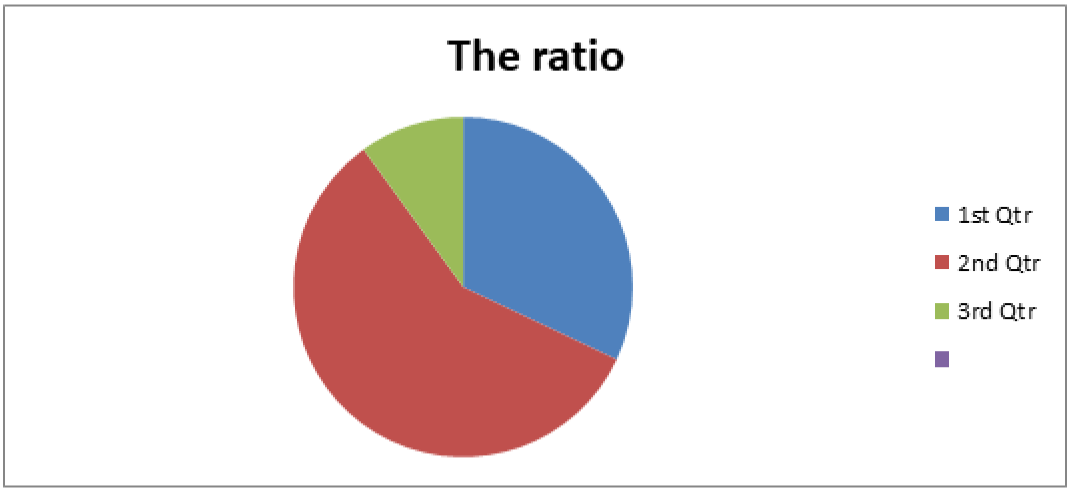


Figure (1): (Relative distribution of the original housing for the workforce in the General Phosphate Company for the year 2013)

1 st = Rawa, Anah, Haditha, Heet, Ramadi, Fallujah, 32%

2 nd =Al Qaim District 58%

3 nd = Baghdad, Basra, Nineveh, Diyala 10%

The General Phosphate Company is located in the Al-Qaim area in Anbar Governorate. The area of the factory is (20105) dunums and at a distance of (20) km to the southeast of the city of Al-Qaim, which is located near the water resource, as shown in Figure. (2)

