TECHNIQUES EMPLOYED IN MEASURING PETROLEUM PIPE SCALE RELEASED BY A DRY RATTLING PROCESS

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ABSTRACT

Over the course of normal oil field drilling operations, pipe scale, concentrated inorganic solids such as barium sulfate, deposits on the inside of down-hole pipes due to drilling-induced changes from subsurface conditions. The deposited scale has a naturally occurring radioactive material (NORM) component; the most common form being radium sulfate. One of the results of scale deposition is the reduction of flow through these down-hole pipes or tubulars. The affected pipes are then removed and sent to a de-scaling facility to be cleaned. Many of these de-scaling facilities exist throughout the country and have serviced the oil field industries for many decades, but the personal exposure scenario has never been fully studied.

This experiment was designed to emulate the actual pipe de-scaling operations as they were conducted at commercial facilities. An industrial pipe de-scaling machine was restored to full operating condition and set up on a geo-textile lined pad. The machine was set up along with its pipe racks on the pad in such a matter that allowed for the setup of air sampling and monitoring equipment, the location of which was determined daily by the prevailing wind direction.

During the experiment, pipes from three oil fields, or formations, were de-scaled and the airborne concentration, particle size distribution, and mass loading from each of these operations were determined. Most of the pipes were automatically rattled on the larger casing machine since this was the most common practice at the commercial yards. However, some tubulars were machine rattled on a smaller machine and others were hand rattled using a power lance. Samplers were deployed to help to determine the local airborne concentration, particle size distribution, and upwind and downwind dust concentration. Examples of the samplers used were low-volume personal air samplers, high volume samplers, size specific samplers such as Andersen-type cascade impactors, and Respicon™ samplers.

The type and number of samplers generally varied throughout the six month period of the experiment; the exceptions being the operator and his helper, who always wore at least one personal air sampler during pipe cleaning operation. The air samplers deployed changed as experience increased and the type of equipment required to determine both the air concentration and size distribution was more completely identified. During the last set of experiments, the on-pad distribution of scale ejected from pipes was determined by the placement of 1,118 Petri dishes on a one-meter grid covering the pad.

INTRODUCTION

Cleaning of used down-hole oil field pipe has been performed ever since large scale oil drilling began over 100 years ago. The need for cleaning of this pipe is due to the fact that during pumping operations, the pipe can build up pipe scale consisting of concentrated inorganic solids. While initial production of oil and gas from a formation is normally anhydrous, water production will increase as pressure decreases over the lifetime of the oilfield. The oil and gas industry is one of the largest producers of subsurface water [1]. The water produced has been found to contain varying concentrations of naturally occurring radioactive material (NORM) in the form of dissolved mineral salts [1,2,3]. These salts from the brine of the subsurface water can deposit in the form of scale on the inner surface of the pipes. A portion of this scale has been shown to contain NORM, predominantly in the form of radium. These salts can plate out inside the pipe to such a level that the amount of scale in the pipe affects the well's flow rate. Substantially occluded pipes are then removed from the well and may be cleaned at one of the aforementioned yards or disposed of.

The Department of Nuclear Engineering at Texas A&M University was initially asked to undertake a study to determine the amount of radioactivity in the plated scale. Once done, this work expanded into a full study of the scale produced by the de-scaling process. In order to accomplish this, a pipe de-scaling machine was placed in a laboratory setting at the university. Using this machine to de-scale actual oilfield pipes, the goals of this research were to determine the airborne concentration, mass loading, and local dispersion of scale released during the de-scaling process. The airborne dust levels were measured at the breathing zone of the operator and his assistant through the use of personnel air samplers worn by each. At the same time, a large array of personal air samplers and high volume air samplers was placed around the machine. These were located both in the areas that workers normally occupied during these processes and in the area of highest dust loading (i.e., directly downwind) to measure the total amount of dust present. A series of size selective samplers was also deployed in the area of highest dust in order to determine particle size distribution.

INITIAL WORK

This project started with a pilot project to measure the radioactivity of pipe scale that was removed from short sections of oil field pipe. Among the goals of these initial tests was to determine the viability of germanium detection system use for the identification and quantification of radionuclides present in the scale deposits. Since oil well chemistry and scale radioactivity levels vary from field to field, pipes from three different oil fields were de-scaled over the course of this experiment.

Once it was determined by the use of counting systems at Texas A&M University that more than a trace amount of radioactivity was present, short pipe sections were sent to Southwest Research Center for more detailed analyses of the scale. These samples indicated a mélange of NORM in the scale. It was determined that, in order to accurately determine the total amount of scale and activity level of the scale, a full size experiment had to be conducted under controlled conditions.

LABORATORY SETUP

The first step in constructing an outdoor laboratory was the determination of site location. Several factors were taken into consideration. First, the site had to be in an open area that allowed the local weather conditions to affect the dust generated by the de-scaling process. Second, the site had to be large enough to accommodate the de-scaling machine, its support equipment, and sampling equipment. The general site also had to be large enough for water storage tanks, support trailers, and storage racks for large numbers of used and clean pipes.

Upon the selection of an appropriate site, the University required a project safety analysis (PSA) for the experiments to be conducted and approval for the storage and use of pipes containing technologically enhanced naturally occurring radioactive material (TENORM). The PSA required the approval of several University and State agencies and the University Environmental Health and Safety Office. Once fully approved, work on the site could begin.

