COMMENTS RECEIVED BY PROFESSOR COGGON ON HIS PROVISIONAL REPORT DATED SEPTEMBER 2009 WITH HIS REPONSE TO THOSE COMMENTS

April 2010

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Comments & questions on the provisional report by Professor David Coggon and on associated provisional reports by the Health Protection Agency and the Health & Safety Laboratory

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11th January 2010

Professor Coggon's provisional report[1] on *Health Risks from Contamination of the Rutherford Buildings, University of Manchester* relies on two other provisional reports: one by the Radiation Protection Division of the Health Protection Agency (HPA), on the risks of radiation-induced effects[2]; the other by the Health & Safety Laboratory (HSL) on the risks of effects due to mercury[3].All three reports represent substantial amounts of work carried out over a period of many months, with considerable care and attention to detail. Nevertheless, they contain errors and omissions, as well as some questionable inferences and conclusions.

Details are given below of three examples of issues where the reports are misleading or in error. These are: (1) the absence of reliable radon-222 measurements prior to remediation; (2) evidence of remediation prior to 1999; (3) the nature of the ventilation system. This is followed by some general comments concerning the conclusions of the inquiry, and the inferences on which they are based. My comments are confined to points where I take issue with the content of the reports or wish to raise questions about them. I have not commented on the many large areas of agreement.

In addition to the examples detailed below, I have added other comments and questions as marginal notes to the relevant pages of the provisional reports, and copies of these pages are appended.

For brevity, Professor Coggon's report is referred to below as *DC*, the HPA report as *HPA*, and the HSL report as *HSL*.

[1] Coggon D (2009) "Health Risks from Contamination of the Rutherford Buildings, University of Manchester" http://www.manchester.ac.uk/rutherfordreview/documents/provisional-report-170909.pdf
[2] Jones KA, Oatway WB, Haylock RGE, Holmes S and Simmonds JR (2009) "Assessment of the possible risks of radiation induced health effects from contamination at the University of Manchester" RPD-EA-10-2009. http://www.manchester.ac.uk/rutherfordreview/documents/EA-10-2009.pdf
[3] Rowbotham A, Gibson R, Easterbrook A, Cocker J (2009) "HSL contribution to the investigation of the Rutherford Laboratories at Manchester University". Report Number AS/2009/15 http://www.manchester.ac.uk/rutherfordreview/documents/provisional-hsl-mercury-report-final.pdf

1. The absence of reliable radon-222 measurements prior to remediation

In considering measurements of Radon-222 made at various times, the HPA report states:

"The earliest known radon-222 measurements were reported in the final report for the decommissioning of Coupland 1 Building (Frith, 2001). However, the measurements were made using a Pylon model AB-5 Portable and calibrated LUCAS LCA-2 scintillation cells. This technique for measuring radon-222 is not thought to be reliable, as it is only based on short time periods." (HPA, page 58)

The first sentence of this paragraph is incorrect. Although Frith (2001) refers to the fact that radon measurements had been made earlier, and to the estimation of likely doses to past occupants, the radon-222 measurements that he reports were made at a later date, after the remediation described in paragraph 3.1 of his paper. These measurements were then used to estimate the doses that may be received by future occupants.

The earliest radon measurements that I am aware of were made in June/July 2000, as summarised in the first column of Table 1 on page 13 of our original report[4] and as detailed in Appendices C6 and C8 of that report. These measurements *were* made prior to any remediation, but the HPA's criticism of the reliability of the methods reported by Frith applies also to them. They are of little or no use in estimating mean pre-remediation levels of radon.

The HPA report then goes on to summarise more reliable measurements made in 2002 using HPA passive radon detectors. However, these measurements are also presented in the HPA report as having been made "prior to remediation". This is extremely misleading. Although further remediation was undertaken after the 2002 measurements were made, this was only because the earlier remediation had been found to be incomplete or insufficient. The 2002 measurements were made *after* considerable quantities of contaminated material had been removed from the building between April 2000 and September 2001, as detailed in Appendices C4, C12, C13, C14, C16, C17, C18, C19, C20, C21 to our original report.

A figure of 60 Bq m^{-3} is then carried forward from section C2.4 of the HPA report as if it were a pre-remediation measurement to be 'supplemented' in section C2.8 by an estimate based on calculation of the radon levels which could be expected given the measured activity levels of radium in the waste removed in 2000-2001, together with various characteristics of the spaces and materials involved. The resulting figure of 180 Bq m^{-3} is then referred to in the Discussion section of the report, as follows:

"Another example of a cautious assumption is that a radon-222 gas activity concentration of 180 Bq m^{-3} was estimated from the historical inventory, whereas the highest measured radon-222 concentration prior to remediation was 60 Bq m^{-3}, a factor of three lower." (HPA, page 24)

The same figures are cited by Professor Coggon as follows:

[4] Churcher J, O'Boyle D, Todd N (2008). "Possible health risks due to ionising radiation in the Rutherford Building (formerly Coupland Building 1) at the University of Manchester". http://www.drop.io/rutherfordbuilding. The reference to "Rn-226" in the title of Table 1 is an error; it should read "Rn-222".

"The activity concentration of radon-222 in the air of the room throughout 1950- 2000 was taken as 180 Bq m^{-3}, which is the level that would be predicted from the highest measured activity concentration of radium-226, and slightly higher than any measured concentration of radon. In the absence of major changes to the Buildings, no important decline in radon-222 concentrations in room air would have been expected over the period 1950-2000." (DC, page 20)

If the figure of 60 Bq m^{-3} were a genuine and reliable measure of pre-remediation radon levels, there might be some force in the implied argument that a forward calculation from observed activity concentrations of radium-226 which produces a result of the same order of magnitude offers some support for the validity of the estimate as representative of historical levels. However, in the absence of any reliable pre-remediation measures, no such confirming support is available.

The problem of the lack of any reliable pre-remediation measures of radon was evident to us from as early as 2002, when we had meetings with staff of the University's Radiological Protection Service. At the meeting on 21/8/02 I asked about the possibility of using radon progeny in glass to estimate historical exposure (Churcher, O'Boyle, and Todd, 2008, page 32). Seven years later, in June 2009, Kelly Jones of HPA-RPD suggested in correspondence that this would be a possible way of assessing past exposure. Glass articles known to have been in contaminated rooms and/or glass windows that have been *in situ* for some time potentially contain records of cumulative radon exposure. However, as far as I know, no tests for radon progeny in glass have yet been undertaken, and the possibility is not mentioned in the provisional reports.

