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Original Research Article



Assessment of the annual dose of the occupational workers involved in dry decontamination of NORM contaminated equipment in Egyptian oil and gas industry

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Abstract

Processing activities for oil and gas production have been known to produce a large amounts NORMs (Naturally Occurring Radioactive Materials) at elevated concentrations as by-product waste streams. This means that TE-NORM (technologically enhanced naturally occurring radioactive materials) can pose Radiation exposure levels that are generated by waste from the oil & gas industry. which necessitate constant monitoring and attention during NORM decontamination of oil and gas equipment. The most common source of exposure is external and internal radiation coming from the ²²⁶Ra & ²²⁸Ra (U-238 and Th-232 series) radionuclides and their progenies. In this study, we focus on the yearly dose of workers who are working in recently established dry decontamination facility as a dedicated tool for NORM contaminated tubing and other small installation's decontamination using abrasive blasting machines instead of High-Pressure Jetting Water facilities, in purpose to minimize the waste volume produced as well as reduce the exposure time of workers involved in the decontamination process. Workers were monitored for one year on three months' basis using the TLD badges. Two groups of workers were formed of 5 persons for each group, working back-to-back 15 days on - 15 days off in field basis, for around 10 working hours/day. All recorded personal doses were within the occupationally acceptable dose limits (20mSv/Year). Most of the workers were exposed to doses range of 700 - 1000 μSv/ 3 months, two readings were away of this range, but even though still within the occupationally acceptable dose limits. It was found that used protective measures against external and internal contamination help enhancement of workers' protection against NORM hazards as well as minimizing the NORM contaminated wastes using the dry decontamination technique to a very far extent in comparison to high pressure jetting water technique which had positive impact on the environment in terms of the radioactive decontamination in oil and gas working environment.

Keywords NORM, Occupational dose, Pipes Decontamination, Egyptian Oil field, scale, Radiation Safety, Environment protection

Introduction

It is well knowing that many raw materials contain traces of naturally radioactive nuclides and as a result of this, they're known as Naturally Occurring Radioactive Materials (NORM). They are encountered e.g. in the phosphate industry, in the mineral sands industry, and the oil & gas industry (IAEA, 2003). A very important arm of effective NORM management strategy is the ability to decontaminate equipment, which has become contaminated with NORM. The removal with a somewhat insoluble NORM scale that has

adhered to equipment surfaces necessitates vigorous agitation of the surface. Engineering controls are used to manage NORM contamination removed from contaminated equipment and to protect employees throughout the decontamination process. These controls must be backed up by administrative processes and personal protective equipment. (PPE) (Bruhl, 1990). NORM contaminated equipment cannot be sold or re-used can expose workers, the general public, and it has higher amounts of radioactivity, which environment to radiation if not properly controlled (ALISA, 2013). The goals of the decontamination process are the safe removal of NORM from

the equipment, delivering insignificant radiation exposure to the workers, and without adverse effect to the environment by spreading NORM contamination (O. S. Desouky, 2018). The main issues of radiation protection associated with the NORM scales are irradiation of staff in areas where scales are deposited and internal contamination by those removing the scales. Surface contamination of pipes and other facility components by naturally occurring radionuclides is a common issue in the petroleum industry (El Ghazaly, 1997). Usually, the reservoir water contains Group II (Periodic Table) cations of calcium, strontium, barium, and radium leached from the reservoir rock. As a consequence, the formation water contains the long-lived radium isotopes Ra-226 ($T_{1/2} = 1620$ y) from the U-238 series and Ra-228 ($T_{1/2} = 5.75$ y) from the ^{232}Th series. The parent nuclides U-238 and Th-232 are not movable with the produced water of the pay zone rocks. Due to operation history, pipes, valves, and further components of the production facilities are more or less contaminated with Ra 6, Ra-228, and their daughter nuclides (Eylander, 1997). In some oil/gas fields, also Pb-210 ($T_{1/2} = 22.3$ a) is dissolved in considerable amounts in the reservoir water, resulting in elevated surface contamination with Pb-210. Another mechanism that may lead to high Pb-210 contamination in components used in oil and gas production is the decay of Rn-222 ($T_{1/2} = 3.8$ d), which has a high solubility in oily reservoir waters (IAEA, 2013).

