# AN OVERVIEW OF A RADIOLOGICAL ASSESSMENT FROM OIL FIELD PIPE CLEANING OPERATIONS

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## ABSTRACT

Throughout the history of underground drilling, the accumulation of scale inside down-hole pipes has been noted. This scale builds up over a period of time to the point at which production from that particular well is reduced. At or before this point, the pipes are removed from service and sent to a facility for cleaning, storage, and possible re-use. The pipe scale that is removed from these pipes contains naturally occurring radioactive material (NORM). The particular type of scale and exact activity levels will vary between oil fields due to differences in the underlying geologic formations.

In order to perform a more accurate radiological assessment of a pipe cleaning operation, a variety of measurements were made during the actual cleaning process. To accomplish this, a pipe cleaning (rattling) facility was constructed on the Riverside Campus of Texas A&M University. This facility consisted of two restored Hub City pipe-cleaning machines, one designed for casing joints and the other for smaller tubulars. Both of these machines were set up on a large concrete pad in a configuration similar to that of a typical pipe cleaning facility. Once the machines were set up and tested for proper operation, a series of pipe cleaning sessions were performed, each done in the same manner as they would have been in a commercial pipe cleaning facility. The pipe-cleaning workers had experience with machines like this one due to work experience in a commercial facility.

Pipes from three different oil fields were cleaned during this assessment. During the cleaning, industrial hygiene and radiation monitoring analyses were performed on the particles generated by the process. The goal of the research was to determine the activity concentration of the removed scale, average airborne scale dust concentration, particle size distribution of scale distributed in the operator and helper breathing zones, and the total amount of scale generated

during the pipe cleaning. These data were determined for pipe scale from three geologically different oil fields and formations. To measure these values, many different types of air sampling equipment were used, including 8 high volume and 26 low-volume air samplers, Respicons, Dusttraks, Sidepaks, and Andersen cascade impactors.

An additional goal of the research was to determine the spread of scale deposition as it was generated by the pipe rattling. This was determined through the use of Petri dishes set out on a 1 m by 1 m grid surrounding the machine. It was determined that 99% of the material generated during pipe rattling fell within two meters of the machine centerline and that the radiation levels from the material deposited here (“groundshine”) dominated the worker dose estimates.

## INTRODUCTION

In order to perform a proper and complete dose assessment under any circumstances, real-time sampling must be performed [1]. To this end, the research team set up a commercial-style oil field pipe cleaning facility at the Riverside Campus. The selected site started with an existing concrete foundation that was leveled and lined with an impermeable geotextile liner. This formed what is referred to as the “pad.” A three-foot burm surrounded the pad and ensured that all materials and water on the pad remained there. The liner not only provided a good working environment, but also allowed for cleanup of the pad following each day’s testing. In one corner, a water sump was installed for the collection of wash water and rain for storage before sampling and disposal. The entire pad was 43 m by 26 m and easily accommodated the pipe rattling machines, support equipment, pipe racks, and sampling equipment.

Each of the rattling machines was set up as they would have been in a commercial cleaning yard and operationally tested with clean rusty pipes. A series of 12 pipe rattling sessions were conducted, using a variety of pipe cleaning machines, with a total of 196 down-hole pipes from three different fields being rattled. During each of the 12 trials, a variety of air sampling and radiation detection equipment were employed in collecting the raw data required for the dose assessment.

The typical pipe-cleaning team consisted of two individuals: the “operator,” who manned the machine controls, and the “helper,” who assisted the operator my loading pipes on to the machine. In order to complete the dose assessment for the operator and helper, it was determined that the following goals must be met:

a) Characterize the activity concentration of the pipe scale from a number of replicate samples
b) Characterize the mass-loading of dust in the air around both ends of a tubular during the rattling procedure. This included characterization of the respirable fraction and particle size-distribution of pipe scale dust in the air
c) Characterize the external exposure rates and dose to workers conducting the rattling.

Once the proper data were acquired, they could be used to estimate the inhalation and ingestion committed dose equivalents for the operator and helper.

Figure 1 provides an example of one of the experimental setups on the pad. During cleaning, a pipe runs along the long axis of the rattling machine. Also shown are the pipe racks for clean and dirty pipes and a series of high- and low-volume air samplers.

**Fig.1. Picture of the outdoor pipe-cleaning laboratory with air samplers in place.**

## METHODS AND EQUIPMENT USED

To form the basis for a full dose assessment, a variety of sampling equipment had to be used to collect diverse real-time data during the rattling process. The correct selection of equipment and the proper placement of that equipment is critical for the collection of proper and useful data. At the site, a local weather station was used to gain site-specific weather information including wind speed and direction. A commercial smoke generator was running intermittently on the pad to provide an instantaneous visual indicator of wind speed and direction. This information was key in deployment of air sampling equipment.