Table 1 of our original report summarised the available data on measurements of radon-222 between June 2000 and November 2002, including those made by the HPA, and clearly distinguished between pre- and post-remediation data, yet apparently it has been ignored in preparing the HPA report. Why is this?

Please see the separate response from HPA.

The statement that is quoted from my report appears accurate. The assumed activity concentration of radon-222 was indeed slightly higher than any measured concentration of radon. It was important to check that no measured concentration of radon, either before or after remediation, exceeded the assumed value. It is correct that most of the measurements of radon concentration were made after some remediation had been carried out, and to make this clearer to readers, I have added:

"…. including the only reliable measurements that were available from before the remedial work of the past decade".

It is important to note that the risk assessment is based on concentrations of radon estimated from measured activities of radium-226, and not from measured concentrations of radon. Thus, the paucity of radon measurements before remediation is not a critical source of uncertainty in the assessment of risk.

I agree with HPA that measurement of radon progeny in glass is unlikely to refine the risk assessment significantly.

2. Evidence of remediation prior to 1999

The method of investigation outlined in the terms of reference for the inquiry included the following as one of the sources of information which would be assembled:

"Renovation, refurbishment and alterations of the Buildings that have been carried out over the past 60 years, which may have reduced levels of contamination and/or changed the relative importance of different exposure pathways (from records held by the University Estates Department, other University records, and recall of people who have worked in the Buildings in the past)." (Terms of Reference, page 2).

The provisional reports repeatedly state that no evidence of substantial remediation is available:

"Of the uncertainties that could have caused risks from ionising radiation to be underestimated, perhaps most important is the possibility of maintenance and construction work between 1950 and 1999 that reduced levels of radioactive contamination. It appears that there was no major re-building or alteration during this period, but if, for example, floorboards were sanded before varnishing or fitting of new floor coverings, this might have removed some surface contamination from the boards. Even in the most extreme case, however, it seems unlikely that such activities could have led potential historical exposures to ionising radiation to be underestimated by as much as a factor of five." (DC, page 31, paragraph 2)

"Information provided by the University (Peters, 2008) does not indicate that any substantial building work or remediation was carried out prior to 1999. Therefore, contamination levels measured before the refurbishment work were used to estimate the contamination levels from 1950 to 1989." (HPA, page 3, paragraph 2)

"Information provided by the University (Peters, 2008) indicated that, although the usage of rooms changed over time and there may have been some associated renovation of the rooms, there was no evidence of major building work or remediation prior to 2000." (HPA, page 53, paragraph 3)

These statements appear to ignore available evidence that offices occupied by Professor EB Paul in the early 1960s (probably rooms 1.56/1.57 on the first floor), which were found to be contaminated when his personal monitor showed a high level, were temporarily vacated until they had been re-plastered and re-painted. The evidence is contained in a letter sent to Professor Coggon in October 2009 and consists of personal recall by someone who was closely associated with Professor Paul. Although anecdotal, this evidence appears to be relevant, unequivocal and credible. The implication is that exposure levels for anyone occupying the relevant offices before this time may have been underestimated. Why was this evidence excluded from the provisional report?

Please see also response from HPA.

The statement that is quoted from my report refers to "major re-building or alteration". At the same time, it acknowledges that more minor work such as sanding of floorboards could have taken place, and I am happy to add as a further example, the anecdotal report of re-plastering and re-painting of the

offices occupied by Professor Paul in the early 1960s. I have also added reference to newly obtained evidence that in the 1960s, refurbishment to the Rutherford Building was approved at a cost of more than £100,000. However, this does not alter my conclusion, that "even in the most extreme case, it seems unlikely that such work could have led potential historical exposures to ionising radiation to be underestimated by as much as a factor of five."

3. The nature of the ventilation system in the building

The HSL provisional report states:

"There has been no suggestion that forced ventilation has ever been installed in the building, and neither is there any reference to fume cupboards or other equipment that would extract air. The absence of extraction is important as it removes a permanent source of a negative pressure that would tend to draw air into occupied rooms from other parts of the building structure." (HSL, page 31)

The authors of the HSL report appear to be unaware that the original ventilation system was described by Schuster in 1900, whose description is quoted by Neil Todd (2008)[5], p.84. Referring to the large Elementary Laboratory on the first floor (later known as room C.1.09), Schuster wrote:

"Visitors may notice the complication of pipes in the north-east corner of this room. These pipes, which will be painted in different colours so as to enable them to be easily distinguished, convey the gas, the water, the steam for heating purposes, the steam for experimental purposes, and air compressed to three or four atmospheres. A large opening for ventilation purposes will be seen in the wall. The general scheme of ventilation has been to place all the rooms which are likely to be crowded or to require a rapid change of air, round a central flue through which heated gases from the boiler furnace will always pass. This flue being always warm will cause sufficient up-draught in the ventilating shafts to draw the vitiated air out of the rooms, but it will also be possible to suck this air downwards by means of fans placed in the basement, and there to throw it into one of the hot flues. Air inlets will be seen in this room in which the air passes over a surface of oil which will deprive it of its coarse dust. This arrangement, the invention of Mr Kenneth Steell, will it is hoped, keep the Laboratory free from that black dirt which at present is so difficult to exclude from our rooms." (Schuster 1900; quoted in Todd, 2008, p.84)

It is also known that fume cupboards were used, some of which were dismantled as recently as the 1970s. Don O'Boyle remembers at least one fume cupboard being in rooms 2.52/2.53 when he took them over in the mid-1970s. There is also a specific reference to fume cupboards in a letter sent to Professor Coggon in 2008 by a former graduate student in Physics who had been asked to undertake a survey of the contamination of the 2nd year Physics labs in the late 1950s or early 1960s. He found significant alpha contamination on two sinks and up the wall to apertures, which had been closed. He wrote that the sinks had obviously been fume cupboards, and presumably been used for storage of radioactive materials. He remembered them as being located in the room on the ground floor, to the right of the entrance.

[5] Todd N (2008) "Historical and radio-archaeological perspectives on the use of radioactive substances by Ernest Rutherford." http://www.manchester.ac.uk/rutherfordreview/documents/HistoricalandRadioArchaeologicalPerspectives.pdf

These errors are particularly surprising because the 2008 paper by Neil Todd is acknowledged at the beginning of the HSL report as having been extremely helpful, and because it is clear that the HSL team are aware of the complexities of ventilation in the building, and of its potential significance in distributing contaminants.