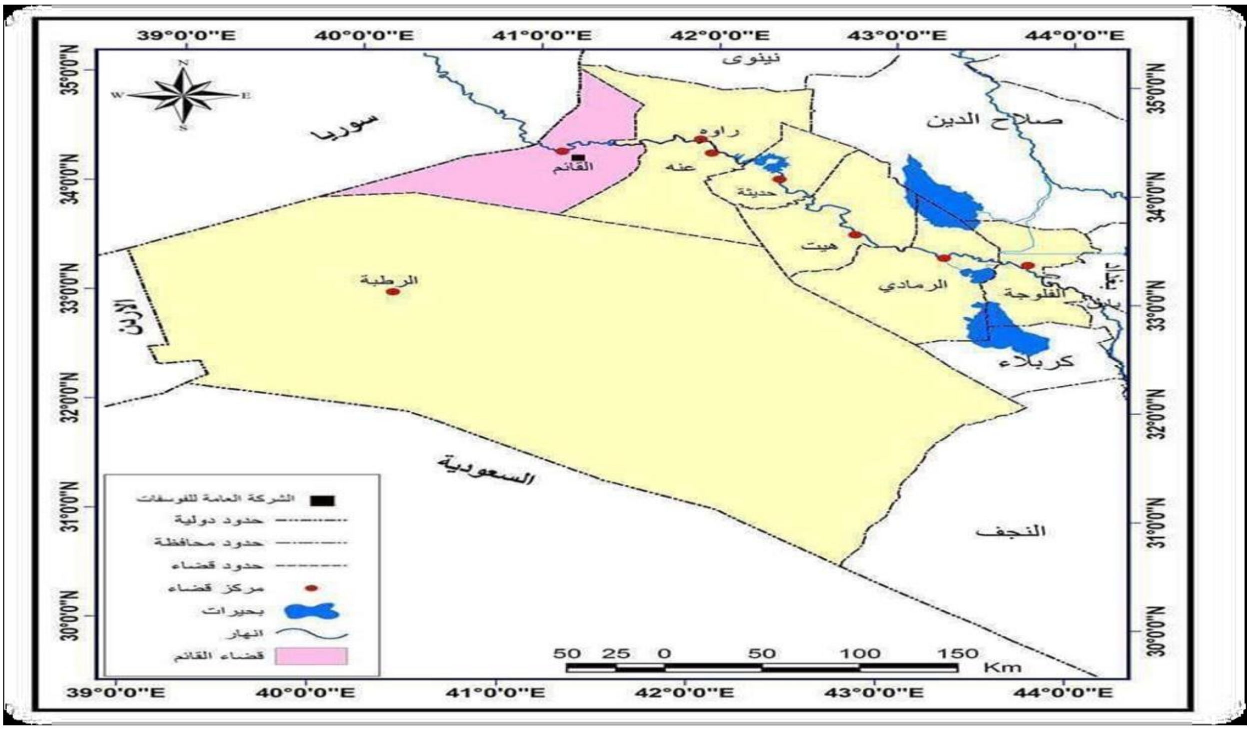


Figure (2): Map of the General Phosphate Company's site in Al-Qaim

1- Fertilizers:

In fact, all types of soil contain an abundance of mineral elements compared to the annual requirements of crops, but many of these mineral elements of the soil are not quickly assimilated. It reaches a minimum that is not commensurate with the yield of the farmer's effort or even meeting the world's food needs[5].

The types of chemical fertilizers are:

1.1.Phosphate fertilizers

The first phosphate fertilizer used extensively in Europe during the first decade of the nineteenth century was bone flour, and when the quantities received from animal bones decreased, human bones were collected from battlefields or burial places. Very dilute phosphorous acid was produced by treating ground phosphate rock with sulfuric acid by extraction and then filtration, then raising the phosphorous acid concentration by evaporation, then treating new ground phosphate rock with this concentrated phosphorous acid[6]

2.1. Nitrogenous fertilizers

For many years, the need to supply plants with nitrogen was considered of secondary importance, despite the recognition of the essential and important role of nitrogen in crop production. The natural sources of nitrogen, which come from following the crop rotation system, were considered sufficient and appropriate, as they fix the nitrogen dissolved in rain water. During the latter part of the nineteenth century, this ammonia became an important source of nitrogen fertilizer, as most of it was converted into ammonium sulfate, while the smaller part was provided in the form of a diluted ammonia solution. The population increase gave evidence and made it clear that the world's needs for food can be met and met through the increased supply of fixed nitrogen. For this reason, research, experiments and experiments in several countries were based on the issue of benefiting from air nitrogen fixation. [7].

2. Preserving workers, the general public and the environment

Non-hazardous solid waste may result from some manufacturing processes of phosphate fertilizers, and among these wastes (phosphate gypsum), which is one of the most important by-products of the process of producing phosphoric acid by the wet method (about 5-4 tons of phosphate gypsum are produced for each ton produced from phosphoric acid,). It contains phosphorous pentoxide and a wide variety of impurities (residual acids, fluorine compounds, trace elements magnesium and lead). These impurities, along with a higher radioactive volume of 12 phosphates, may be released to the environment (soil, groundwater and surface water). Pollution prevention and control practices specifically related to industry include the following:

- Depending on its potential hazard (eg whether it is radioactive for radon), phosphate gypsum can be treated to improve its quality and re-used (eg as a building material). Possible options include:

Production of phosphate gypsum that is more pure than raw materials (phosphate rock) and has low levels of impurities

- Using the kneading technique
- Using the process of recrystallization of dihydrate through double-stage filtration.
- If phosphate gypsum cannot be recycled due to the lack of commercial or technical availability of suitable alternatives, it should be managed as hazardous or non-hazardous industrial waste based on its characteristics in accordance with the recommendations presented in the operating instructions and may include alternatives regarding environment, health and safety [8].