Once the wind direction was determined, up to 8 high-volume air samplers with 47 mm cellulose filter paper and flow rates from 110 to 280 Lpm were placed around the machine. One was placed upwind to determine the background ambient air concentrations and another approximately 30 m downwind. The remainder were positioned around the operator and helper. During the course of a sampling session, these high-volume samplers were monitored for decreases in flow rates. If the flow rate decreased by 40 Lpm, the pipe cleaning was halted while the loaded filter was removed and a new filter paper was placed in the sampler.

Up to 35 low-volume air samplers were used during each session. Most of these were placed on PVC pipe stands at ~1.5 m to ensure breathing zone samples were being taken. The majority of these samplers had closed-face filter cassettes, but ten had cyclone separators on the inlets to eliminate non-respirable particles. Each of the cyclone separator-equipped cassettes was paired with an open-face sampler in the same location. All cassettes were loaded with matched weight filters of mixed cellulose ester, 37 mm diameter, 0.8 µm pore size. Each of these cassettes was supplied by a certified industrial hygiene laboratory. At the conclusion of each trial, the cassettes were shipped to a certified environmental radiation measurement laboratory for analysis. Eight low-volume samplers were in fixed sampling locations adjacent to the cleaning machine and one was placed in the upwind direction to measure background conditions. The remaining samplers were placed in two concentric arcs directly downwind from the source. Most of the samplers were calibrated prior to each session to sample at 2.8 Lpm. These samplers were turned on just prior to the start of pipe cleaning, ran continuously during operations, and were turned off immediately after the session was done for the day.

The activity level on each of the low volume filters papers was determined by gravimetric analysis. The filters were then analyzed for Ra-226 and Ra-228 using wet chemistry techniques. All of the high-volume sampler filter papers were weighed prior to use and after removal. Once loaded with scale dust, they were analyzed by gamma spectroscopy.

Another area of interest was size selective sampling. This raw data was collected with industrial hygiene air sampling instruments located downwind from the discharge end of the pipe during cleaning. Respicons and Andersen cascade impactors provided aerodynamic particle size-selective sampling. Because of the low average dust concentration and the low flow rate of the Respicons (two to three liters per minute), these instrument were unable to collect sufficient mass. The Andersens, with their higher flow rates of 28.4 Lpm were able to collect the necessary data for the determination of the particle size distribution from each pipe cleaning session.

Both workers on the pad during the operations were issued personal dosimeters for radiation dose monitoring. These Luxel badges were only issued during pipe cleaning days. The local area radiation levels also were monitored with a Ludlum Model 19 Micro R meter. Regular surveys were performed in operator and helper areas, around the pipe racks, and along the axis of the rattling machine.

Another unknown in the pipe rattling process was the disposition of the pipe scale once it was ejected from the end of the pipe. In order to determine the deposition footprint of this material, 1,118 Petri dishes (100 mm x 18 mm) were placed on the pad in a one-meter grid. For each of two sessions, individual dishes were color coded, numbered, and tared. The entire array of dishes was set in position with their covers on. Just prior to starting the run, all covers were removed and placed under the open dish. Following the completion of the trial, each dish was recovered, boxed, and sent back to the laboratory to be weighed again.

## RESULTS

All the raw data provided by each of the sampling methods presented in the previous section were used as inputs to the dose assessment.

The activity concentration of the Ra-228 and Ra-226 were determined for each of three operational oil fields in this dose assessment. The Ra-228 and Ra-226 and progeny results for

Field #1 were 14.6 ± 2 Bq $g^{-1}$ and 33.6 ± 0.4 Bq $g^{-1}$, respectively; Field # 2 were 26.6 ± 0.3 Bq $g^{-1}$ and 65.5 ± 0.7 Bq $g^{-1}$, respectively; and Field # 3 were 81.4 ± 8.5 Bq $g^{-1}$ and 57.7 ± 0.4 Bq $g^{-1}$, respectively. These values were determined from scale samples that were removed from the pad after each cleaning operation.

Total airborne mass was calculated from the data collected by low-volume air samples in the breathing zone. The average dust exposure calculated from data that exceeded the lower limit of quantification was found to be 1.4 mg $m^{-3}$ with a 95% confidence level.

The size selective results from the Andersen cascade impactor were treated in the most conservative manner possible. For the most part, clean but rusty pipes made up the majority of the workload of these commercial yards. This workload would result in the absence of NORM dust as well as a much different particle size distribution. Conservative collection and use of the data in dose calculations leads to an overestimate of the normal exposure of a worker that would normally have been less exposed. Table I presents the size selective results from the pipe cleaning sessions.