It is also worth noting that while in the HSL report the specific patterns of ventilation within the Rutherford building are given considerable attention as a factor in the transport of mercury vapour, it receives very little attention in the HPA report as a factor in the transport of radon and of solid radionuclides attached to dust, although it must be similarly relevant. Todd (2008, pp. 84-5) discusses the implications for radon, but this is not considered in the HPA report. Why not?

Please see the responses from HPA and HSL.

The assessment of past exposures to ionising radiation is conservative in that it assumes no loss of radon through ventilation. Estimates of exposures to radon following remediation are derived from empirical measurements made over three months, and thus take into account the effects of current ventilation.

Ventilation systems that operated only before 1980 do not affect my conclusion that "It is unlikely that any harm to human health has occurred in the past 20 years, or will occur in the future, from mercury contamination of the Buildings". The uncertainty about risks from mercury contamination in earlier periods is already acknowledged ("There is more uncertainty about risks from mercury contamination in earlier periods. However, any toxic effects from possibly higher exposures to mercury more than 20 years ago would have been present at the time, and would have tended if anything to resolve as exposures reduced.").

4. Some general comments concerning the conclusions of the inquiry, and the inferences on which they are based

(a) The effect of errors in the evidence

Among the main conclusions of the inquiry are the following:

"On current evidence, none of the identified contaminants in the Rutherford Buildings could plausibly account for the cases of pancreatic cancer, brain cancer and motor neurone disease that have occurred among past occupants of the building. In particular, the apparent cluster of pancreatic cancer cannot be explained by exposures to radionuclides, mercury or asbestos, either alone or in combination. By far the most likely explanation for the cluster is that it has occurred by chance coincidence." (DC, page 5).

"It is unlikely that any harm to human health has occurred in the past 20 years, or will occur in the future, from mercury contamination of the Buildings." (DC, page 4)

The evidence which is assembled in support of these and other conclusions consists mainly of historical information about the inventory of radioactive substances available to Rutherford and his co-workers, measurements of contamination levels in

the waste removed during recent remediations, together with a very large number of assumptions of various kinds, e.g. about rates of accidental loss of contaminating materials, their spatial distribution within the building over time, and consequent potential risks to health.

Errors of fact, such as those detailed in sections 1-3 above, may lead to the use of erroneous assumption, and this may invalidate or weaken the conclusions of the inquiry.

The estimates of potential exposure to ionising radiation are based mainly on measured levels of radioactive contamination with conservative assumptions about the size of contaminated areas, the proximity of occupants to the contamination, and the time that they spent in such close proximity. The calculations based on historical inventories of radioactive substances are recognised to be uncertain, but were performed to check that the estimates based on measured levels of contamination were not manifestly unreasonable.

The exception to this is exposure from radionuclides in the uranium-235 decay chain, for which an assumption was made that: a) the available historical inventories gave a reasonable estimate of the amounts of the parent nuclides that were used in the laboratory relative to radium-226; and b) the proportion and distribution of spillage was similar to that for radium-226. It should be noted that this calculation did not entail specification of the proportion of material spilt or of the area over which spills were distributed – only that they were similar to those for radium-226.

As indicated above, I do not think the points raised in sections 1-3 call into question the conclusions in my provisional report. Moreover, I remain of the view that the important uncertainties in the risk assessment have been identified and adequately taken into account in the conclusions drawn.

(b) The limited value of 'cautious' or 'conservative' assumptions

Various sources of uncertainty in the assessments of risk are acknowledged, including those which

"…stem in part from the limitations of current scientific knowledge, but also from a dearth of historical data on levels of contaminants in the Rutherford Buildings and the absence of firm information on building and maintenance work that was carried out in the Buildings before 1999." (DC, page 31)

It is then claimed that any inadvertent underestimation of risk due to this uncertainty can be offset by the combined effect of assumptions that are 'conservative' or 'cautious':

"… the risk assessment for ionising radiation incorporated multiple assumptions that would have tended to inflate risk estimates. These include, for example, the assumptions: that a worker occupied a room in the building for 40 consecutive years (in practice the longest occupancy is likely to have been less than this); that his chair was situated immediately above an unusually large patch of floor contamination, and immediately next to a hotspot of contamination on the wall; and that all radionuclides in each decay chain were present in these patches of contamination at the highest levels

that had been measured anywhere for any individual radionuclide from the chain. Conservative assumptions of this type will have tended to counter any underestimation of risk because of failure to allow for undocumented and unrecalled maintenance work."

Although this kind of reasoning is familiar and has an intuitive appeal, it is in principle impossible to estimate the extent to which any underestimation of risk will actually be compensated by a series of informally cautious assumptions. A more reasonable and cautious conclusion concerning the cluster of pancreatic cancer would therefore be that on current evidence it is not possible to decide between two hypotheses, each of which remains plausible: (i) that the cluster has occurred "by chance coincidence"; and (ii) that it is due to exposure to one or more of the contaminants.

The wording in the quoted passage was chosen carefully. In particular, it states that "Conservative assumptions of this type will have tended to counter any underestimation of risk because of failure to allow for undocumented and unrecalled maintenance work". This is not a claim that the conservative assumptions will have completely offset any underestimation of risk because of maintenance work, only that they will have biased risk estimates in the opposite direction. I stand by this assertion. The possible extent of underestimation of risk because of earlier maintenance work was addressed in the statement that "even in the most extreme case, it seems unlikely that such work could have led potential historical exposures to ionising radiation to be underestimated by as much as a factor of five." It was with this reasoning, that I concluded that ionising radiation could not account for the observed cluster of pancreatic cancers. Indeed, even if exposures to ionising radiation had been underestimated by several orders of magnitude (which I do not think is plausible), they still would not explain the observed cluster. Nor, for the reasons set out in my report, do I think that exposures to mercury could plausibly explain the cases of pancreatic cancer.