This study aim is to estimate the occupational workers' dose during decontamination of NORM contaminated equipment using the newly established Dry decontamination facility. Workers were monitored for one year on three monthly' basis using the Thermo-Luminescent Dosimeters (TLD) badges. The Group of workers was divided into two groups of five persons for each group, working back-to-back 15 days on 15 days off in field basis, for around 10 working hours/day.

Materials and Methods

Decontamination facility

The decontamination unit is presented in a closed loop blasting facility illustrated in (Fig.1). Its components are installed in 40' container (as blasting room) and directly connected alongside one 20' container the "Blasting Machine Containe" was placed, which contains the Problast machine, the control system, the filter system for exhaust air, and the equipment for a collection of blasting waste into 200 L drums as an extension. The surveying of contaminated equipment was conducted in an earlier prepared designated area around the decontamination container using output-rack and an extra erected rack for clearance measurements. Besides that, a "Personnel Access Lock Container" (length of 20') was provided, which is sub-divided into a "white area" and a "black area". It is used for changing clothes and contains sanitary equipment for regular use, a shower for incidental use. The contaminated pipe is placed inside a blast room with help of a manual push-pull trolley provided on an overhead conveyor system and the blasting operation is carried out by an operator manually to clean out the pipe internally and externally as well.

Fallen abrasives on the floor from there it is collected manually & again filled into the Recessed Hopper from there it will be belt conveyed, sieved in a media separation unit, and pumped again into the blasting machine for filtration and reuse. The dust and fines from the room are sucked and are directed into the dust Collector and clean air is discharged into the atmosphere, maintaining a clean and friendly environment. During work, all workers put on the proper personal protective equipment (PPE) to prevent internal contamination, standard dust mask, disposable special coveralls, double layer work gloves, and safety boots. After use, the PPE is taken off in the designated area, used coveralls and face masks are directly disposed-off and another rubber PPE is washed up then surveyed to determine if it had become contaminated with NORM or not. If it is proven free from NORM contamination, the PPE could be re-used. All equipment is cleaned and decontaminated to natural background radiation level before reuse.

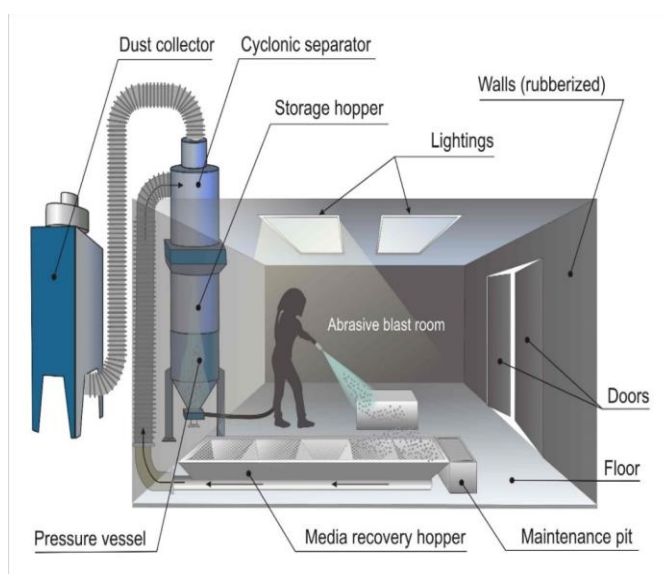


Fig. 1 showing a drawing for a typical Abrasive Blasting Room

Abrasive media used

As most contaminated equipment /facilities in the petroleum industry such as vessels, tanks, pipes, etc, are made of carbon steel so the proper selection for abrasive media is founded on the fact that we must keep the structure of contaminated facility unharmed in parallel to effectively remove the contaminants' scale and sludge, so the selected abrasive media was garnet.

