Remediation of Occupied Commercial Property Subject to Widespread Radium-226 Contamination – Confidential Client in the South-West of England – 12570

Philip Sinclair, AMEC, UK

ABSTRACT

AMEC was contacted by a company that managed commercial office space in 2010. High Rn-222 measurements had been observed throughout the facility and the landlord had been advised to commission a radiological survey of the site. The site had been purchased by the client in the 1990's. Initial desk studies found that the building had operated for around 50 years as a compass factory.

Non-intrusive investigation identified widespread Ra-226 contamination. Ra-226 was found in the fabric of the building, in attic spaces, buried under floor boards and underlying car parks.

Intrusive investigation was undertaken to estimate volume(s) of waste, waste categories, activity concentrations and the total inventory of radioactive materials on site. This work identified the presence of 180 GBq of Ra-226 on site.

A programme of work is currently underway to remediate the site tackling areas posing the greatest risk to site occupants as a priority. We have worked closely with Regulators, our client, and tenants, to decontaminate the fabric of the building whilst areas of the building remain occupied. The radiological risk, from irradiation, ingestion and inhalation (of Ra-226 and Rn-222) has been assessed before, during and after intervention to minimise the risks to site occupants. Tenants were moved from areas of unacceptable radiological risk to areas unaffected by the presence of radioactive materials. Rn-222 mitigation measures were installed during the remedial operations to minimise the hazard from Rn-222 that was liberated as a result of decontamination activities. Decontamination techniques were required to be sympathetic to the building as the ageing structure was in danger of collapse during several phases of work.

The first phase of remediation is now complete and the decontaminated building is being returned for use as office space. The radiological risks have been significantly reduced and, in areas where decontamination was not possible (e.g. due to concerns over the structural integrity of the building), mitigation measures have been installed.

Importance and Benefits of this Work

The project has addressed a number of key problems:

- Decontamination of a radioactively contaminated facility occupied by the general public;
- Working with Regulators, our client and tenants to deliver the desired outcome;
- Comparison of the risks from Ra-226 irradiation with Rn-222 exposure, and;
- Balancing the achievement of the proposed radiological end point with the structural integrity of the building.

This project has demonstrated that effective remedial solutions and dose reduction can be achieved working sensitively with a wide range of stakeholders. We have had to consider doses from different pathways and conflicting regulatory regimes. We have developed remediation end points for both Ra-226 contamination and Rn-222 gas. And finally, negotiated pragmatic remediation end points and appropriate mitigation measures in areas where working to regulatory standards would have been counter-productive.

INTRODUCTION

Around 10 years ago our client bought a site in the South-West of England that comprised of a wide range of buildings on an old industrial site. Initial desk studies identified that the site had been used during the previous 50 years as a compass factory. It is known that radium-226 was commonly used to luminise the faces and needles of compasses during that era. These sites are often contaminated with radium-226 as a result of the manufacture and maintenance of these instruments and the local disposal of primary and secondary wastes. AMEC was commissioned by our client to investigate the potential presence of radioactive contamination on this site and provide initial advice of remediation options.

The initial site survey has triggered an extensive programme of work to investigate and remediate radioactive contamination from the site. This work has been planned and executed whilst areas of the site remain occupied by tenants. Site operations were particularly sensitive and therefore a comprehensive programme of stakeholder engagement was untaken to ensure the support of the regulators and impacted communities.

This paper aims to describe the work, planned and delivered, and share some of the lessons learned so far during this site clean-up

METHOD

Works to date have been undertaken in the following phases:

- Non-intrusive Investigation;
- Intrusive Investigation;
- Decontamination / Remediation; and
- Verification.

Non-intrusive Investigation

Non-intrusive investigation of external areas of the site was undertaken using a 76 x 76mm sodium iodide probe linked to a high-resolution Global Positioning System (GPS). The instrument recorded measurements every metre across the site. The instrument was calibrated to respond in Bq/g of radium-226 contaminated soil based on a number of key assumptions.