(c) Absence of evidence is not evidence of absence

The provisional reports do not distinguish clearly between *absence of evidence* of risks to health and *evidence of absence* of such risks. As a result there is a tendency to conclude from an absence of evidence of risk that there was no risk, or that any risk was minimal. This tendency is particularly clear in Professor Coggon's justification for not undertaking an epidemiological investigation, despite this having been advocated by a number of current and former members of staff, where he writes:

"It was possible that systematic ascertainment would identify further cases of the diseases that were of particular a priori concern (e.g. pancreatic cancer). However, given what was already known, and the work that was already being undertaken, the discovery of additional cases of disease would not have impacted materially on the initial conduct or interpretation of the investigation. This was because a detailed search was already being carried out for possible hazardous exposures in the Buildings. If, after thorough investigation, no hazardous exposure could be found that could plausibly explain a cluster of, say, pancreatic cancer, then the observation of additional cases would not alter the conclusion that the cluster was unlikely to have been caused by a feature [of] the Buildings or of the work that was carried out in them.

"If, on the other hand, a known or suspected cause of pancreatic cancer were identified in the Buildings, then assessment of the level of risk to occupants would be determined by collating estimated levels of exposure with what was known from elsewhere about the relation of risk to levels of exposure." (DC, pages 8-9)

A key phrase is "what was known from elsewhere". The argument seems to be that the small size of the population of past occupants of the Rutherford Buildings puts limits on the value of an epidemiological study, and that such a study could only be of scientific value if there were independent grounds for believing in the existence of a causal relationship between the contamination and observed disease. This argument effectively rules out any possibility of establishing such a relationship epidemiologically for the specific environment consisting of the Rutherford Buildings. It also implies that in the absence of other (non-epidemiological) evidence for such a causal relationship, *no* increase in the numbers of observed or recorded cases of e.g. pancreatic cancer would be sufficient to alter the conclusion reached. In other words, the absence of non-epidemiological evidence for a causal relationship is regarded as equivalent to evidence of the absence of a relationship.

The difficulty in reconciling this argument with everyday intuitions about risks and causes of illness becomes acute if we imagine a situation in which a significant number of additional cases of cancer were discovered, such that the size of the cluster would make it difficult for anyone to be confident that they were due to 'chance coincidence'. In correspondence last year Professor Coggon made it clear that in such a situation he would have to consider the possibility that there was some other potent and previously unrecognised cause of the disease that was fairly unique to staff based in the Rutherford Buildings. This position appears to exclude *a priori* the possibility that known contaminants might act in hitherto unknown ways under the specific conditions prevailing at Manchester. Yet Neil Todd's work makes it clear that the radiological environments created by the work of Rutherford and other early workers in the field of radioactivity are rather different from those which have hitherto provided most of the medical and epidemiological evidence.

I am well aware of the distinction between absence of evidence and evidence of absence, and throughout my report, I have borne this in mind carefully in both my reasoning and my wording. I do not anywhere say that an epidemiological study could only be of value if there were independent grounds for believing in the existence of a causal relationship between the contamination and the observed disease. Rather, my position is that an epidemiological study would only be worthwhile if it addressed outstanding uncertainties with sufficient statistical power materially to alter scientific understanding and future decisions in managing the contamination of the Rutherford Buildings (including considerations of attribution of disease and possible eligibility for compensation).

As argued by the eminent epidemiologist, Dr Kenneth Rothman, "with very few exceptions, there is little scientific or public health purpose to investigate individual disease clusters at all" (Am J Epidemiol 1990;132 Suppl 1:S6-S13). In this particular case, for the reasons set out in my report, I do not think that an epidemiological study would be helpful. The argument is not about an absence of evidence in support of a hazard, but rather that there is a considerable weight of evidence that ionising radiation is at most, an

extremely weak cause of pancreatic cancer, that mercury is not a cause of the disease at all, and that the only other hazardous substance identified in the Buildings, asbestos, while a well established cause of lung cancer and mesothelioma, again does not cause cancer of the pancreas. In the context of such a strong body of evidence, a study of people who had worked in the Rutherford Buildings, which inevitably would be of limited size and statistical power, would have minimal impact on the overall weight of evidence that ionising radiation, mercury or asbestos cannot explain the observed excess of pancreatic cancer.

The situations in which an epidemiological study might have been worthwhile would be those in which initial investigations indicated exposures to a known hazard at levels that could be sufficient to cause a detectable increase in disease, or revealed an exposure for which hazard was uncertain, but which could not be ruled out as a cause of the cluster of pancreatic cancer. In the first case, an epidemiological study might help to refine risk estimates for occupants of the Buildings, while in the second, it could be used to explore whether and how risk of the disease was related to the exposure in question, and thus generate evidence for or against a hazard. However, despite careful exploration, no exposures were identified that met either of these criteria.

I have revised the wording of my report to try to make this reasoning clearer.

(d) The pressure for certainty and closure

In the circumstances of this inquiry, in which various groups and individuals are urgently seeking clear conclusions and/or some kind of closure, and when there has already been considerable expenditure of resources (personally, financially, and institutionally), there can be a strong pressure to go beyond the available information and to make claims that are not fully justified by the available facts. The claim that "by far the most likely explanation for the cluster [of pancreatic cancers] is that it has occurred by chance coincidence" is an example of such a claim. There is no doubt that the cluster *may* be a chance coincidence, since it is a well-known feature of the Poisson distribution of unrelated rare events that such clusters will occur by chance. However, the claim that the cluster *cannot* be explained by exposures to one or more of the contaminants is not justified, given the very considerable uncertainties that remain. Despite the understandable wish for certainty and closure, it may be necessary to accept that we still don't know whether or not there has been a material risk to the health of former occupants.

Clearly, this is a matter of professional judgement. The opinion that I give in my conclusions represents my independent assessment, taking into account the uncertainties that I have identified. However, I accept that others may differ in their interpretation.

Not surprisingly, these activities caused some consternation among the occupants of rooms that had to be vacated for remedial work. Questions were raised about the exact nature and level of the contamination, and about possible risks to the health of people working in the rooms that were affected. The concerns were set out formally in a report by three members of staff (two recent and one current) from the Department of Psychology (the Churcher report) [Churcher et al, 2008]. As well as highlighting the widespread contamination that had been found in the building, the authors drew attention to the occurrence of cancer in two former colleagues, who had occupied contaminated rooms, and asked whether there might be a causal link. They concluded by calling for an independent review of the risks to past and future occupants of the Building, and of arrangements for protecting their health.

We were unaware of the 2004-5 remediations when we wrote our report in 2008.

Nevertheless, I think the report did set out the concerns about the exact nature and level of contamination and the possible risks to health of people working in rooms that were affected.

