NORM Waste Disposal Alternatives Generated by the Egyptian Oil Industry

Nadia Helal[1], Mahrous A. Hameed[2] and Wafaa Khaleel[2]

[1]Egyptian Nuclear& Radiological Regulatory Authority, 3 Ahmed El-Zomor St., P. Code 11762, P. O. Box 7551, Nasr City, Cairo – Egypt,
[2] Cairo University, Faculty of Science, Biophysics Department, Geza, Egypt.
Email: Nadiahelal1969@gmail.com

Abstract

The present work describes the Egyptian experience with respect to NORM waste generated by the Egyptian oil industry. Three main categories of NORM waste have been identified which are: a) hard scales from decontamination of contaminated equipment and tubular, b) sludge waste and c) NORM contaminated soil. Disposal options of each type of NORM waste have been proposed and implemented. Firstly, hard scales contains the highest levels of radium isotopes (^{226}Ra, ^{228}Ra, and ^{224}Ra), currently stored in standard barrels in a controlled area. Secondly, plastic lined disposal pits were constructed in each area for temporary storage of sludge wastes containing low levels of radium isotopes. Thirdly, disposal lined pits are used for NORM contaminated soil generated as a result of uncontrolled disposal of produced water. In Egypt, there is an established system of regulations specified for NORM operations, residue and wastes. National guideline (PET 1) is based on IAEA safety standards, issued 1999 and updated 2006 (1). Also, there is a national waste management facility, operated by Egyptian Atomic Energy Authority. Regulations, Site categorizations and management will be highlighted in this work. The main objective of this paper is to describe a strategy study executed under supervision of Egyptian Nuclear& Radiological Regulatory Authority for disposal of NORM wastes generated by the Egyptian oil industry. This strategy includes NORM waste safe disposal criteria for NORM waste, selection of disposal methods and the implementation and monitoring of the selected disposal routes.

1. INTRODUCTION

Oil and gas production and processing operations sometimes accumulate NORM at elevated concentrations in by-product waste streams. The presence of high concentrations of NORM in formation water associated with oil and gas production has been recognized since 1904. However, concerns about the possible associated health risk did not arise until the mid-1980s, when the industry and regulators realized that TE-NORM occurrence was more widespread than originally thought and the activity levels could be quite high (2).

The main sources of most of the radioactivity are isotopes of U-238 and Th-232, which are naturally present in sub-surface formations from which oil, gas and formation water are produced. The primary radionuclides of concern in NORM wastes are radium-226 (Ra-226) of the U-238 decay series and radium-228 (Ra-228) of the Th-232 decay series. Other radionuclides of concern include radionuclides that form from the decay of Ra-226 and Ra-228, such as radon-222 (Rn-222) (3).

In this work, we study and analyze the TE-NORM deposits from technical point of view during production of oil and gas in Egypt to find out the best practice for the safe disposal and the alternative methods for the safe disposal of TE-NORM wastes in the oil and gas industry. Re-injection disposal methods was found to be the best solution as realistically safe method for disposing of TE-NORM-contaminated wastes but the slurry-fracture injection technique for waste disposal provides the most safe solution (4, 5).

2. National NORM Guidance

Egyptian Atomic Energy Authority has asked the radiation protection advisory committee to provide an advice on NORM. In1999: PET (1) was issued to meet Atomic Energy Authority' requirements for site categorizations. In2006: PET 1 has been updated to PET 2 (6). According to the National Laws and Regulations, it is not allowed to dispose or release any radioactive waste or contaminated materials without authorization from ENRRA. In case that TE-NORM has been identified on site, the contaminated waste should be treated.

Methodology

1. External Gamma dose Rate measurement
Measurement was made to determine the external gamma dose-rate at the surface of the contaminated pipes and equipment.

2. Personnel equivalent doses assessment
Tracking for the personnel equivalent doses in the site under investigation was recorded for continuous 6 years using the Thermo-Luminescent Dosimeters (TLD).

Results and Discussions

The field under investigation is a mature field after more than 20 years of production; about fifteen wells are now producing, with a range water-cut of (35–89) % producing to a central processing facility. It is well known that the amount of produced water may increase during the production life of each field, which carries soluble and insoluble minerals to the surface. The amount of produced water in a typical production field is given in table (1) and represented in fig. (1). It is noticed that there is a dramatically increase in the water cut of the production wells and this indication that the amount of oil decreases in this reservoir, the graph shows the decrease and then the increase in the amounts of produced water due to reducing the flow rate of the producing wells then increase again after a while, based on technical decision to keep up the facilities and the oil reserve at certain limit.