Non-intrusive investigation of the building was undertaken using 2” x 2” sodium iodide probes together with pancake Geiger contamination probes. Walls and floors were surveyed focussing on high-risk areas e.g. drainage systems and air vents.

Intrusive investigation

Intrusive investigation of external areas was undertaken via a programme of trial pitting. Trial pits were used in order to delineate volumes of contaminated soil and confirm the isotopic concentration of contaminated wastes.

Intrusive investigation of the building was undertaken in order to try to isolate the extent of radioactive contamination within each impacted areas. Areas were investigated by the incremental removal of the fabric of the building. Wooden floors were investigated by removing carpet, floor boards and insulation materials. Concrete floors were investigated with breaking equipment and excavation. Walls and ceilings were investigated by the removal of plaster and brickwork. Each area was systematically surveyed and sampled in order to estimate the volumes and concentrations of radioactively contaminated material.

Decontamination / Remediation

To date targeted areas of the building have been decontaminated. Decontamination has been achieved by the identification, removal, sentencing, segregation and packaging of radioactively contaminated materials. Decontamination techniques employed include scabbling and removal of contaminated brickwork, planing and removal of wooden surfaces, vacuuming of loose contamination, and excavation and removal of contaminated soils.

Verification

The achievement, or otherwise, of the remedial end point was confirmed by a programme of verification surveys employing both direct probe measurement and, sampling and radiochemical analysis.

RESULTS

This work has generated a considerable volume of data and therefore only a representative number of areas are reported:

Non-intrusive Survey

The results of the non-intrusive survey of external areas are presented below:

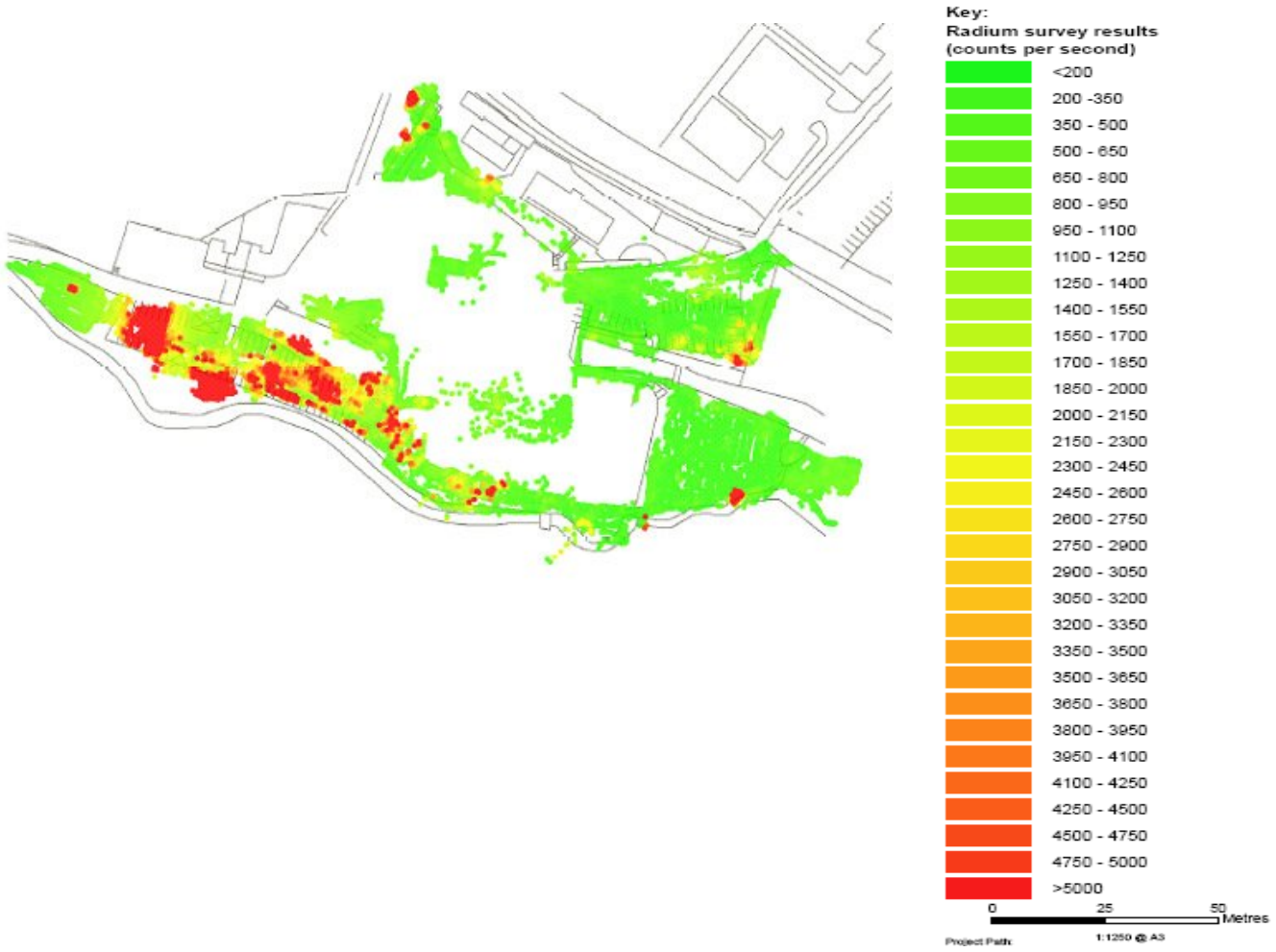

Figure 1. Non-Intrusive Investigation of External Areas

The surface survey indicated widespread concentration of contaminating radium-226. This data was used to begin to estimate the remediation liability and to focus the intrusive investigation. The magnitude of probe measurement is represented by a graduated colour scale e.g green < 200 counts per second (cps), yellow 2500 cps and red > 5000 cps. The instrument was calibrated to allow calculation of activity concentration directly from these measurements.

Building Survey

Indicative results from the building survey are presented below:

Table I Typical Results of Building Survey

Building Area	Unit / Room	Average Probe Reading (cps)	High Readings / Hotspots (cps)
Building A	Landing 1	800 - 3000	3060
	Landing 2	3000 - 5000	7050, 7210, 8190 and 11,020
	Stairwell 1	1200 - 3500	3400 and 3770
	Stairwell 2	1700 - 2650	5680 and 7740
	Stairwell 3	1600 - 2800	2840
	Toilet A	880 - 2300	2370
	Toilet B	900 - 1700	2990
	Room 1 - A	700 - 2500	2760
	Room 1 - B	700 - 2400	2430 and 5290
	Room 1 - C	1000 - 5000	5000, 5110, 7060 and 7560
	Room 2	900 - 4500	8160, 9060 and 16,500
	Room 3	800 - 3000	14 hotspots ranging from 2000 - 9020 cps
	Room 4	1100 - 2500	3040, 3050 and 7150
	Kitchen	1200 - 4000	4200, 4810, 8410, 10,400 and 14,400
	Southern Stairwell	1300 - 3000	2200, 2270, 2300 and 4030

The instrument was calibrated such that 1600 cps = 1 μSv/hr

The results above were used to identify the presence of radioactive material, to advise the client on radiological protection measures and to plan intrusive works.

Intrusive investigation

The results of the intrusive investigation were used to calculate waste volumes:

Example results from external areas:

Table II Typical Output from the Radiological Survey of External Areas

Site Area	Estimated Average Thickness of Contaminated Material (m)	Estimated Area of Contamination (m^2)	Approximate Volume of Soil Waste Streams			
			Total Volume (m^3)	LLW (m^3)	Exempt Waste (m^3)	Clean Waste (m^3)
Area 1	Contaminated soils = 0.3	5 x 15 = 75	22.5	16.88*	5.6	-
Area 2	Contaminated soils = 0.4	1750	700	525*	175	-
	Tarmac and sub base Average = 0.4		700	-	-	700

Example results from within the buildings:

Table III Typical Output from the Radiological Survey of Internal Areas

Building Area	Contaminated Material	Estimated Average Thickness of Contaminated Material (m)	Estimated Area of Contamination (m^2)	Approximate Volume of Contaminated Waste				
				Total Volume (m^3)	Low Volume High Activity (Litres)*	LLW - Drummed Volume (Assumes 60% loading)	Exempt Waste (m^3)	Clean Waste (m^3)
	Dust, floorboards and steps	0.03 (Floorboards) 0.05 (Steps) Average = 0.4	Landing and staircase areas = (8 x 3) x 3 = 72	28.8	8	10 = (14)	18.8	-
	Carpet and Step coverings	0.005(Carpet), 0.025 (Wooden coverings) = Total 0.03		2.16	-	-	-	2.16
	Dust and Floorboards	0.03	5 x 5 = 25	0.75	0.5	0.20 = (0.28)	0.55	-
	Linoleum	0.005		0.13	-	-	-	0.13

Decontamination / Remediation

The results of the surveys were used to determine the radiological risk to site occupants, the volumes of radioactive wastes to be retrieved and therefore the liability to our client. This information was collated and reported in a remedial action plan. The plan described the impacted areas of the site and the required remedial action.

The overall liability posed by the contamination was prohibitively expensive for our client and therefore a phased approach was agreed and implemented. The initial programme would target areas causing an unacceptable risk to site occupants, and; areas impacting on the commercial operation of the site. As an interim measure tenants were relocated to areas of the site that were free from radioactive contamination.

All wastes retrieved during the remediation were bagged, sentenced and accumulated prior to disposal. The waste inventory for this phase of work was as follows:

Table IV Waste Inventory

Waste Category	**Number of Bags of Waste**
Clean (<0.4 Bq/g)	881
Exempt (between 0.4 and 4.9 Bq/g)	1267
Low Level Waste (> 4.9 Bq/g)	608 (74 x 200 litre drums)

Verification

In the vast majority of cases the remedial end point (0.4 Bq/g radium-226) was achieved. There were notable exceptions where we proposed a relaxation of the standard to the site Regulators and this was agreed. This process was triggered in instances where, it was feared, that remedial action was causing significant and irreparable damage to the building. In these cases it was judged that continuing decontamination was causing a greater risk to site occupants than the residual contamination. In each case the contamination was permanently logged in site records and appropriate mitigation measures installed.

Figure 2. Building Decontamination

The photograph above shows remediation operations in a room where the load-bearing structure of the building required relocation and remediation was finally suspended due to impacts on the structure of the building. The excavation area is in the centre of the photograph with accumulated waste to the left. The ducting provided air movement to mitigate doses from radon inhalation.

DISCUSSION

The presence of radioactive contamination on site was initially detected by routine radon monitoring. Throughout the work radon was the dominant pathway for the potential irradiation of site occupants and decontamination operatives. Unearthing volumes of radium contaminated materials had a significant impact on radon concentrations within the building during remediation works as shown in the graph below, though this was countered by the use of air moving equipment.