A site was selected on the far northern side of the Texas A&M Riverside Campus in an open flat field. A pre-existing concrete slab proved to be a good base for the 3 m wide and 24 m long casing and tubular rattling machine and all of its supporting equipment. Heavy equipment was used to level the site and extra fill was added to ensure a site large enough to accommodate the equipment and a 3 m wide and 0.6 m tall berm surrounding the pad. This berm was installed to ensure containment of rain and wash water. Once completed, the new 26m x 43m pad was covered with an impermeable geo-textile liner that extended 3 to 4 meters beyond the berm. In one corner, a 1 m by 1 m by 0.5 m deep water collection sump was created to collect all wash and rinse water. The area also had an old road bed that was used for support trailers and pipe storage. Full electrical and water service were established at the site over the course of the experiment and enabled the laboratory to be fully operational.

EQUIPMENT USED

A Hub City Ironworks model PCM 13375 pipe cleaning machine was used in these experiments due to this model's known use in historical operations. As the pipe was moved up the length of the machine, a stationary air-powered cutting head would remove the scale from the inside while steel brushes cleaned the outer surface of the pipe. This machine was restored to proper operating condition so as to emulate the industrial scale removal processes employed in the operating yards during the periods of concern. Pipe racks were placed on either side of the machine to hold pipes before and after de-scaling, and a smaller non-casing machine and manual lance system were on site for future use.

Since the goal of the experiment was to determine the particle size distribution of the dust generated during de-scaling, a series of air sampling equipment was used. A series of low volume SKC personnel air samplers were deployed during most of the pipe runs of the experiment. These were placed on PVC holders and deployed at breathing zone level. High volume air samplers were also deployed in a wind-dependent sampling array in order to collect the dust near the cutting head, and in both downwind and upwind directions. Aerodynamic size selective sampling to ascertain Respirable fraction and particle size distribution was performed using a variety of samplers including Andersen-type cascade impactors and Respicons™.

Additionally, important considerations in sampler positioning were wind speed and direction, so a weather station was placed onsite to support optimum sampler placement. Further to this end, a commercial smoke generator was employed on the pad to give immediate visual confirmation of wind direction.

OVERVIEW OF EXPERIMENT

Since this entire experiment was run over the course of six months and involved 196 dirty pipes, a variety of runs were conducted. The first series of runs was using clean pipes so as to ensure proper operation of the machine in both manual feed mode and automatic operation. These initial test runs also enabled the testing of the air sampling equipment, the weather station, and the smoke generator.

There were three stages in this ever-evolving project. First, pipes from each field were cleaned on the large casing and de-scaling machine with air samples collected during each of these runs. The second phase of the experiment was to run the pipes on the second, smaller, machine that only de-scaled the inside of the pipe and did not clean the pipe exteriors. The last phase of the experiment was to manually de-scale the pipe interiors using the hand lance.

Prior to each de-scaling run, the low volume air samplers were calibrated to 2.7 lpm for the samplers with only filter cassettes and 1.9 lpm for samplers with cascade impactors. High volume air samplers were calibrated for a variety of air flows ranging from 70 to 280 lpm depending upon location. Just before being deployed, each sampler had a pre-weighed filter placed in the sampler nose. If during the course of the day's run the paper became so loaded that any sampler flow dropped 30 lpm, the run was stopped and these filters were replaced. Prior to all pipe runs, the Andersen sampler and the other size selective samplers were also calibrated and set up. Upon completion of the day's activities, the filters from the high volume air samplers were all re-weighed and sealed. These filters, along with the cassettes from the low volume air samplers, were sent off to a laboratory for radioactive analysis of the dust collected on them.

As with the course of any experiment, the amount and type of sampling equipment grew in scope over the six months. In addition to just air sampling, two more specialized tests were also conducted. The last two days of pipe cleaning were used to conduct a detailed experiment to determine the spread of particles generated by the de-scaling process. In order to accomplish this, the machine pad had a grid spray painted on it at one meter intervals, some 1,118 sample locations. Prior to the test, pre-weighed empty Petri dishes were placed on the grid and a series of pipes run. All the dishes were then covered and re-weighed. From the data acquired, distribution patterns of the particles dispersed during the de-scaling operation were created.

LESSONS LEARNED

This experiment grew from a simple idea into a very involved process encompassing a great deal of manpower and equipment. This type of work had never before been done in a laboratory setting and required a good deal of planning and preparation. By the time the last of the pipe runs had been completed, the number of low and high volume air samplers deployed had doubled and several specialized size selective samplers had been purchased. The scope of the project grew from the initial estimate of running 50 pipes to the final total of 196 pipes. Over the course of the experiment, personnel coordination improved and, by the end of the experiment, the sampler preparation time had been cut in half and the time to change out filter papers was greatly reduced, which allowed for the running of all the required pipes in a single session.

FUTURE WORK

Over the course of the experiment, it was observed that scale from each field was very unique not only in the type of dust generated during the de-scaling process but also the time and effort required to de-scale the pipes. Due to unique chemistry, each field had its own level of NORM present in the pipes and the scale itself was physically different. The results of this test can only be used in the general terms since there is a large variation in the radioactivity between each formation. This experiment was limited by the number of oil fields from which pipes were received and the number of pipes from each field. Since the machine and equipment remain in place, further research could be performed on pipes from other fields and formations. This is only the first study done on this particular subject and since the impacts of these pipe cleaning operations have become an area of concern, other formation-specific studies would be beneficial.

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