Contaminated equipment

At the time of this study, many contaminated equipment was accumulated over time as result of dismantling during maintenance projects for the facilities, it includes: valves, fittings, bended pipes, etc. Also, tubing and pipes with diameters from 27/8" to 12" with original lengths of about 10m were measured then racked waiting to be mobilized into

the blasting room appropriately for blasting both internally and externally. This is in addition to 115 pieces of valves, fittings, etc. were measured, identified as NORM contaminated, and racked to be ready for decontamination process. In total, about 1220 tubing previously registered as contaminated with NORM were managed, including about 70 tubings that were cleared as uncontaminated based on respective measurements. About 1130 tubing were cleared after successful blasting, and about 20 each tubing had to be re-blasted after been chemically treated, as a result of their oily or tar-like contamination, which could not be removed by abrasive blasting only with acceptable effort. And the 115 separate pieces of valves and fitting were cleared out of NORM contamination and were ready to be used again after functional inspection.

NORM survey instrumentation

Dose rate meter 6150AD and accessories

The survey meter used in the radiation survey in this work has a built-in GM counter (Fig.2) and additionally provides a probe socket to connect external probes. If a probe is connected, the internal counting tube is automatically turned off; the detector of the probe is now measuring. The type of the probe is automatically recognized (e.g., display “ext 17” when a 6150AD-17 probe is connected). Display range and units are chosen automatically according to the type of probe. Also, there is no fixed assignment between probe and instrument.



Fig. 2 Dose Rate Meter model (6150 AD 6)

Surface Contamination meter (CoMo 170)

CoMo 170 is one of the most modern instruments in the field of surface contamination monitors, with the following background noise level of α approx. 0,1 cps, β/γ approx. 15 - 20 cps (Fig.3).



Fig. 3 showing the contamination meter – CoMo 170

NORM survey procedure

Before commencing the NORM survey, environmental radiation (background) intensity measurement was made for determining the incremental radiation dose. Ambient background radiation measurements were made on a level of 1-meter height from the ground outside the contaminated equipment area. A (background) radiation intensity is from 0.06 to 0.14 $\mu\text{Sv/h}$, and the NORM existence is considered starting from double the background. Background radiation is a term used to describe radiation that occurs naturally in the environment. Background radiation is composed of cosmic radiation from outer space, rocks, and soil containing radioactive elements, and radiation from radon gas and its progenies in the air.

Occupational dose measurement

The group of workers involved in this study is ten workers. The workers were supplied with Thermo-Luminescent dosimeters (TLD) (Fig.4) to estimate the external effective dose before commencing the job; the TLDs were evaluated every three months. The assessment of the TLDs was carried out using Harshaw reader. The TLDs were calibrated using Cs-137 source and UNIDOS meter (PTW, Freiburg). The combined uncertainty value is 1.75% for secondary standard dosimetry. The calibration method is performed according to the IAEA safety reports.



Fig. 4 showing the Thermo-Luminescent Dosimeters (TLD) badges

Results and Discussion

During the production process, NORM flows with oil, gas, and water mixture and accumulates in scale, sludge, and scrapings. Also, a thin film can be also formed on the interior surfaces of gas processing equipment and vessels as the result of radon gas decay. The accumulation level of NORM can be dramatically varied from one facility to another (radioactive materials are not necessarily present in the soil at every well site) depending on many factors such as geological formation, operational parameters.

The NORM nuclides of primary concern in oil production are ^{226}Ra and ^{228}Ra . These decay into the various radioactive progeny, before becoming a stable lead. ^{226}Ra belongs to the the238U decay series and ^{228}Ra to the ^{232}Th decay series. The radioactivity detected level can vary significantly, dependent on the salinity of the well-produced water and the radioactivity of the reservoir rock the more NORM that is mobilized, the higher the salinity. Because salt levels rise with a well's age, older wells have higher NORM levels than younger ones. The specific activity concentrations of ^{226}Ra and ^{228}Ra in hard scale ranged from 0.1 Bq/g to15 000 Bq/g and 0.05 to 2800 Bq/g, and in the case of the sludge, it ranged from 0.05 to 800 Bq/g and 0.5 to 50 Bq/g respectively (IAEA, 2003). The level of surface contamination was re-measured upon decontamination completed as shown in (table 1), found most of the decontaminated tubing were in the background level except 20 tubing (3.6 % of total tubing count) was relatively measuring high readings that were rejected and re-blasted again, was a successful lowering down of the contamination level to be within the background level has been shown. The Surface contamination level after decontamination versus percentage of total tubing count was illustrated in (Fig. 5).

