WorleyParsons
resources & energy

EcoNomics

Industry Case Study: NORM in the oil & gas sector

NORM and Natural Radiation Management, 19th - 20th April 2010
Hilton Paddington, London
Mark Liddiard & Joe Toole – WorleyParsons

WorleyParsons
resources & energy

Overview

- Recap previous Radon survey in Dec 2008
- Follow-up Radon survey July 2009
- Radon dose assessment
- Review of in-situ radiation surveys 2005 – 2009
- NORM waste accumulation (pending disposal)
- Radiological risk assessment for platform

EcoNomics

WorleyParsons
resources & energy

Background

- Previous surveys on platform identified presence of NORM; elevated gamma dose rates at some separators and at waste drums.
- Clients' Regulator requested measurements of both Radon-222 and its alpha daughters (progeny) on the oil platform, both during ambient conditions and during work/maintenance activities.
- The results of exploratory radon measurements are to be made to confirm or otherwise that inhalation doses due to radon and progeny are very much less than those from external gamma radiation.

EcoNomics

WorleyParsons
resources & energy

Choice of Radon monitoring system

- Several options explored
- Track detectors – typically 3-month exposures, no daughters X
- Electret – typically 2-7 days exposure, no daughters X
- FemtoTech Pulsed ion chamber, real-time, no daughters X
- AlphaGuard +AlphaPM – real time, includes daughters ✓
- Real time measurements and use of DataExpert software package will allow results for all areas to be displayed and reported prior to leaving platform

EcoNomics

WorleyParsons
resources & energy

Radon and Radon progeny measurements

- AlphaGuard radon monitor

Radon gas diffuses passively through a filter into an ionisation chamber

Sampling period 10 minutes

Detection limit ca 10 Bq/m^3 radon-222

- AlphaPM (progeny meter)

Internal pump, high-precision flowmeter, filter intercepts Rn progeny, alpha decays counted by semiconductor detector