3. Effect of phosphate fertilizer piles on workers

Phosphate fertilizers are stored in the silo near the phosphate fertilizer factory, which leads to the possibility of pollution transmission despite the precautions and praises followed by the workers, as well as in the transportation and packaging process as in Figure (3).

Figure (3): shows the piles of phosphate fertilizers

Among these risks are:

1.3. Radon gas pollution

Radon-222 gas released from phosphate fertilizer piles, which is an inert gas produced from the disintegration of radium-226, is one of the most important radioactive pollutants from the natural background[9].

2.3. Plankton:

The plankton resulting from storage and packaging of phosphate fertilizers is one of the potential sources of radioactive contamination, although this process has no appreciable effect in increasing the concentration of plankton in the air due to the formation of a cohesive crust on the surface of the phosphate fertilizers[8,9].

3.3. Direct exposure to gamma rays

Phosphate fertilizers are a direct source of gamma ray exposure, because they contain radium-226 and its derivatives (lead-214, bismuth-214) that emit gamma rays. The surface of phosphate fertilizer piles, in Louisiana, reached 0.37 micro sieverts / hour, and this constitutes about 60% of the annual permissible dose for public exposure [9].

3.3. 2.9 RESRAD Code

RESRAD is a computer model designed to estimate the hazards and radiation doses of radioactive materials. RESRAD is (Residual Radioactivity materials) was first in 1989 and was developed by Argonne National Laboratory. It uses a method in which the relationship between the concentrations of radionuclides in the soil and the dose is expressed. Nine environmental pathways are considered are direct exposure, inhalation of dust and radon, ingestion of plant foods, meat, milk, aquatic foods, soil, and water. [10]. Figure (4).shows the program software interface RESRAD code(7.2).

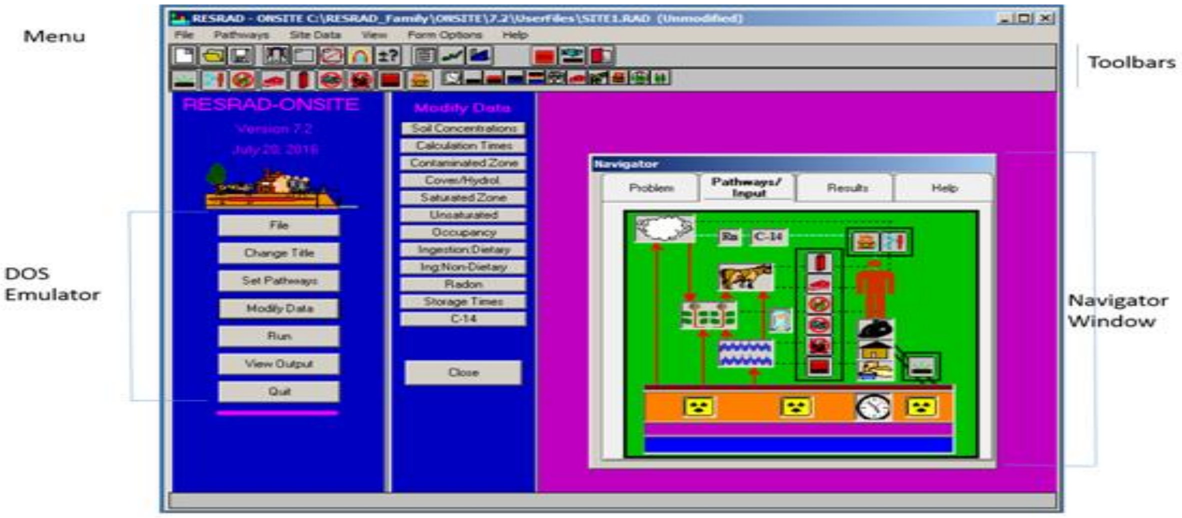


Figure (4): Program software interface RESRAD

4. Material working methods:

A- Conducting field tours to select the most frequently occupied sites by workers throughout the working days of the week. These sites are:

1- The main granary, with an area of approximately (200 x 450) square meters.