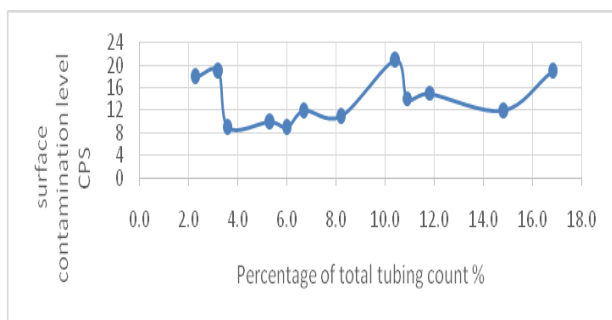


Fig. 5 Surface contamination level (after decontamination) versus percentage of total tubing count

TLD measurements of exposed workers

The occupational exposure dose rate for the workers was tracked for one year on three months' basis using the TLD badges. In the study, two groups of workers; five persons in each group, working back to back 15 days on 15 days off on a field basis, for usually around 10 working hours/ day. The results of occupational exposure dose-rate as shown in (Table 2) showed that; all of the individual doses are within the

occupational dose limits (20 mSv/Year). Most of the workers were exposed to a dose in the range of (700-1000) $\mu\text{Sv}/3$ months (Fig.6). Two workers showed very low /high readings comparing to others. Further investigations showed that; those 2 employees were working back to each other and one of them was in sick-leave for 70 days in the third quarter (low reading) and his work was covered by his relief for the same period (the high reading), which caused these unusual exposures doses, however still within the occupational dose limits (Fig.7).

Table 1. Surface contamination level (after decontamination) versus percentage of total tubing count

Sr. No.	% of total tubing count	Surface contamination level in cps
1	2.3	18
2	3.2	19
3	3.6	9
4	5.3	10
5	6.0	9
6	6.7	12
7	8.2	11
8	10.4	21
9	10.9	14
10	11.8	15
11	14.8	12
12	16.8	19

Table 2. Effective doses for occupational workers exposed to NORM over one year in $\mu\text{Sv}/\text{h}$

Worker's No.	March	June	Sept.	Dec.	Accumulated Annual dose
1	785	850	810	790	3235
2	930	790	885	760	3365
3	990	1012	810	905	3717
4	710	960	320	890	2880
5	810	1031	795	893	3529
6	878	1075	560	785	3298
7	685	915	758	965	3323
8	674	951	730	912	3267
9	689	1007	1560	965	4221
10	985	1012	674	745	3416

