

A PROGRAM FOR DISPOSAL OF NORM CONTAMINATED SOIL

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ABSTRACT

Radioactive contamination by Naturally Occurring Radioactive Materials (NORM) in Syrian oilfields has been evaluated. Preliminary gamma survey of contaminated sites has shown a significant area of land being affected. The highest gamma count rate observed was about 9000 CPS; the estimated contaminated land area being about 1.1 km². Volumes of contaminated soil with NORM that need treatment as radioactive wastes, according to the Syrian criteria for clean-up and disposal have been evaluated for each oilfield. Assuming an average contamination depth of 50 cm, the volume of contaminated soil containing ²²⁶Ra higher than 5.2 Bq/g was about 30000 m³. Based on these findings, a remediation plan was prepared and submitted to the Syrian Regulatory Office for review and approval. Several description of the remedial operation and safety precautions adopted in this work is presented.

INTRODUCTION

Naturally Occurring Radioactive Materials (NORM) resulting from the ²³²Th and ²³⁸U-series can be concentrated and accumulated in tubing and surface equipment in the form of scale and sludge as a consequence of physical and chemical processes associated with the oil and gas industry (1, 2, 3, 4, 5). This accumulation of NORM in oil and gas producing operations has been recognized since the early 1930s although the first documented case was observed in 1904 in Canada (6, 7, 8, 9, 10, 11, 12, 13). Radioactive wastes containing NORM are production water, which contains mainly radium isotopes, solid residues and production equipment. Solid residues containing radium deposits consists of sludge and scales from tubing pipes and other production equipment. These radioactive waste require treatment or disposal in an appropriate methods (5, 14, 15, 16). Uncontrolled disposal of this type of waste could lead to environmental pollution and thus eventually to radiation exposure of members of the public. However, the largest generated volume of these wastes is produced water. Produced water is usually separated from oil and disposed of by some means such as down an injection well and disposal well. Some companies may discharge this water into the environment for evaporation. Unlined lagoons or pits are usually built to collect this water. These lagoons become with time highly contaminated with NORM. Leaching processes may occur, and radioactivity may be transferred to underground water. This type of contamination has occurred in the Syrian oil field for a long time.

Syrian oil wells are located at several sites situated approximately 700 km to the northeast of Damascus and near to the City of Der Ezzor. Oil and gas together with production water are routed to various Central-Processing Facilities (CPF) for separation and processing. In the past, unlined evaporation pits or lagoons has been used to hold water, which have been lost by evaporation. Some run-off channels had been created to allow water to run-off into the desert. Few lagoons have a number of sinkholes in their bases from which rapid drainage has been

observed into the sub-surface. A significant degree of sub-surface contamination is therefore to be expected. This radioactive contamination problem has urged the Syrian oil companies to initiate a remediation program in cooperation with the Atomic Energy Commission of Syria. This program consisted of four phases:

Preliminary radiation survey.

Determination of contaminated soil volume.

Preparation of a remediation plan.

Remediation work and final survey for certification.

In this paper, a full description of the remediation program is presented.

FIELD AND LABORATORY WORK

Gamma survey of the affected areas in all fields was carried out using Saphymo SPP2 NF monitors (counts per second). Measurements in the channels were carried out every 5 meters on seven lines, one at the middle of the channel and three at each side (2 m, 7 m and 12 m). While gamma measurements of the lagoons were carried out with a grid of 5m×5m (lagoons areas varied between 50 m x 50 m and 200 m x 200 m) . Distances were measured with a distance wheel and proper directional bearings were also maintained with a Compass.

Surface soil and core samples were collected using a stainless steel core sampler (Auger) with a 7-cm diameter. The number of surface and core samples depended on the area of contaminated land and the number of the hot spots in each lagoon. However, surface soil samples were taken with a grid of 5m×5m and the one-meter core samples were taken only from the hot spots. The core samples were sliced every 10 cm. More than 200 surface soil and 80 core samples were collected. All soil samples were dried in the oven for 48 hours at 105 °C. The samples were then grinded and about 40 g of each sample was filled in a special counting container and stored for two weeks for counting. ^{226}Ra activities in the collected samples were determined by measuring its gamma emitting daughters, ^{214}Bi and ^{214}Pb using gamma spectrometry systems [(high-resolution (2 KeV at 1.332 MeV) germanium detectors with relative counting efficiency of 46% and 80% (Eurisyss)].