2- Phosphate fertilizers store Sp Its area is approximately (150 x 300) square meters.

3- Storehouse of nitrogen fertilizers (Np) It has an area of approximately (150 x 300) square meters As in Figure (5)

Figure (5): Fertilizer stores

B - Taking dose measurements for the sites mentioned above, as shown in Figure (6).

C- Taking other important readings that are within the inputs of the (RESRAD) program.

D- Entering information into the program and working on analyzing and recording the results.

C - Discussing the results and comparing them with international standards

Figure (6): Required measurements

5. Results and Discussion:

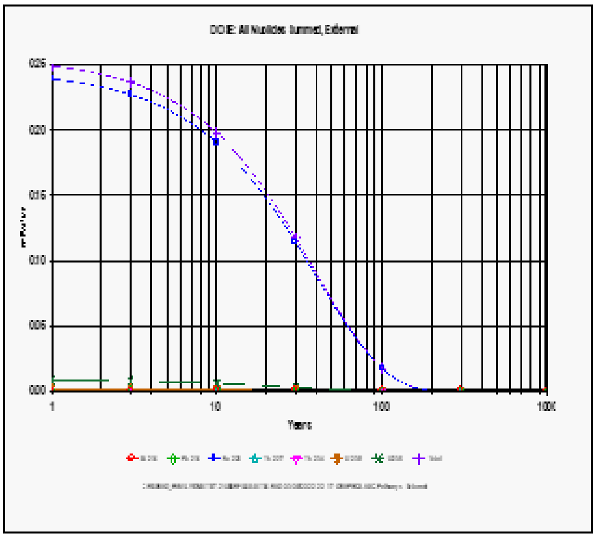
The dose rate was calculated by the (RESRAD ONSITE) program, one of the family of (RESRAD) programs, which was prepared in 1980 by a cadre of the Department of Environmental Sciences at the American International Argonne Laboratories, where this program calculates and evaluates doses and radiation risks on Workers inside a polluted work site using accurate analytical and practical methods and analyzing multiple parts of the site. This package has been developed and updated to appear in its current version.

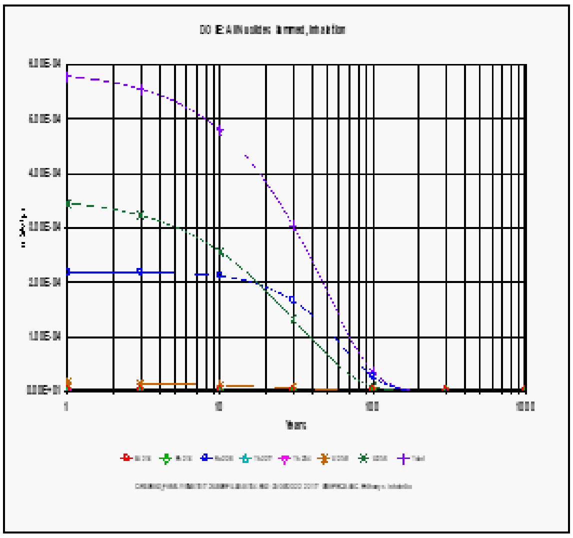
The dose rate for workers in the workplace has been calculated, considering the worker works for (8) hours per day, for (5) days per week, and for (50) weeks per year, i.e. (2000 h/y). We note from the results shown in Table (2) The total radiation dose rate at the silo site is (0.252 mSv/y), which is less than the permissible limits for the general public (1 mSv/y) according to the relevant safety standards contained in the publications of the International Atomic Energy Agency in its publication Part 3 of the General Safety Requirements (GSR. Part 3) which is (1 mSv/y)[11], as well as in the SP store where the dose rate was (0.235 mSv/y) and also in the NP store where the dose rate was (0.2 mSv/y).