**Table I. Observed particle size distribution, by formation.**

| Particle size / Source | Field #1 | Field #2 | Field #3 |
|---|---|---|---|
| 1 micron (<1.1 µm) | 3.0% | 1.2% | 0.2% |
| 5 micron (>1.1 µm, <5.8 µm) | 30.5% | 25.8% | 12.3% |
| 10 micron (>5.8 µm, <9 µm) | 12.9% | 15.3% | 29.9% |
| Total Respirable Fraction | 46.4% | 42.3% | 42.4% |

As previously mentioned, two pipe cleaning sessions were dedicated to creating a map of particle deposition by mass. Both trials had similar results and the map for one of these is presented in Figure 2. The results indicated that more than 99%, by weight, of the deposited scale fell within two meters of the machine centerline, the great majority of which was deposited in the downwind direction.

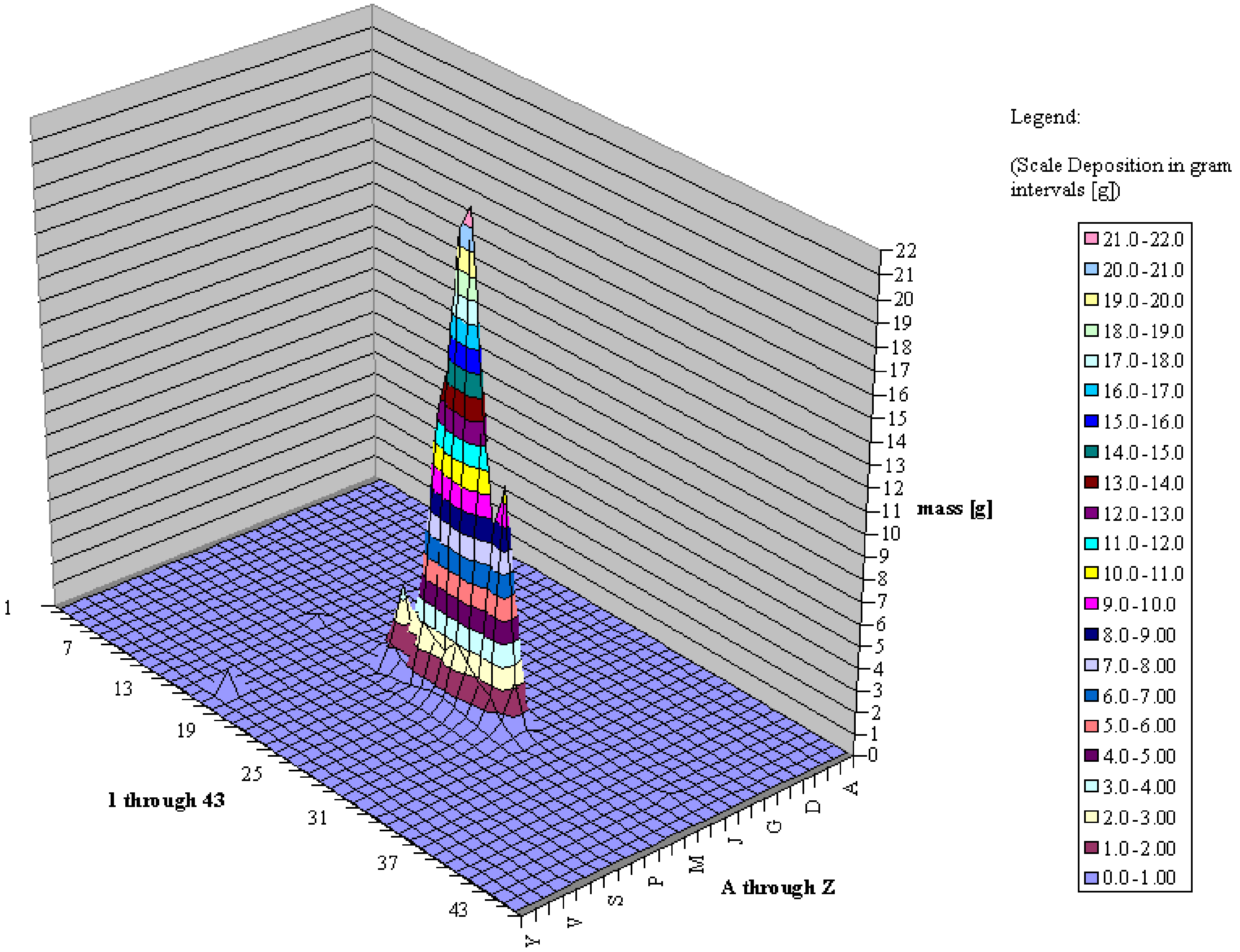

**Fig. 2. Map of scale deposition. The cleaning machine runs down the centerline of the graph (along "M").**

The external dose data from the workers' dosimeter badges indicated that they received doses between background and 0.01 mSv per day of work. In order to analyze for other sources of external radiation, area surveys were performed around the pipe racks and the on the accumulated scale on the pad following the day's work. This survey data was combined with measurements made of 1 and 4 cm deep scale to estimate the groundshine from the scale deposited on the ground after many days of pipe cleaning operations. When compared to other pathways, groundshine was the largest contributor to the estimated dose.