Sampling period 10 minutes, units EEC, Bq/m^3

Synchronised to AlphaGuard

- DataExpert database software package

EcoNomics

WorleyParsons
resources & energy

Instruments deployed

EcoNomics

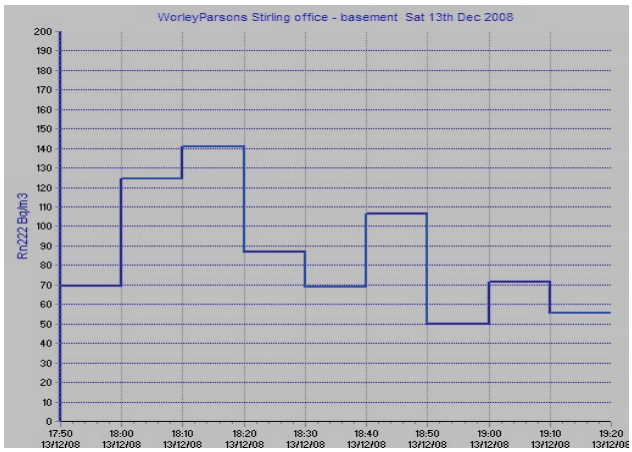
WorleyParsons
resources & energy

Detector display

EcoNomics

WorleyParsons
resources & energy

WorleyParsons Office basement, Stirling



EcoNomics

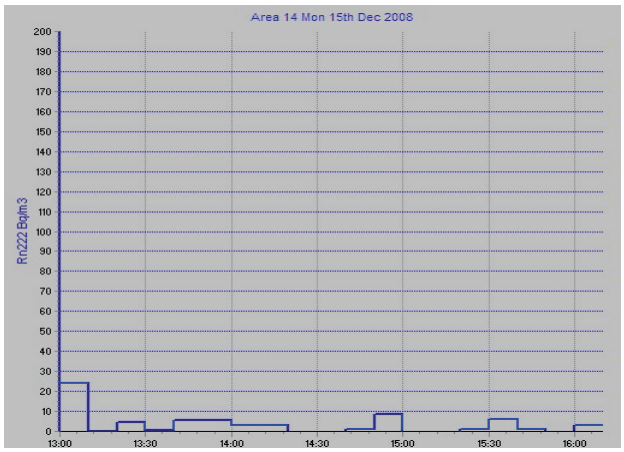
WorleyParsons
resources & energy

Oil/water sampling cabin

EcoNomics

WorleyParsons
resources & energy

Oil/Water sampling cabin



EcoNomics

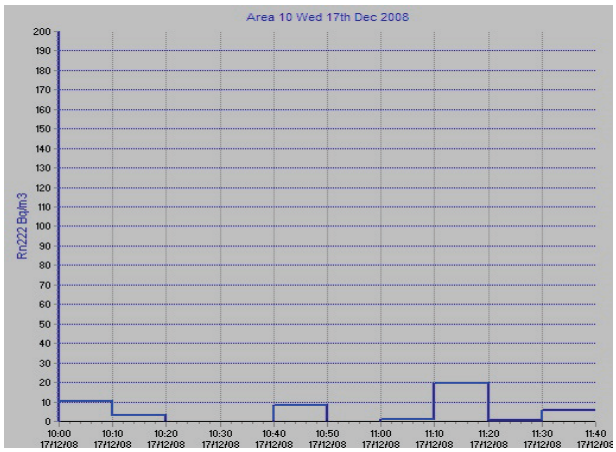
WorleyParsons
resources & energy

Between separator tanks

EcoNomics

WorleyParsons
resources & energy

Between separator tanks



EcoNomics

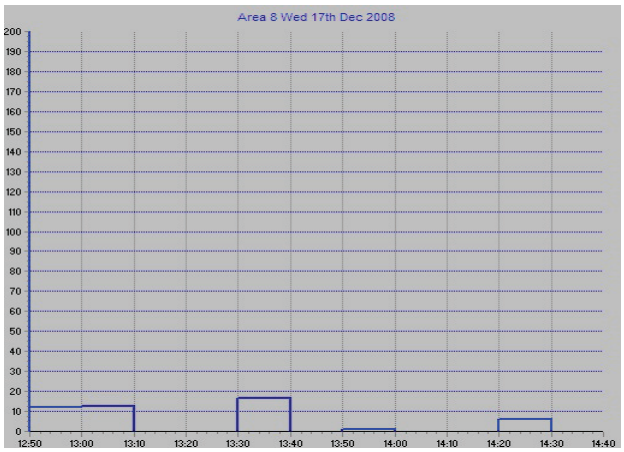
WorleyParsons
resources & energy

Beside NORM solid waste drums

EcoNomics

WorleyParsons
resources & energy

Beside NORM solid waste drums



EcoNomics

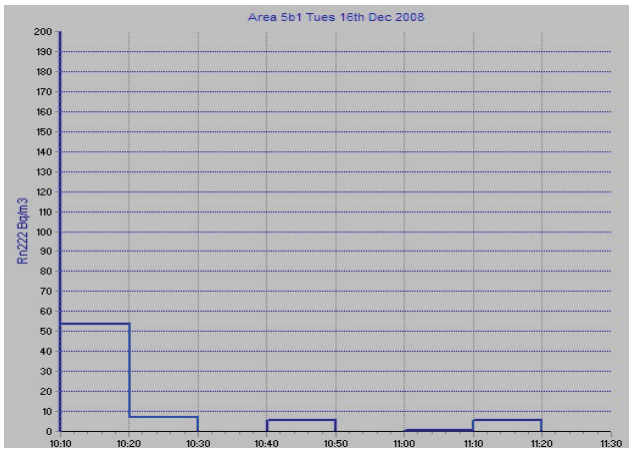