Table (1) :Results of laboratory analysis of soil models

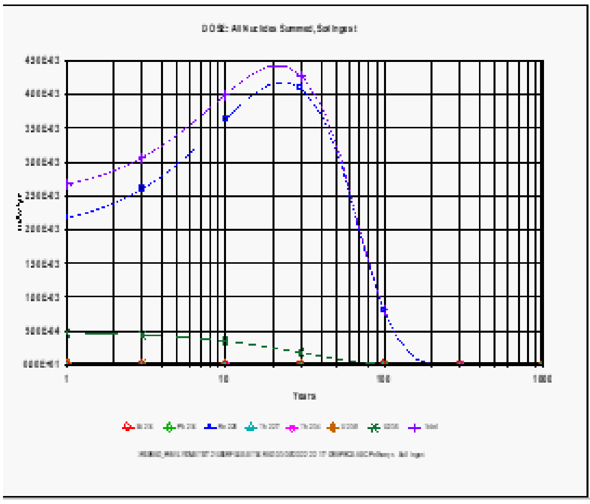
The radioactivity of phosphate samples is in Bq/Kg units									
N.	Model name	K-40	Bi-214	P b-214	Ra-226	Th-227	Pa-234m	Th-234	U-235
1	BG-1	295.8±13.7	31.2±1.2	27.7±1.06	46.96±1.8	BDL	BDL	BDL	3.2±0.4
2	silo	BDL	542.9±6.2	326.1±5.3	552.7±9	43.2±2.5	1075.8±92.1	1530±53	45.2±2.8
3	sp store	BDL	433.2±5.3	306±5.1	518.6±8.6	41±3.1	942±89.9	621.9±22.7	60.1±2.1
4	Np Store	BDL	335.1±4.1	260.2±4.2	441.1±7.1	35±2	741.4±68.2	568.4±20.5	45.5±1.4

5.1. Silo





(1) (2)



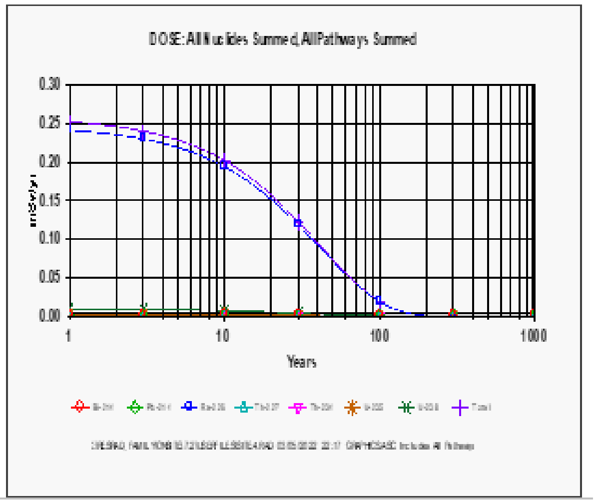
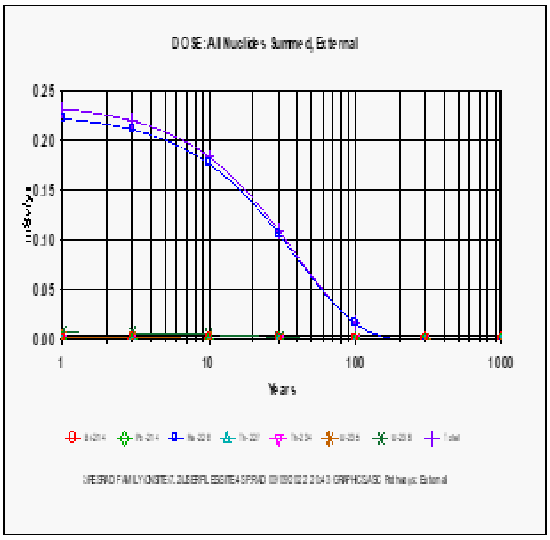
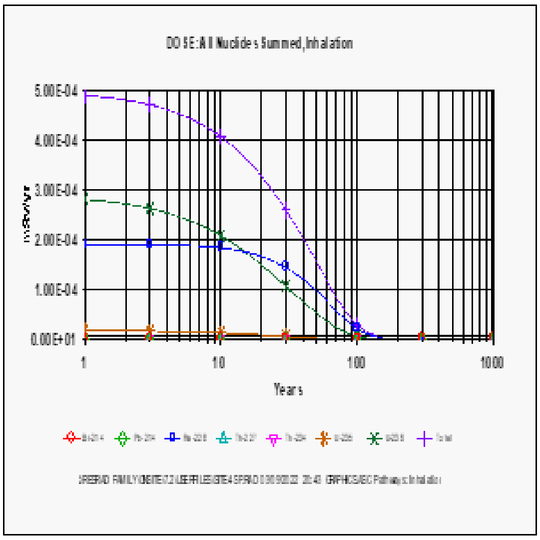