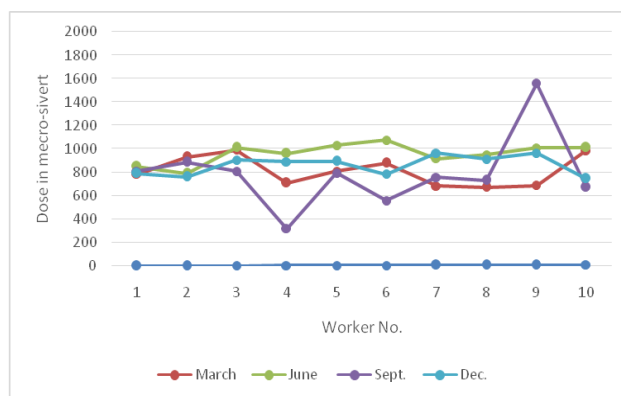


Fig. 6 showing Occupational workers' doses on a quarterly basis

Discussion

In this work, TE-NORM deposits have been studied, focusing on the safe decontamination procedures taking in consideration the dose limit of NORM decontamination workers and the proper precautions to reduce the absorbed dose during conducting the decontamination activities in an Egyptian oil field. By studying and discussing the NORM contaminated facilities in oil and gas we found that; hard scales formation is widely distributed in all parts of the field oil installations. This formation urges us to have a NORM Decontamination Facility (NDF) with a technology that provide minimum waste volume, reasonable time frame, reasonable cost, and at the same time doesn't consume the water as decontamination media. By the NDF hard scales can be cleaned out from contaminated equipment and tubular, stored as waste materials in standard storage barrels in a controlled storage area; transferred for previously prepared temporarily NORM storage area as per the national laws and standards (Law#7/2010 for Egypt) and international standards.

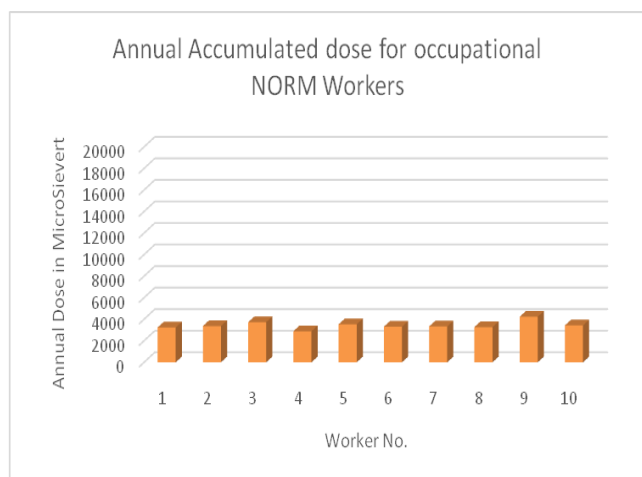


Fig. 7 Showing the annual accumulated dose for occupational NORM workers

Workers involved in NORM decontamination activities must be trained, qualified, and certified in the associated hazards. All NORM operations are planned and organized. All hazards and precautions are addressed and assessed before commencing the operations. Appropriate PPE must be worn and should consist of disposable special coveralls, gloves, Half-face respirators with HEPA cartridges or Quarter-face HEPA disposable respirators. Eating, drinking, and smoking prohibited in the operations area, or radioactive storage area when working with NORM. The time spent in NORM contaminated working areas are optimized by calculating the allowable time spent in the controlled area. In addition, workers wear a personal dosimeter (TLD) during their time on the job.

Conclusion

The abrasive blasting cleaning facility and the dry decontamination method used in NORM decontamination, have proven adherence to regulatory guidelines for the clearance of decontaminated oil field equipment, using accurate and effective field measurements. It turned out to be appropriate methods of very low volume waste with almost zero secondary waste- almost 95% lower waste volume-. Moreover, it presented a cost-effective decontamination method that may enable E&P companies to maximize the benefits of stockpiled assets by decontamination for unrestricted reuse. In monitoring the occupational personnel using TLDs at the processing facility, the most important factors were the dose received and working time spent during Normal activities, repairs, cleaning, and disposal times. The exposure pathways were mainly external exposure caused by gamma radiation and internal exposure due to radon and its progenies and inhalation of contaminated dust which have been minimized by personal protective equipment. The highest reading for TLD of workers showed a received dose of 4221 μSv over 1 year, by comparing it by the occupational workers' dose limits; it is still under the area of permissible dose. With the relatively detected low doses, NORM still requires a monitoring program, since mobilization of NORM is directly proportional to the age of operations and the presence of NORM also varies strongly between reservoirs, individual wells, installations, and production conditions. It is suggested that extra attention be made to NORM decontamination occupational workers to control their radiation exposure. In addition, the selection process of the proper PPE should be ensured that matching the international industry standards, in order to reduce the inhaling or ingestion of radioactive airborne. The results support the setting of national screening for exposure levels to NORM in different activities and developing national control regulation dealing with NORM industries.

Conflict of Interest

The author hereby declares no conflict of interest.

Consent for publication

The author declares that the work has consent for publication.

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