WorleyParsons
resources & energy

Wellhead deck

EcoNomics

WorleyParsons
resources & energy

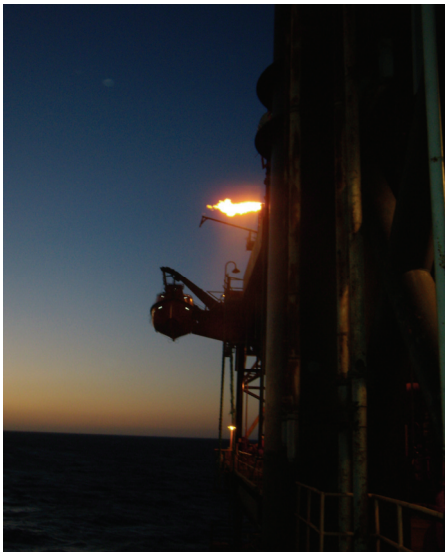
Wellhead deck



EcoNomics

WorleyParsons
resources & energy

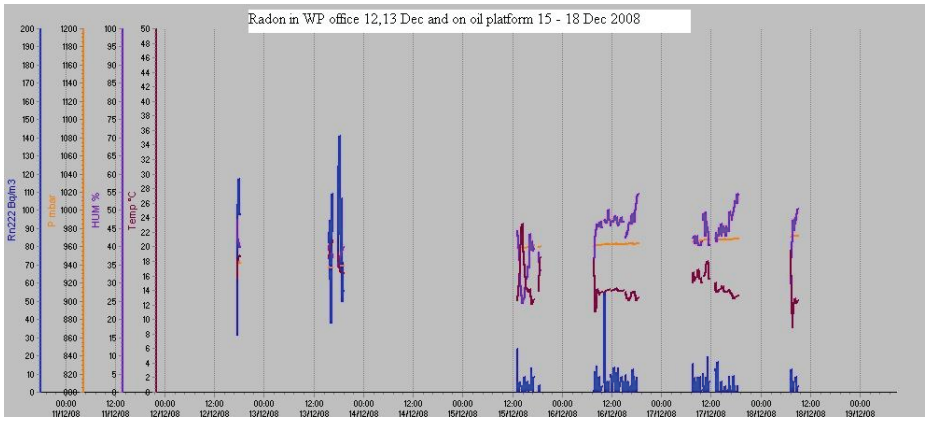
sunrise



EcoNomics

WorleyParsons
resources & energy

All Radon results (Dec 2008 survey)



EcoNomics

WorleyParsons
resources & energy

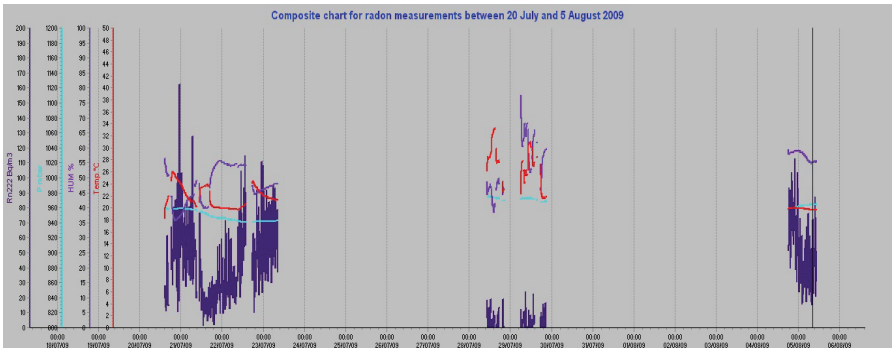
Follow-up survey July 2009

- A follow-up to the Dec 2008 survey
- sampling taking place in the summer period, on 28th and 29th July 2009
- temperatures were substantially higher than before (20-32 ºC compared to typically 12 -22 ºC in December) and much less wind.
- Most sampling locations were at or close to those which were sampled in December, although overall there were fewer samples since the survey was carried out over two days compared to four days in December.
- In total, eight sites on the Production deck were sampled using the same equipment as before.