RESULTS AND DISCUSSION

Before implementation of the remedial program, detailed site gamma survey and soil characterization was performed to assess the volume and type of waste materials at all NORM contaminated sites. In general, gamma surveys have only enough details for order of magnitude estimates of contamination and are not sufficient for detailed volume and remedial cost estimates. Therefore, in order to estimate the volumes of contaminated material requiring disposal, information was required on the distribution of radioactivity in the surface and with depth in each of the lagoons. This was achieved by selective core sampling in the hot spots and average contamination zones. In addition, the volume of contaminated material to be removed was also determined by the exemption criteria applied (i.e. the level below which a material is considered not to be a radioactive substance). The Syrian clean-up and disposal criteria for NORM contaminated soil has been defined as follows (17):

A soil containing not more than 0.15 Bq/g of ^{226}Ra does not need any treatment.

All contaminated soil having specific activity of ^{226}Ra higher than 5.2 Bq/g need to be treated as radioactive waste.

All contaminated areas containing ^{226}Ra with concentration between 0.15 Bq/g and 5.2 Bq/g need a special treatment on site to reduce the exposure to a value below 100 $\mu\text{Sv/y}$.

Preliminary Radiation Survey

NORM concentrations in the oil industry vary from background levels to levels exceeding those of uranium mill tailings. The most common way to identify NORM contamination is to utilize radiation survey instruments (18). Radiation contour maps were established for each site where different zones being defined using Surface Mapping System Software (version 5) for data analysis. Fig.1 Non-uniform distribution of radioactivity in the lagoons and channels have been observed in all areas. Gamma count rates varied between background levels (30CPS) to several thousands counts per minutes. The highest reported value in the oilfield was more than 9000 CPS in many sites. However, a map for each site was established and used to determine the number of soil and core samples required for determination of contaminated soil volume.

Estimated Volumes of Contaminated Soil

Although radioactive concentrations and gamma exposure readings are interrelated, it is difficult to predict the radionuclide concentrations of soil sample media from gamma measurements due to self- shielding and NORM distribution. Fig.2 shows the surface ^{226}Ra activity distribution in one of the lagoons area. It can be seen that only small area were found to be contaminated with ^{226}Ra having activity higher than 5.2 Bq/g, they are distributed at the edges of the lagoons and this may be due to presence of sludge or scale. The highest surface ^{226}Ra -activity observed in the Syrian oilfields contaminated soil was about 100 Bq/g. Moreover, less contamination levels were also found in other sites. Furthermore, radioactive depth profiles results showed that radioactive contamination has reached a depth of more than one meter in some areas, while in others the contamination has not reached a depth of more than 30 cm in the hot spots. The volume of contaminated soil for all areas, which needs to be disposed as radioactive waste, was calculated assuming an average contamination depth of 50 and found to be 30000 m^3 .

Preparation of a Remediation Plan

Once soil media had been identified as regulated NORM, the next step was to remove the contaminated materials with NORM. A remediation plan based on the results of the preliminary gamma radiation survey and estimated volume of the contaminated soil with NORM according to the Syrian cleanup and disposal criteria has been prepared and submitted to the Regulatory Authority. This plan included results of the survey, brief description of the situation of the contaminated land, the proposed clean and disposal option, procedure for the remediation work and monitoring programs of the site after remediation. The criteria used for choosing the method of remediation and disposal of highly contaminated soil was based on number of factors; viz. volumes of contaminated soil requiring disposal, availability and capacity of existing storage and disposal site, cost/ m^3 of providing new or extra storage or disposal capacity, logistics of waste movement between sites, regulatory approval and others.

Taken into account all of these factors, the following option was adopted:

The contaminated soil within the lagoons and channels was excavated until clean up criteria were met and hauled to the disposal pits.

The disposal pits were constructed by excavating and enlarging one or two of the existing evaporation lagoons in each field.

The pits were lined (floor and top) with impermeable/durable materials (permeability in the order of 10^9 cm/sec) and covered by compacted clean soil. The liners were made by mixing sludge from sludge pounds with natural clays (clay/sludge at a ratio of 4:1) plus limited amounts of bentonites and lime, followed by spreading and compacting. The sludge has been used as stabilizing materials for the contaminated soil.

Monitoring program for radon gas in air and ^{226}Ra concentration in ground water was established.