To calculate inhalation dose, the worker breathing rate was assumed to be 1.2 $m^3 h^{-1}$ rather than the 1.5 $m^3 h^{-1}$ recommended in ICRP 66 [2]. This assumption was made based upon the observed low activity level of the workers during the pipe cleaning operations. Using the previously determined average breathing zone dust exposure estimate of 1.4 mg $m^{-3}$ and the respirable dust fractions presented in Table I, the average amount of dust inhaled per pipe is 0.11mg. Additionally, secular equilibrium for all nuclides below Ra-226 and Ra-228 until Po-210 was assumed, and this was supported by the sample data. Lead-210 and its progeny are treated as if there had been 10 years of ingrowth. These facts and assumptions result in a committed effective dose estimate of 0.022 µSv per pipe from Field #1, 0.040µSv per pipe from Field #2 and 0.090 µSv from Field #3. For this dose assessment, it was assumed that 20 scale-laden pipes were cleaned per day, 250 days per year. This would result in annual inhalation doses of 0.11 mSv from Field #1, 0.20 mSv from Field #2 and 0.45mSv from Field #3.

Incidental ingestion of the pipe scale generated during the pipe cleaning process was also considered as a pathway in this dose assessment. The accidental ingestion rate of 100 mg $d^{-1}$, the NCRP Report No.129 rate for construction workers [3] was used. Also, the ICRP 72 dose coefficients for committed effective dose were applied under the same assumptions of equilibrium that were made in the inhalation dose estimates. This resulted in an estimated committed effective dose of 0.08 µSv $d^{-1}$ when Field #1 pipes were cleaned, 0.16 µSv $d^{-1}$ from Field #2 and 0.039 µSv $d^{-1}$ from Field #3. Based upon this data the calculated annual committed doses from the dust generated from pipe cleaning is 0.19 µSv from Field#1, 0.39 µSv from Field#2 and 0.97 µSv from Field#3 for both of the workers.

Based upon experiments conducted with the most radioactive of the scale, and taking into consideration the shielding effect of the machines and the working positions of the machine operator and the helper, the maximum estimated annual dose for the operator from groundshine is 2.8 mSv and the helper is 4.1 mSv. The helper has an additional external exposure pathway of pipeshine, radiation from the pipes before cleaning, which leads to an additional estimated annual dose of 0.28 mSv.

A summary of the estimated annual dose to oil field pipe rattler operator and helper are presented in Table II.

**Table II. Estimated annual dose to oil field pipe rattling operator and helper (mSv).**

| Dose pathway | Operator | Helper |
|---|---|---|
| Inhalation | 0.45 | 0.45 |
| Ingestion | 0.097 | 0.097 |
| Pipeshine | 0 | 0.28 |
| Groundshine | 2.8 | 4.1 |
| Total[a] | 3.3 | 4.9 |

[a] These doses are based on 20 dirty pipes cleaned per day, 250 days per year.

## CONCLUSIONS

The results of the estimated annual dose clearly indicate that groundshine is the major contributor to overall dose in a commercial pipe cleaning facility. Several additional factors should be taken into account, however. This groundshine result was based upon pure scale, whereas the material on the ground at a pipe yard would be a mixture of scale, rust, and possibly other non-radioactive materials that may serve as shielding. Also, there are indications that at times the helper actually stood on top of the pipes rather than on the ground in the scale, thereby providing some shielding from the groundshine. The dose estimate is also based upon the highest activity concentration of the scale from the three fields.

The 12 pipe cleaning sessions performed at Texas A&M University were the first attempt under controlled conditions to obtain real-time live data on operational pipe rattling and cleaning machines. The raw data collected here, along with certified laboratory analyses and the employment of proven dose assessment techniques and assumptions resulted in estimated dose estimates lower than previous estimates. The use of an extensive array of sampling equipment and the attempt to have the equipment wholly within the main plume of generated material ensured the best possible data collection with the equipment on hand as well as the most conservative (maximum) air-loading and dose results. Whenever possible, the collected data was used rather than assumptions. This resulted in a solid, but over-estimating dose assessment for the workers at these facilities.

## REFERENCES

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