EcoNomics

WorleyParsons
resources & energy

All Radon results (July 2009 survey)



EcoNomics

WorleyParsons
resources & energy

Radon results

- Ten-minute average Radon-in-air concentrations ranged from < 10 Bq/m^3 to 53 Bq/m^3 across 24 sample sites on the oil platform over both surveys.
- The highest concentration occurred next to a location where pipe maintenance work was being carried out (possibly linked) but was only 13% of the relevant limit of 400 Bq/m^3 for workplaces
- no meaningful values of radon progeny could be calculated given the very low radon concentrations; EF median 0.4, mean 0.5

EcoNomics

WorleyParsons
resources & energy

Preliminary radon dose assessment

- Use maximum observed 10-minute reading 53 Bq/m^3 Rn across whole year (very conservative)
- Use Equilibrium Factors suggested by UNSCEAR (typically 0.4 for indoors, 0.6 for outdoors)
- Use an effective dose conversion factor for radon of 9 nSv/hr per Bq/m^3
- Use an occupancy factor appropriate for areas on the oil rig (rounded 2000 hrs/yr)

Dose (inhalation) = 53 X 0.6 X 9 X 2000 = 0.57 mSv/yr

EcoNomics

WorleyParsons
resources & energy

Review of 2005 -2009 in situ surveys

- Since the first realisation in 2003 that naturally occurring radioactive material (NORM) was present on the oil & gas platform, the company initiated a series of radiological surveys. These were carried out between 2005 and 2009 and they continue under a scheduled annual programme. These surveys showed that NORM was present in tubulars, pumps, valves, separators and other top plant, consistent with the NORM issues seen on most other oil and gas platforms around the world.
- Using actual recorded measurements of radiation and radionuclide activity concentrations available for the platform, estimates of radiation exposure and effective doses have been made for the highest realistic potential exposure situations.

EcoNomics

WorleyParsons
resources & energy

Example oil/water/gas separator

EcoNomics

WorleyParsons
resources & energy

NORM drums, sludge transferred from separators

EcoNomics

WorleyParsons
resources & energy

Interim waste accumulation

- The clean-out of the Separators in September 2007 has had two effects:

1. The residual gamma dose rates at 1 metre at the two Separators dropped from between 1 - 4 μSv hr^{-1} to between < 0.16 to 0.6 μSv hr^{-1}
2. Gamma contact dose rates measured in April 2008, December 2008 and April 2009 at the drums into which NORM sludge has been transferred from the Separators are as high as 60 – 75 μSv hr^{-1}, some 4 to 5 times higher than when the material was in the Separator. This area is segregated.

- for one separator, recorded contact gamma dose rates were 0.1 to 0.7 μSv hr^{-1} after cleanout in Sept 2007 and 3.5 μSv hr^{-1} in April 2008 i.e. NORM is increasing again in separator.
- Company are in advanced discussions with Regulator to transfer NORM waste from drums to holding tank for slurry discharge to disused well.

EcoNomics

WorleyParsons
resources & energy

Dose calculations

- Skin dose estimate
  Skin dose (µSv) = (1.89 µSv hr^{-1} / Bq cm^{-2}) X Bq cm^{-2} X hr (exposure time) [dose conversion factor ref Healy 1971, to be refined for more recent beta dose models]
- **Inhalation dose** = (m^3 hr^{-1}) X (mg m^{-3} /1000) X (Bq g^{-1}) X (Sv Bq^{-1} X 1,000,000) X (hr yr^{-1}) = µSv yr^{-1} [summed for 3 radionuclides]
- **Ingestion dose** = (mg hr^{-1}) X (Bq g^{-1} /1000) X (Sv Bq^{-1} X 1,000,000) X (hr yr^{-1}) = µSv yr^{-1}[summed for 3 radionuclides]
- **Direct exposure** to gamma rays in µSv are calculated using the measured dose rate in µSv hr^{-1} at a particular distance from the source and an assumed residence time at that distance (hours).