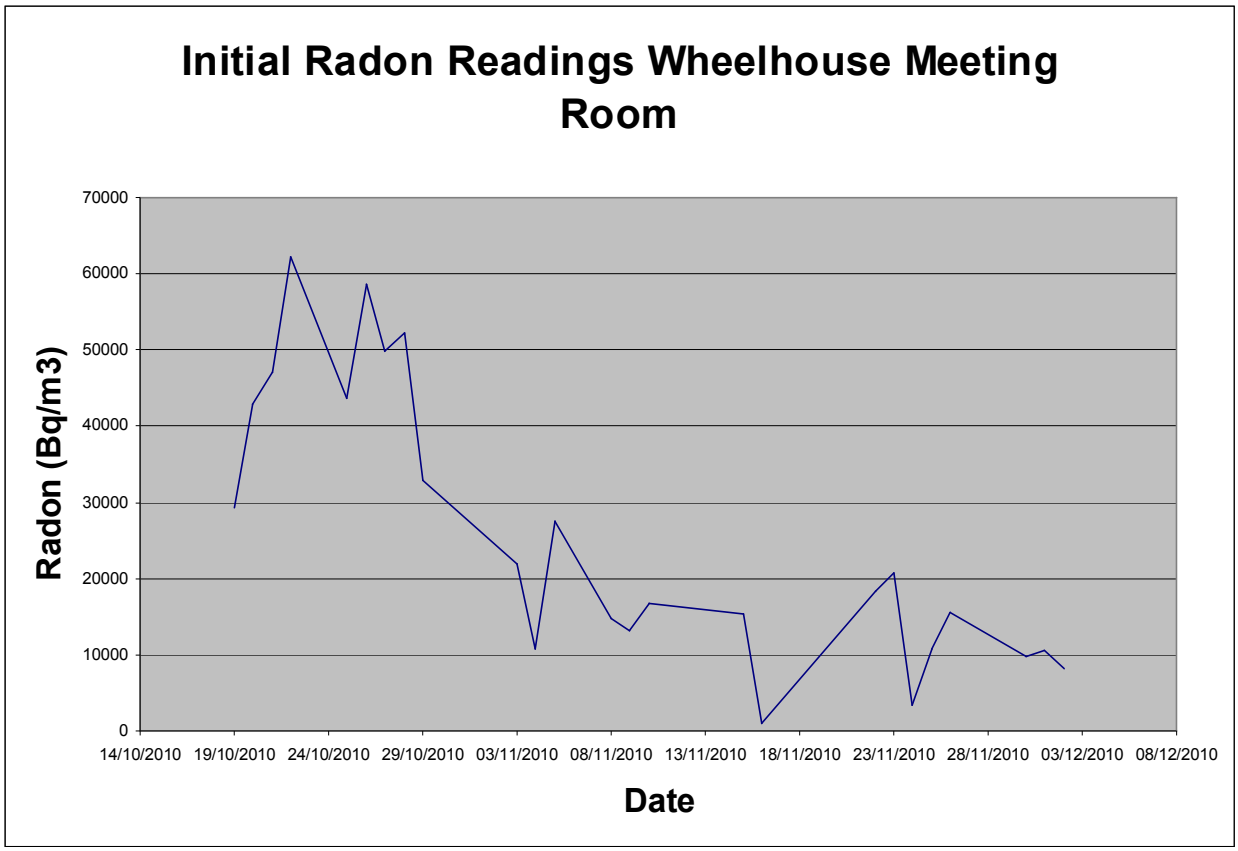

Figure 3. Radon Monitoring Results

Remedial operations successfully reduced radon concentrations to acceptable levels. In areas where residual concentrations of radium were left in-situ appropriate radon mitigation measures were introduced.

Site tenants were informed of the presence of radioactive contamination on site and the decontamination works. Tenants were temporarily relocated in response to the radiological risk and to facilitate remediation. Tenants are now returning to decontaminated office space with the agreement of site Regulators.

In a number of cases decontamination operations were halted prematurely due to the impacts on the fabric of the building. Following advice for a structural engineer these areas were reinstated with appropriate mitigation of both radium and radon risks.

AMEC has offered a responsive and pragmatic approach to the decontamination of this site. This was achieved by recognizing the potential radiological risks to site occupants whilst balancing the needs for both cost-effective action and sensitivity to an ageing building. Work delivered against the remedial action plan has successfully decontaminated areas of the building and allowed reoccupation of commercial site tenants.

Works continue on the site to remove the radiological hazard and release further areas for unrestricted use.

The lessons we have learned, to date, in delivering this work include:

- The dominant radiological risk is not always the most obvious - The risks to tenants and site workers were predominantly from radon inhalation rather than direct irradiation / inhalation / ingestion of radium-226.
- Remedial action can significantly increase the short-term radiological risk to tenants and site workers – Unearthing volumes of radium-226 contaminated material caused a significant increase in the radon gas concentrations throughout the building. Pre-emptive installation of air movers maintained radon concentrations at acceptable levels in the working area and throughout the building.
- Remediation of an occupied radioactively contaminated site is achievable – Open and honest communication of radiological risks and site operations ensures that all stakeholders are fully informed and are supportive of the ongoing works.