Next, an assessment was made of the levels of exposure to the pollutants that could have occurred during the past 60 years, and of the levels of exposure that might be expected in the future. Various exposure scenarios were considered, including normal occupancy of the Buildings, the performance of maintenance work including some intrusive tasks on the fabric of the Buildings, and living in a house to which articles of furnishing or furniture had been transferred from the Buildings. The cut-point of 60 years was chosen because it would cover the large majority of people who had worked in the Buildings and who were still alive. Moreover, estimates of earlier exposures would be less reliable.

Finally, the estimates of potential exposure were collated with the evidence on risk by levels of exposure to produce assessments of possible risks to health. These assessments did not address the specific circumstances of any named individual. Rather, as a first tier exercise, they considered what would be a reasonable worst-case estimate of risk for each exposure scenario. The option was retained to derive more realistic person-specific assessments where the first tier analysis did not rule out the possibility of material risks to health.

Information on causes of death prior to this would still be relevant

Systematic information on causes of death before 1950 is not available, but its absence does not impact critically on the risk assessment presented.

This is illustrated in Table 1, which shows expected numbers of deaths from various causes in a "cohort" of 2,876 workers that was followed for mortality over a period of up to 45 years [Coggon et al, 2003]. The numbers were calculated with the assumption that the cohort had the same sex- and age- and calendar period-specific death rates as the general population of England and Wales.

Should be 2004

This has been corrected.

(except where branching in the relevant decay chain led to a deviation). In the case of the uranium-238 and thorium-232 decay chains, the level of activity was taken as the maximum that had been recorded for any radionuclide in the decay chain in any measured dust sample. For radium-226, this gave the value that would have been expected if approximately 1% of the radium that was known to have been used by Rutherford and his colleagues [Todd, 2008] had been spilt across a total floor area equivalent to a 1 metre diameter circle in each of 20 rooms. As no activity levels had been measured for the uranium-235 decay chain, the level of activity for radionuclides in this series was derived from the quantity of actinium-227 that was thought to have been used by Rutherford. This quantity was taken from data reported by Neil Todd [2008], and the calculation assumed that the proportion of actinium-227 that was lost through spillage was the same as was estimated for radium-226 (i.e. about 1%). The activity level for a radionuclide contaminating a surface (in Bq cm^{-2}) was taken to have the same numerical value as its activity in the surface material, and in dust derived from it, in Bq g^{-1}. The justification for this assumption lay in the ratio of surface activity to activity in dust for radium-226 in two sets of monitoring data from 2000 [Jones et al, 2009].

With rounding up, this method gave values for surface and dust contamination as set out below.

This figure of 1% loss through spillage seems very low. Neil Todd's research suggests the possibility that the proportion lost was an order of magnitude higher than this. (See also comments added to the HPA provisional report, pages 52-3)

I agree there are uncertainties about the proportion of radium lost through spillage, as there are also about the area over which spills were distributed. However, within the limits of that uncertainty, this calculation indicates that the retrospective estimates of exposure from recent measurements are not manifestly implausible. I have added some text to clarify this.

Articles removed from Building

From the ways in which radioactive contamination of the Rutherford Buildings is thought to have occurred (principally breakage of equipment and spillage prior to 1920), no important contamination would be expected of furniture or furnishings that were first placed in the Buildings after 1920. This is supported by the absence of detectable radioactivity in articles removed from the Buildings that have been monitored by HPA RPD. It thus seems reasonably certain that any exposure to ionising radiation from furniture or furnishings taken from the Buildings would be less than that which could occur from long-term occupancy of the Buildings as an office worker.

It is reasonable to suppose, however, that articles made wholly or partly of glass,as well as glass windows in situ, would retain radon progeny which could be used to estimate past exposure to radon.

5.3.5 Assessment of risk

The risks of cancer from the exposure scenarios set out in Section 5.3.4 were estimated using the relevant UNSCEAR risk models (see Section 5.3.3). The main index of risk that was derived was the "Risk of Exposure-Induced Death" (REID), which is the lifetime risk that an individual will die from a cancer of the type under consideration as a consequence of his/her radiation exposure. Also calculated were "baseline risk" – i.e. the lifetime risk that an individual will die from the cancer in question in the absence of any radiation exposure, and the "loss of life expectancy if death occurs". The latter measures the average years of life that would be lost by a person who died from a radiation-induced cancer.

See comments above about the potential value of measuring radon progeny in glass.

d) There are no reports or records of refurbishment or structural rearrangements between 1990 and 2004 that could have altered ventilation and airflow in a way that significantly reduced airborne concentrations of mercury in rooms.

In the Casella Winton 2004 survey, one room (2.52) had recorded mercury concentrations of 10.7 µg/m^3 and 4.9 µg/m^3. Three other rooms (2.62, 2.63 and 2.53) had measured concentrations between 2 and 6 µg/m^3. All other measurements were less than 2 µg/m^3. Under-floor concentrations of mercury in the Manchester Museum survey by Diamond Environmental were roughly an order of magnitude lower than those subsequently recorded in Coupland 1, making it unlikely that levels in room air would have been higher than the highest value recorded in Coupland 1.

Although a maintenance worker who lifted floor boards or worked close to crevices in the floor might temporarily be exposed to relatively high concentrations of mercury, the highest cumulative exposures would be expected in a member of staff who spent prolonged periods (the equivalent, say, of 8 hours per day, five days per week, 48 weeks per year over 40 years) in a room with the highest concentration of mercury. From the reasoning set out above, the highest average concentrations of mercury in any room since 1980 are likely to have been less than 15 µg/m^3.

It seems highly probable, however, that the ventilation systems in the building have been changed since Rutherford's time. This could be relevant to the uncertainty about mercury levels in the earlier period.

This is not of concern in relation to the conclusions that are drawn on risks from mercury exposure since 1990. The uncertainties about earlier periods are already acknowledged.

Review of "Health risks from contamination of the Rutherford Buildings, University of Manchester. Provisional Report. September 2009" by Professor David Coggon.

Neil Todd,
University of Manchester,
January 2010.

The recent Provisional Report by Professor Coggon, commissioned by the University of Manchester following the recommendations by Churcher et al (2008), has been informed by two other reports, the first by the HPA, on risks associated with radioactive contamination (Kelly et al 2009), and the second by the HSL on mercury contamination (Rowbotham 2009). The historical context to the review and risk assessment has in turn been informed by a supplement to the Churcher report by Todd (2008), which has provided data on the nature and quantity of radioactive substances employed by Rutherford.