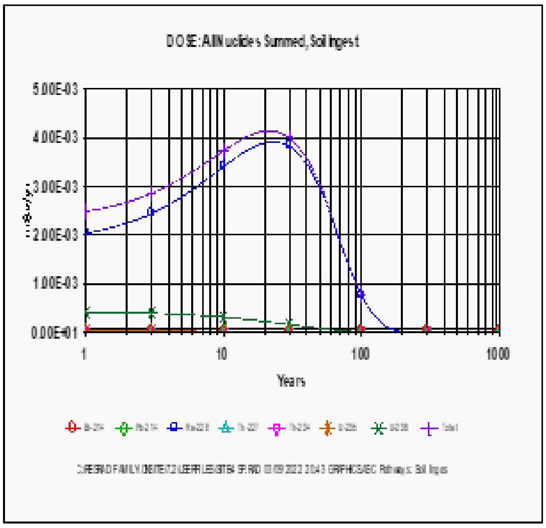
Figure (6): graphs of average external exposure dose (1), inhalation dose (2), dust ingestion dose (3), and total dose (4) in the silo

5.2. Sp. store





(1) (2)



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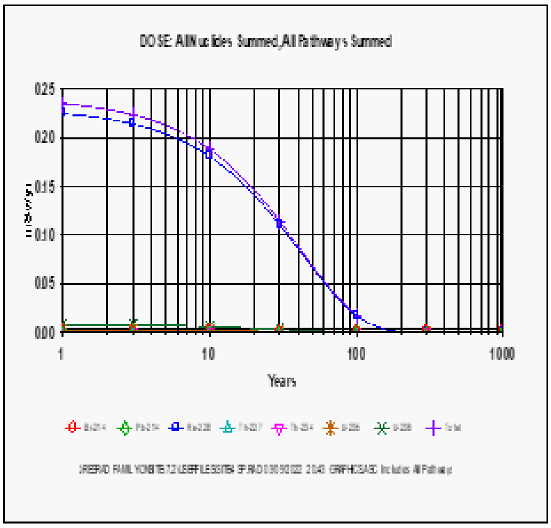
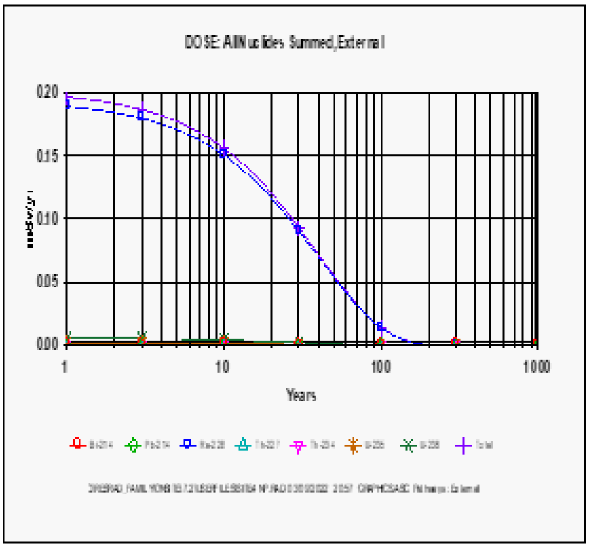