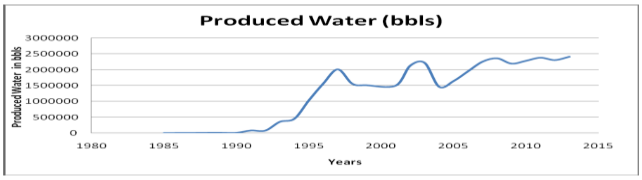

Figure (1) showing a typical field produced water rate.

The oil, gas and water produced are directed from the well to the production facility through surface flow lines, entering via a production manifold. External gamma dose measurement at the well manifold surface for some wells is represented in fig. (2). The data were obtained since 1996 and these shows a retardant relation-(under normal conditions) - between the radiation dose and the maturation of the field. Radiation levels at W-3 and W-4 are relatively higher than all other wells; this observation was matched with the fact that the W-3 and w-4 recorded the highest water content in the oil compared with the other wells.

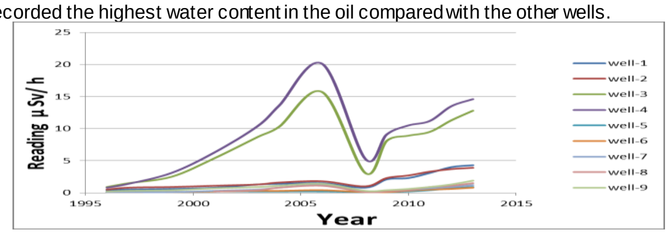

Fig.2 follow-up measurements on TE-NORM for some typical producing wells (μSv/h)

TE-NORM levels in the contaminated scale inside the Free Water knock Out (FWKO) 2 phase separation vessel (Hydrocarbon- Water) increase with the increase in produced water. TE-NORM measurements were taken at some points along the vessel as shown in Figure (3). The cleaning activities were proved that it reduced the amount of contaminated sludge and scale at some points of the vessel as represented in Figure (4).

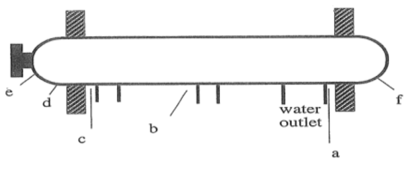

Fig.3: TE-NORM measuring points in a typical FWKO vessel

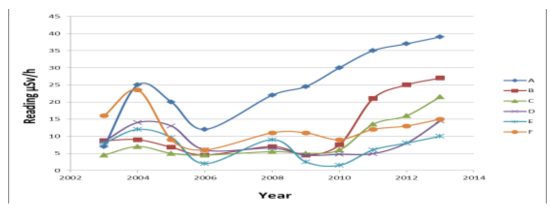

Figure 4: TE-NORM levels in a typical FWKO vessel (μSv/h)

Personal exposure doses for the workers were monitored for 6 years continuously on 6 month basis using the TLD badges. By the analysis of the results of personal exposure doses found that; all the personal doses are within the occupationally dose limits (20 mSv/Year). And by more investigation for the results and classificatins found that most of workers were exposed to a dose in the range of (100 – 400) μSv/ 6 months. But there were 4 readings out of this range and were high in relation to this range. By checking the history of work found that those 4 employees were involved in repairing job in the same time, which caused these high exposures doses but even though still within the occupationally dose limits.

Discussion

TE-NORM deposit life cycle starts from formation, deposition, identification, and control up to final safe disposal have been the focus of this study. By studying and discussing the NORM wastes characterizations we found that; hard scales formation have been decontaminated via decontaminatedfacility (NDF). By the NDF hard scales were removed from contaminated equipment and tubulars by high pressure water systems and then stored as wet materials in standard storage barrels in a controlled storage area; then transferred for previously prepared concrete bunkers with internal isolation.

Sludge, oily sediment that is produced during cleaning operations of oil separators, storage tanks and other surface equipment, is considered as NORM waste. These wastes were found to contain less activity than the hard scale. Oil companies implement NORM management systems regulated by ENRRA using plastic lined disposal pits that are constructed in each area for temporary storage.

NORM contaminated soil; the third main NORM waste produced by oil and gas industry is contaminated soil. Radioactivity, mainly radium isotopes, distribute in surface, subsurface and contaminated soil. Other two important wastes observed in the Egyptian oil fields are the contaminated equipment and produced water. Contaminated equipment and tubulars are stored in NORM yards of each oilfield until they are decontaminated and cleaned; controlled areas were defined in each oil field and inspected periodically by the Regulatory Authority.