Prior to 1999 there are no extant radiological data and two methods were used to estimate historic levels of contamination, a forward calculation based on documented amounts of substance in the possession of Rutherford from 1907 – 1919 and a backward calculation based on post 1999 radiological data. These estimates were used to set-up a "worst case" scenario of exposure to direct radiation, and to exposure by inhalation or ingestion, and resultant doses used to calculate risks for various organs by means of standard biokinetic models. The conclusion from these estimates and assessments is that "none of the identified contaminants in the Rutherford Buildings could plausibly account for the cases of pancreatic cancer, brain cancer and motor neurone disease that have occurred among past occupants of the Buildings".

As acknowledged in the review, there is a considerable degree of uncertainty in the calculations. The main sources of uncertainty are the forward and backward estimates of historical contamination. There is an absence of extant radiological data from before 1999 and an absence of any formal records of any remediation which may have taken place before 1999 so it is necessary to make a number of assumptions. In addition the exposure scenario which is used to calculate dose is of necessity based on an additional number of assumptions, although an attempt has been made to make this scenario "worst case". My comments are reserved to these issues of uncertainty.

Since I prepared my interim report (Todd 2008) I have conducted a considerable amount of further research into Rutherford's use of radioactive substances (Todd 2009a), the funding of his work by the Royal Society (Todd 2009b) and levels of contamination in archival materials of Rutherford held at Cambridge (Todd 2009c), and in archival documents of his contemporaries and students including William Ramsay, Frederick Soddy, James Chadwick, Patrick Blackett and Norman Feather. I have also been able to obtain useful historical information on contamination in the Old Cavendish Laboratory at Cambridge where Rutherford moved in 1919. These new data throw more light on the Manchester contamination and allow us to reduce some uncertainty.

1. Radioactive Contamination in the early 20th Century.

An important historical fact to emerge from the materials which I have examined is that 1903 stands out as an important date for the onset of contamination of the kind found at Manchester, i.e. from radioactive substances from the three natural series, i.e. uranium-radium (U238/Ra226), uranium-actinium (Ac227) and thorium (Th232). Five years after the discovery of radium (Ra226), 1903 was the year when concentrated samples of radium salt became readily available on a commercial basis. There was a huge demand for the stuff and many physical scientists of the day obtained quantities of it for experimentation, not least Arthur Schuster (see Todd 2008, 2009ab).

One of the patterns to emerge from the archival surveys referred to above is that contamination appears to have been an inevitable consequence of the manipulations carried out with radioactive substances. Radiochemical procedures in particular were the most prone to produce contamination, but contamination could occur just by handling these materials. Contamination can be found in the archive documents, particularly laboratory notebooks, from all the scientists who used radium in the early days, including Rutherford, Ramsay and Soddy. However, the contamination is not confined to laboratory notebooks and can found in letters and other non-experimental documents, such as offprints. It is reasonable to assume that the archival contamination is correlated with wider contamination of apparatus, furniture and buildings from this period. Historical evidence, such as biographical material, supports this view (Todd 2009c).

Most of the contamination in the archive material is from radium, particularly in the earliest period, but as the science developed, and radioactive sources from the active deposits of radium were preferred, radium D (Pb210) contamination becomes more prominent. In spite of a growing awareness of the problems of contamination, and efforts to avoid it, significant contamination continues in archival material up to the invention of particle accelerators in 1932 when radium became redundant (although sealed radium-beryllium neutron sources continued to be used after 1932).

2. Arthur Schuster's radium 1903-1907

As noted above Arthur Schuster, Rutherford's predecessor as Langworthy Professor, joined in the great radium rush of 1903 when he purchased initially 20 mg of radium bromide and later an additional amount so that by 1906 he possessed 60 – 70 mg of "the most active preparation of radium bromide" (Todd 2009a). As described in Todd (2008) a series of experiments were carried out with this radium prior to Rutherford's arrival in 1907. We can be sure that some contamination took place in the Physical Laboratories at Manchester between 1903 and 1907 and given the nature of the experiments it is quite possible that this was significant.

A critical issue here is how much of Schuster's radium was available to Rutherford when he arrived in 1907. According to Rutherford's first biographer Arthur Eve there was "a great shortage of radioactive material of all sorts". During his negotiations with the Vienna Academy for a loan of radium in a letter of 5th Oct 1907 he wrote "I may mention

that the University of Manchester possesses at present less than 20 milligrams of pure radium bromide". A month later he complained in a letter of 11 Nov 1907 to William Ramsay "I do not know whether you are aware of my state of poverty in regard to radium. The maximum quantity available for experiments is 7 milligrams". These letters imply that there was quite a significant quantity of Schuster's radium unaccounted for. The difference in the two amounts, 20 vs 7 mg, may be due to 13 mg being used for other experiments (as documented in Todd (2008)). According to Fox (1998) Schuster sold a small quantity (£6 worth) in 1905 to a Professor Robert Wild, the first to use radium in Manchester for medical purposes, but at the 1903 price (£30 for 5 mg) £6 would only buy 1 mg.

The proportion of missing radium is dependent on the purity of the original quantity. As described in Todd (2009ab), the preparation of radium salt as a bromide (RaBr2), by recrystallisation of a radium barium mix, was relatively efficient compared with the original Curie method as a chloride (RaCl2), which required thousands of stages. It is likely therefore that Schuster's RaBr2 was relatively pure ("the most active preparation" in his words), at least 50% radium to barium. Assuming a 50% purity then of the 60-70 mg, 30 – 35 mg would be pure radium bromide, which leaves missing 10 -15 mg of pure radium bromide. The fraction of elemental radium in hydrated radium bromide (RaBr2.2H2O) is 0.54 (in anhydrous RaBr2, the fraction is 0.58) which leaves missing about 5.5 – 7.5 mg pure Ra, of activity 5.5 – 7.5 mCi or 200 – 300 MBq.

One of the assumptions made in the risk assessment was that the proportion of radium lost was 1%. The documentary evidence that we have available, however, indicates that for Schuster's radium the proportion lost was considerably higher than this. By weight the loss would be between 30 - 60%. Jones et al (2009) estimated that the total activity of radium possessed by Rutherford (Appendix C1) was 12 GBq, equivalent to 324 mg elemental radium (1 Ci = 37 GBq or 1000 mg Ra). A 1% loss corresponds to 3.2 mg elemental Ra. Thus even considering the missing Schuster radium alone, without loss of Rutherford radium, this would appear to be an underestimate of contamination due to Ra226.