EcoNomics

WorleyParsons
resources & energy

Maximum recorded activity concentrations/ dose rates

Sample type	Measurement		
Sludge from drums	^{226}Ra 221 Bq g^{-1} dry wt	^{228}Ra 0.49 Bq g^{-1} dry wt	^{210}Pb 197 Bq g^{-1} dry wt
Tubular from well	3000 cps 17.3 Bq cm^{-2}		
Separators before cleaning	15 µSv hr^{-1}		
Contact dose rates at NORM drums	75 µSv hr^{-1}		

EcoNomics

WorleyParsons
resources & energy

Maximum readings, continued

Sample type	Measurement		
Dose rates 1 metre from NORM drums	5 μSv hr^{-1}		
Water from feed tank effluent	^{226}Ra 150.4 Bq L^{-1}	^{228}Ra (2.02 Bq L^{-1})	^{210}Pb 0.47 Bq L^{-1}
Radon at production deck level	^{222}Rn 53 Bq m^{-3}		

EcoNomics

WorleyParsons
resources & energy

Dose summary

Source	Exposure route	Receptor	Estimated dose (mSv yr^{-1})
^{226}Ra in sludge	Gamma exposure 1 metre from separator prior to clean-out	worker	0.8
^{226}Ra in sludge	Gamma exposure 1 metre from separator after clean-out	worker	0.12
^{226}Ra in sludge	Gamma exposure 1 metre from isolated NORM waste drums, 10 minutes per day	worker	0.17
^{226}Ra, ^{228}Ra and ^{210}Pb in sludge	Inhalation of resuspended dried sludge following spill	worker	0.021
^{226}Ra, ^{228}Ra and ^{210}Pb in sludge	Inadvertent ingestion of dried sludge following spill	worker	0.04
^{222}Rn in air	Inhalation of radon and radon progeny on production deck, 12 hours sustained exposure	worker	0.0035

EcoNomics

WorleyParsons
resources & energy

Unlikely/avoided exposure scenarios

Source	Exposure route	Receptor	Estimated dose (mSv yr^{-1})
^{226}Ra in sludge	Gamma exposure at surface of NORM waste drums	worker	15
^{226}Ra, ^{228}Ra and ^{210}Pb in feed water	Inadvertent ingestion of water as potable water (500 litres per year)	worker	21.9
^{222}Rn in air	Inhalation of radon and radon progeny in unventilated separator (estimated 3.5 GBq 226Ra) prior to clean-out, ten minutes exposure	worker	23

EcoNomics

WorleyParsons
resources & energy

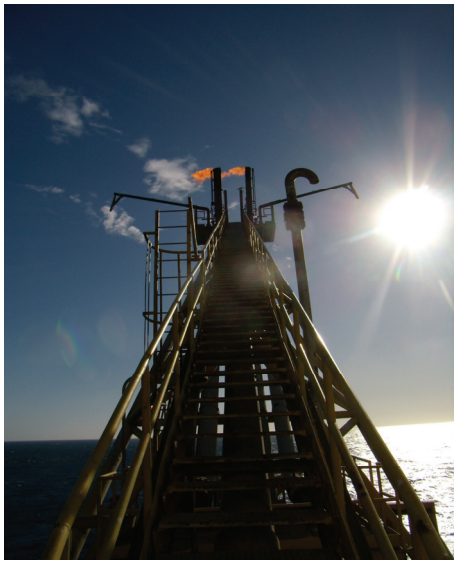
Conclusions

- Under realistic exposure scenarios, estimated annual doses due to the presence of NORM, including Radon, on the studied platform range from 0.0035 to 0.8 mSv which is between 1 and 4 orders of magnitude lower than the annual (5-year) exposure limit of 20 mSv.
- In two unlikely exposure scenarios, the annual (5-year) exposure limit of 20 mSv is exceeded, however in one case the water considered is far from potable quality and in the other case, exposures in the confined space considered would not be realised due to standard risk mitigation procedures and ventilation.
- The use of written procedures, worker training and restricted area designation can avoid worker doses which approach the annual dose limit.

EcoNomics

WorleyParsons
resources & energy

Contact details



mark.liddiard@worleyparsons.com
joe.toole@worleyparsons.com
+44 (0)1786 477320
www.worleyparsons.com

40 Countries
137 Offices
29,100 Staff

- Other offices currently involved in this area of work include Dubai, Abu Dhabi and Oman.

EcoNomics