(4)

Figure 7: Average external exposure dose graph (1), inhalation dose (2), dust ingestion dose (3), and total dose (4) in SP store

5.3. NP. Store



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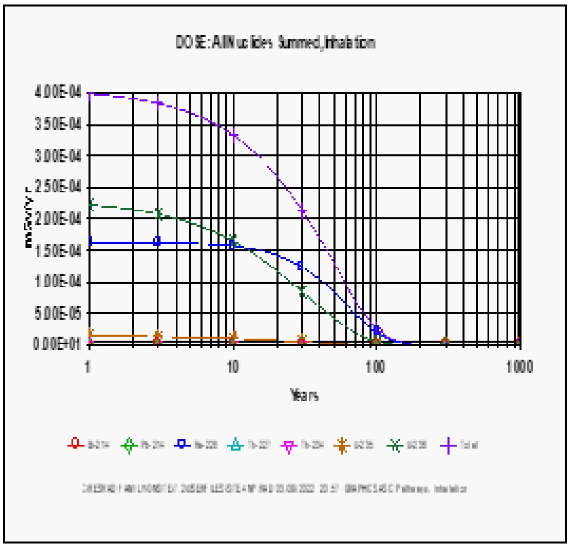

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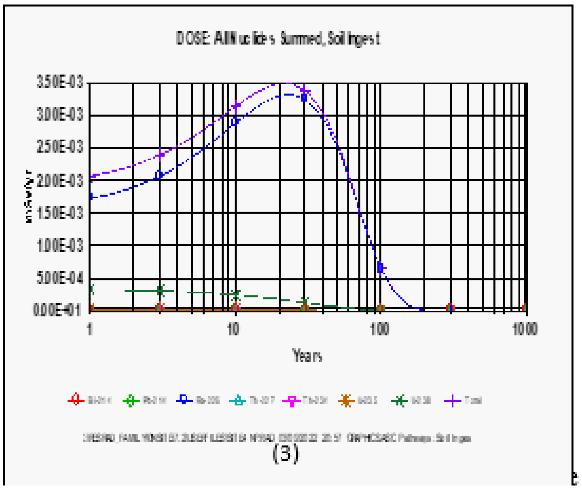

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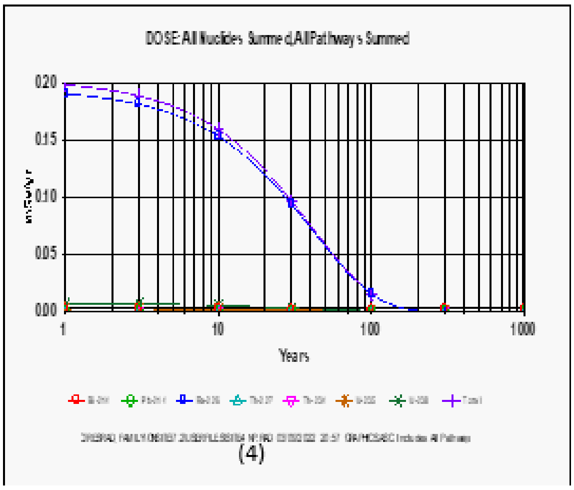

(4)

Figure (8): graph of average external exposure dose (1), inhalation dose (2), dust ingestion dose (3), and total dose (4) in the NP store

Table (2): Average external exposure dose, inhalation dose, dust ingestion dose, and total dose

N.	Location	External Dose mSv/y	Inhalation Dose mSv/y	Ingestion Dose mSv/y	Total Dose mSv/y
1	**silo**	0.249	$0.58X10^{-3}$	$2.67X10^{-3}$	0.252
2	**sp store**	0.23	$0.49X10^{-3}$	$2.48X10^{-3}$	0.235
3	**Np Store**	0.196	$0.4X10^{-3}$	$2.08X10^{-3}$	0.2

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