The higher proportion lost from the Schuster radium is quite plausible given the nature of the experiments carried out by Schuster, e.g. subjecting radium to high temperature and pressure. In the earliest days from 1903 it was quite common for there to be large amounts of loss. For example, James Dewar spilled quite a large amount of radium loaned from Pierre Curie at the Royal Institution. Accidents and spills continued to occur throughout the first few decades of radium use, in spite of the greatest of precautions, and many of these accidents are well-documented (Fox 1998). On this point, therefore, I am at odds with the statement in C1.3 of Jones et al (2009) concerning the unaccounted Schuster radium. There is documentary evidence that the Physical Laboratories were already contaminated before Rutherford arrived. By far the largest amount of material removed during remediation was from the ground floor laboratory (Private Laboratory in 1906) which would have been used by Schuster. Basement rooms would have been used by Schuster's research workers, including Sydney Russ and Hans Geiger, for experiments making use of radium solution.

3. Rutherford's Inventory of Radioactive Substances

In Appendix C1 Jones et al (2009) state that "Professor Rutherford was known to have obtained 500 mg of radium bromide from Vienna, but the exact composition and corresponding activity was unknown." Since the interim supplement was made available (Todd 2008) I have been able to establish the quantity of radium with some precision (Todd 2009a). When the Vienna radium was delivered on Feb 14th 1908 Rutherford himself carried out a measurement of its activity by means of an emanation electroscope.

The following is a quote from Rutherford's notes*.

"Recd from O Brill. Saturday Feb 14th [1908].
Radium weight 3 .95 grams of RaBaCl2 recd in quartz tube with stopper.
Amt of Ra tested in terms of 3.69 mg BaBr2 stand.
Emanation (glass) electroscope A employed.
Natural leak = .19 [divisions per minute]
Standard placed in shelf below electroscope, 1.26 = 1.07
Vienna Radium in same position, 60 [divisions] in 27.2" = 132 divs per min
Amt of Ra = 3.69*132/1.07 = 455 mg BaBr2
Another observation next day = 447 mg BaBr2
The amount of Ra is slightly larger than this since a small fraction of emanation leaks."

Thus we know that, unlike Schuster's radium, Rutherford's was a rather impure radium barium chloride mix, but was equivalent in its activity to about 460 mg of radium bromide. As above the fraction of elemental radium in hydrated radium bromide (RaBr2.2H2O) is 0.54, so that the amount of elemental radium would be 248 mg. This estimate comes to a similar amount as that stated by Jones et al. (2009).

In addition to the large quantity of Austrian radium Rutherford accumulated a number of smaller radium sources. At one point he had access to at least five radium standards which he labelled A (Austrian), B (Boltwood), C, D (Dewar) and E (see Table 1)†.

Table 1. Rutherford's radium standards

Source	Label (if any)	Equivalent mg RaBr2
A	Austrian	10.45 – 11.02
B	Boltwood	7.84
C		3.69
D	Dewar	54
E		32

* Rutherford's laboratory notes recording the arrival of the Austrian radium in February 1908. From AD 7653/PA 182 in the Rutherford Papers, University of Cambridge Library.
† From AD 7653/PA192 "Measurement of Ra Standards", dated 3 -11 February 1910, in the Rutherford Papers, University of Cambridge Library.

The C standard was the 3.69 mg RaBr2 source used to calibrate the large Austrian source. The larger D standard was probably a radium chloride source owned by the Royal Society which in 1910 was theoretically in the hands of James Dewar. In total the standards amounted to 108.6 mg equivalent RaBr2. Adding these to the large Austrian source (460 mg equiv RaBr2) and the stated amount of Schuster radium remaining (20 mg equiv RaBr2) the total amount of radium in his inventory was 588.55 equivalent RaBr2, or 318 mg elemental radium. This corresponds to a total activity 12 GBq which is also close to that estimated by Jones et al (2009).

Estimating the proportion lost from this total quantity is difficult, but it is reasonable to assume that there would likely be little or no loss from the standards. By definition they were precisely measured quantities and would have been kept in sealed containers. We also know for a fact that they were transported to Cambridge in 1919 and were regularly used for training purposes (e.g. there is reference to them from the late 1920s in the papers of Norman Feather). We already have an estimate of loss from the Schuster radium (about 5.5 – 7.5 mg element Ra). This should be added to the loss from the Austrian radium. Assuming a 1% loss from the large Austrian source plus the stated remainder (20 mg) of the Schuster radium (20 + 460 = 480 mg RaBr2.2H2O; equivalent 260 mg Ra) gives 2.6 mg element Ra. The total loss then would be 8 – 10 mg, which is up to three times the amount, 3.2 mg, estimated by Jones et al (2009).

Pitchblende residues

In addition to the above we know that Rutherford came into possession of quite large amounts of pitchblende residues which contained Ra226, as well as other radioactive substances. These include 49 kg "Oxides contenant l'actinium" of activity 800 times uranium and 60 kg. "Sulfure contenant de Polonium" of activity 300 times uranium, both of which were from the working up from 500 kg of pitchblende on behalf of the Royal Society. The actinium residues were later worked up in London and then by Boltwood for Ionium (Th230) and Actinium (Ac227). According to the memoirs of George de Hevesy Rutherford was also provided from the RS with a large quantity (possibly several hundred kilograms) of radiolead.

Rutherford was regularly asked to calibrate radioactive sources for external parties. For example in 1908, Edward Thorpe, the Government Analyst at the Laboratory of the Government Chemist, sent Rutherford 300 grams of residues from different stages of fractionation of radium barium chloride, extracted from the same RS 500 kg of pitchblende residues as above. He also played a major role in certification of radium for the Manchester Radium Institute set up in 1914 (Fox 1998). It should also not be overlooked that with his student James Chadwick he played an important role in devising new methods of calibration for the International Radium Standards Committee, and would therefore have received other standards for calibration.

Considering these other radium sources, it is reasonable to believe that the total amount of radium held in the Physical Laboratories during Rutherford's time exceeded the amount estimated from the large Austrian source.