Remediation Work and Final Survey

After obtaining the remediation license from the Syrian Regulatory Office, the actual remediation work was started. The remediation work has been performed with heavy equipment (Poclain Tracked excavators, Front End Loaders, Tipper Trucks, 5000 Liter Water Truck) under the supervision of a project manager from the oil company and one Radiation Protection Officer (RPO) from the Syrian Atomic Energy Commission at each site. Measures to control wind blown contaminated soil dust were fundamental requirements during the operations. This was achieved by a combination of carefully controlled excavation/loading/dumping with the continuous application of water spraying at each location. Equipment was also washed down as work progressed to minimize contamination build up on the equipment. Personnel involved in water spraying were positioned upwind of the work. Control and administration of contamination procedures was carried out by the Radiation Protection Officer throughout the operation. While control and administration of civil operation was carried out by a local civil engineering contractor. Personnel were kept upwind of operations and wore personnel protective equipment (PPE) consisting of coverall with integral foot and hood, gloves, and FFP3 type mask. All drivers wore PPE and kept cab doors closed and air conditioning switched on. Frequent contamination measurements were required and a continuous presence of a monitoring technician was necessary. Soil samples from the excavated areas were collected and analyzed for radium activity. In addition, detailed radiation measurements were also made by the Radiation Protection Officer. All equipment and vehicles were washed down using Electrical and mechanical water jetting units at the end of the work and monitored for contamination. Used PPE and other waste generated from the work were collected in plastic bags for disposal. Reports were documented and kept for inspection purposes. The Regulatory Office has sent from time to time some inspectors to control the license requirements. Moreover, a final survey was carried out after completion of the work. The area was verified according to the requirements of the license. In addition, water samples from several observation wells around the pits areas in addition to agriculture wells based in the area were taken for analysis. In general, most of the analyzed samples were found to contain relatively low concentrations of radium isotopes (^{224}Ra , ^{226}Ra and ^{228}Ra) and lower than the lower limits of detection of the counting systems.

CONCLUSION

Radioactive contamination by NORM in Syrian oilfields has been evaluated; quite significant areas of land have been found to be highly contaminated. Large volumes of contaminated soil that need disposal as radioactive waste according to the Syrian criteria were disposed of by well constructed disposal mounds. This option of disposal is an internationally accepted method for disposal of waste from uranium mining and millings, and can be used for waste generated from the oil industry. The adopted remediation program here can be used for other areas having similar problem.

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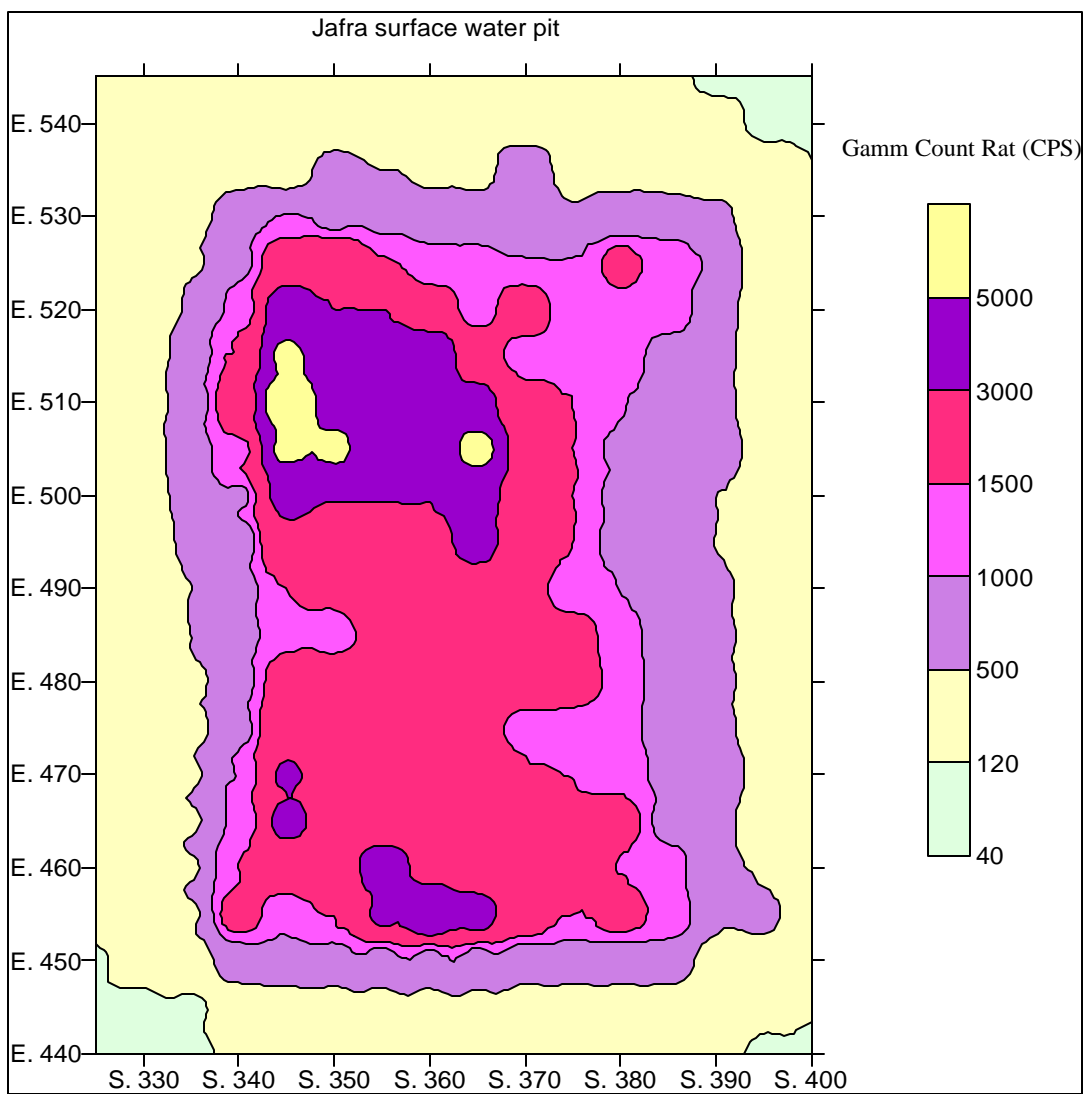