No. of worker	Sep-06	Mar-07	Sep-07	Mar-08	Sep-08	Mar-09	Sep-09	Mar-10	Sep-10	Mar-11
1	310	265	271	266	278	301	301	199	335	362
2	347	246	285	252	341	255	255	208	367	255
3	361	395	267	271	261	246	246	281	295	216
4	211	343	241	292	288	215	215	263	264	247
5	268	391	265	299	244	213	213	241	238	341
6	280	395	199	285	213	244	244	258	361	309
7	201	303	263	312	262	287	287	264	300	264
8	227	314	210	327	284	357	357	242	267	288
9	252	368	197	308	211	366	366	263	246	291
10	353	355	214	256	209	285	285	233	218	274
11	223	397	231	202	319	284	284	187	296	263
12	150	355	276	233	285	296	296	257	215	258
13	322	379	255	284	268	299	299	269	264	307
14	393	365	332	273	294	308	308	255	251	344
15	378	356	238	239	217	334	334	216	233	319
16	301	361	233	314	234	316	316	231	302	267
17				325	263	271	271	219	309	249
18				277	388	364	364	237	354	218
19				353	391	353	353	200	382	263
20				367	222	367	367	290	199	254
21				263	307	263	263	220	264	316
22				369	226	369	369	223	283	317
23				296	249	296	296	185	263	322
24				399	291	399	399	164	354	289
25				300	325	350	350	264	268	342
26				286	275	300	300	245	289	286
27				294	291	286	286	261	247	257
28				288	275	294	294	211	263	249
29				254	291	288	288	238	356	293
30				297	285	254	254	187	362	264
31								100	248	318
32								727	269	337
33								945	288	264
34								690	231	227
35								144	267	296
36								682	274	308
37								168	216	297
38								300	300	241
39								149	309	364
40								265	366	300
41								209	325	268
42								167	294	291

External gamma radiation resulting from the deposition of TE-NORM on the flow-lines; tanks, separators, etc, were measured and analyzed for some typical production facilities in the eastern desert. The selected field was a mature asset with a broad range of water-cut, with the maturation of the field the quantity of produced water increased (figure 4), and the field produced water contained enhanced concentrations of naturally-occurring radionuclides dissolved in the produced water. As the produced water increased the radioactive elements leached from the reservoir increased, which led to an increase in the scale formation and sludge deposits inside the field equipment.

Table (4-1) showing the absorbed doses for employees who exposed to NORM during their work over continuous 6 years.

In assessing the occupational doses for workers using the TLDs at the processing facility, the most important factors were the dose received and working time spent during normal activities, repairs and including cleaning and disposal times. The exposure pathways were mainly external exposure to gamma radiation and internal exposure to radon and radon daughters and inhalation of contaminated dust is prevented by protective clothes, the highest reading for TLD of workers showing the dose received was 727 μSv over 6 months period, by comparing it by the worker exposure dose limits; it is still under the area of permissible dose.

CONCLUSION

TE-NORM is considered as a potential source of radiation exposure, which needs to be controlled and safely disposed. On the analysis and field measurements the following conclusions were reached:

- External gamma dose measurement at the surfaces of different water handling equipment is dependent on the amount of water produced, and the radioactive content in the formations;
- Only external exposure and inhalation of radon and dust contribute significantly to the total occupational radiation hazard. External radiation exposure can be minimized by assigning control areas and internal contamination can be minimized by using proper personal protective equipment;
- The study supports re-injection disposal methods as realistically safe method for disposing of TE-NORM-contaminated wastes;
- Workers involved in the process of NORM-handling require more education and training regarding the cycle of NORM management (responsibilities, identification, assessment, control, monitoring and disposal).

References

1. Egyptian Atomic Energy Authority, 2006, Radiation Protection Requirements for Handling of TE-NORM in the Petroleum Industries. EAEA, Regulatory Rule PET 1 and PET 2.
2. M.A.M. Gomaa, "Personal dosimetry for radiation workers upgrading an old petroleum oil field", Naturally Occurring Radioactive Material (NORM VI), proceedings of an International Symposium Marrakesh, Morocco, 22–26 March 2010.
3. El-Ghazaly, S., Hassib, G.M., and Huseen, N.H., 1997, "Norm Survey and Control System in the Oil Production Facilities in Egypt", Paper SPE46565, Proc. SPE Int. Conf. on Health, Safety, Cairo, Egypt.
4. International Atomic Energy Agency, "Technologies for the Remediation of Radioactively Contaminated Sites", IAEA-TECDOC-1086, Vienna, 1999.
5. International Atomic Energy Agency, "Factors for Formulating Strategies for Environmental Restoration", IAEA-TECDOC-1032, Vienna, 1998.
6. International Atomic Energy Agency, "Siting of Near Surface Disposal Facilities", Safety Series No. 111 G-3. 1, IAEA, Vienna, 1994.
7. International Atomic Energy Agency, Safety Series Guide: "Use and Management of Personal Protective Equipment in Radioactive Contaminated Environment", IAEA Final Draft, November 1994.
8. International Atomic Energy Agency, "Radiation Protection and Safety in Industrial Radiography", Safety Reports Series No. 13, IAEA, Vienna, 1990.