Fig 1. Example of Gamma Contours Maps

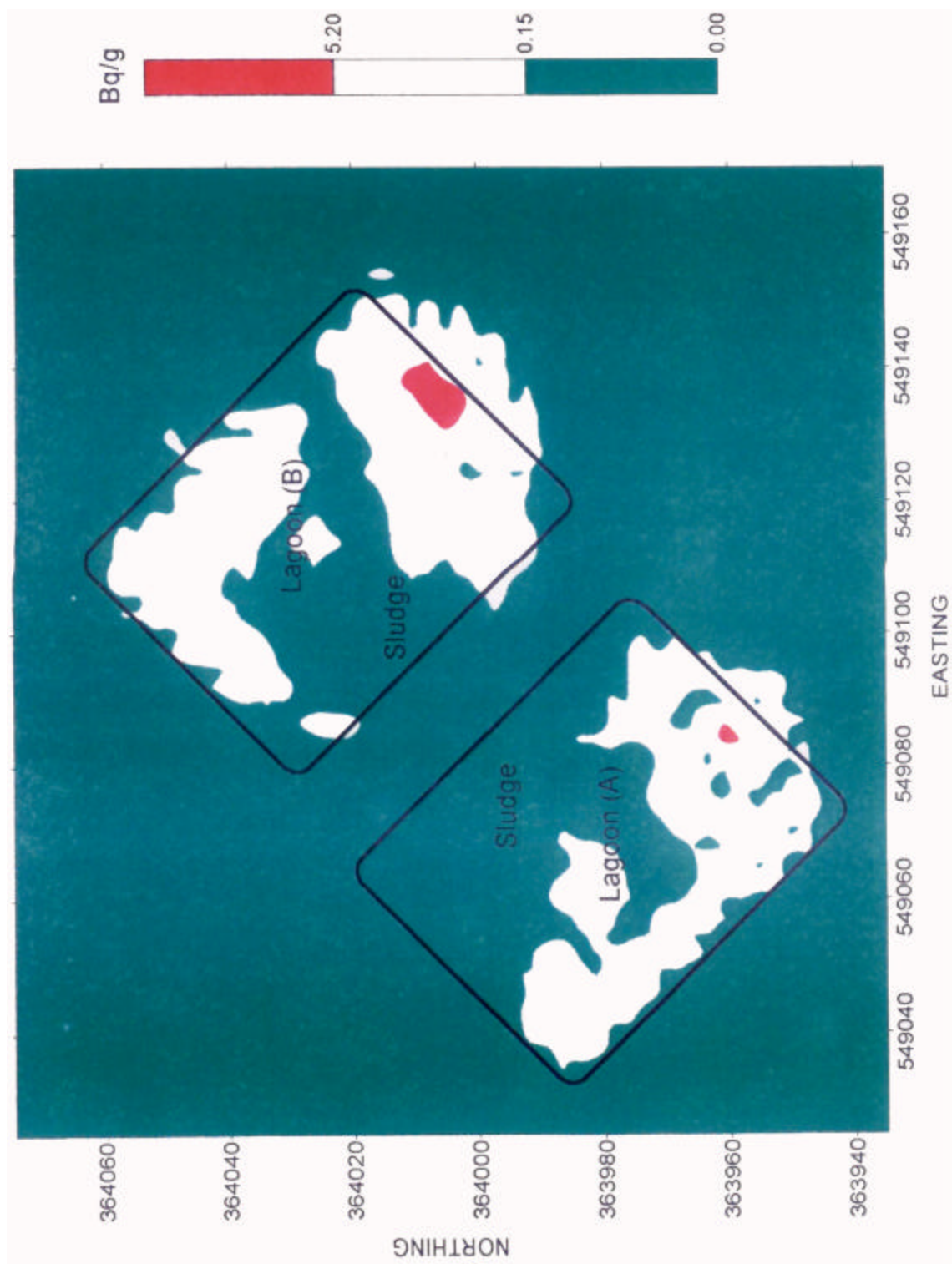


Fig 2. Example of ^{226}Ra Activity Surface Distribution