4. History of the Manchester Contamination

In this section I give a brief review of the history of the contamination updated from the account in Todd (2008) with the new information.

1903 - 1919

As was noted above it is entirely plausible that significant contamination took place before Rutherford arrived in 1907. However, in the five years to 1912 when the extension was completed, a further significant amount of contamination took place, especially with the large number of research students who came to work with Rutherford. The extent of the contamination was such that it impaired the research work being undertaken, especially for the beta- and gamma-ray spectroscopy which was to be the main thrust of Rutherford's work after 1912. This problem of space is described in detail by Arthur Schuster at the opening of the extension.

"With the steady increase in the number of research students, it became more and more difficult to provide sufficient space... This difficulty was emphasised by the nature of many of the investigations... In these researches it was necessary to employ large quantities of radium and radioactive substances. As is well known, these remarkable bodies emit a very penetrating radiation, known as gamma-rays, which is able to traverse the walls and floors of the Laboratories, and to disturb electrical measurements of workers, not only in the immediate vicinity but in the neighbouring rooms. During the last few years this problem has
become very acute, and in order to isolate the workers as far as possible from one another it has been found necessary to encroach on the space intended for laboratory instruction. .." [1912]

On the particular issue of contamination.
"In addition to the difficulty of avoiding disturbances due to penetrating radiations, a Laboratory in which large quantities of radioactive substances are in continual use gradually becomes contaminated by the distribution of active matter. For example, an invisible trace of radium on a finger suffices to make permanently radioactive every object that is touched. Although precautions have been taken to reduce this infection to a minimum, it has proved sufficiently serious to render difficult, if not impossible, some of the more delicate measurements required in researches on radioactivity …" [1912]

For these reasons six new uncontaminated rooms were set aside in the extension for the spectroscopy work.

"The Physics Research Rooms marked A to F on the plans, are situated on the first floor of the north wing facing Bridge St. In this position they are well outside the range of penetrating radiations from active material in the main building, which is some 30 yards further south. Primarily intended for experiments in connection with radioactivity, they are nevertheless equally well adapted for other branches of Physical work. ... If necessary, several of the rooms can be darkened for photographic or special radioactive work." [Schuster 1912]

It is clear from Schuster's description that the contamination in the 1900 Building must have been high. Although there are no quantitative measurements we can make a qualitative guess of the level from the fact that it was "difficult, if not impossible" to carry out spectroscopic measurements, that gamma activity could be detected through walls and floors and that it was necessary to be a good 30 yards away from the main building to make delicate measurements.

1919 – 1936 WL Bragg – Chadwick's Letter

In 1919 Rutherford was appointed to the Cavendish Chair at Cambridge and was succeeded at Manchester as Langworthy Professor by WL Bragg. Although he took most of his radioactive sources with him there can be no doubt that the contamination remained behind when he left. It is also likely that he left behind some of the waste residues, e.g. radiolead, which were of no use to him. I have at this time not been able to find any reference to the contamination between 1919 and 1936, although I have not yet had the opportunity to look through the papers of WL Bragg. However, I did find a reference to the contamination in a letter of February 1936 from James Chadwick to Rutherford after Chadwick had visited Manchester to give a lecture. In a hand written note at the bottom of the letter he notes that he had just visited the old lab at Manchester and "it is still contaminated in places". This suggests that some attempt had been made to clear up the contamination after 1919, i.e. that there had been some remediation, but that it was only partially successful (clearly). Chadwick's biographer writes of this letter.

"Attitudes to radiation safety were still cavalier in the 1930s, although with the premature deaths of radiologists and a few notable physicists like Marie Curie, the risks were becoming more apparent. All the Rutherford school of physicists received radiation doses that would be regarded as dangerously high by present day standards, but as a group they were curiously lucky. The laboratory stewards who handled the sources the most were not so fortunate, and Rutherford writing to Chadwick in May 1936 informed him that 'Crowe is in London undergoing a special grafting treatment for his fingers'. It was George Crowe who in 1919 had put Rutherford's precious radium from Manchester into solution [at Cambridge]." [Brown 1997].

It should be noted that among the radiologists who died prematurely were employees at the Manchester Radium Institute (Fox 1998). Rutherfords's own assistant, William Lantsberry, also died prematurely. Before WWI he worked in the laboratory Radium Room (2.62) preparing sources (and probably conducting quality control of Institute radium). Later he worked as a radium technician in the radiology department at Baltimore Hospital. According to William Kay, Rutherford's Manchester laboratory steward, Lantsberry's death was due to pernicious anaemia. Although pernicious anaemia is actually caused by a vitamin deficiency, the symptoms of radium induced blood count disturbance "strongly resemble" it (Fox 1998). For this reason in the early days terms like "aplastic pernicious anaemia" were used to describe leukaemia associated with radium use. Marie Curie's daughter Eve uses this term in her biography of her mother (Curie 1938).

1937 – 1940 PMS Blackett – Bernard Lovell's Geiger measurements
The remaining contamination which Chadwick refers to was well known about by the occupants of the Physical Laboratories at Manchester as is testified by the account of Sir Bernard Lovell who arrived at Manchester as a young lecturer in late 1936. He initially worked with Hartree, then located in the basement laboratories, but with the arrival of Patrick Blackett he switched to work on cosmic rays in the two years before the outbreak of WWII when he went to work on radar at RAF Worth Matravers. As part of this work it was necessary to build their own Geiger counters for the coincidence detectors which were standard for cosmic ray research. It was during this time that he discovered that a number of rooms were radioactively contaminated. He particularly remembers the tea room, which we now believe to be the room where Rutherford kept his radium on the 2nd floor (i.e. rooms 2.62/2.63), but also a number of basement rooms were contaminated. At this time the contamination was regarded as a source of amusement and there were no heath concerns. Using coincidence methods the contamination was not considered a problem for the cosmic ray work, although Blackett's lab was some way away from the main sites of contamination. (Blackett himself would have been familiar with contamination from his years at the Cavendish. A few of his own laboratory notebooks are still mildly active.) Lovell was not able to recall a specific count reading but during a speech in 2008 he recalled his Geiger measurements anecdotally that by today's health and safety standards would have been enough to have the room "sealed up". After WWII in 1945 Lovell became more detached from Manchester as his interest lay at Jodrell Bank.

1955 -1968 S Devons & BH Flowers - Henry Hall and EB Paul
After Blackett left in 1953 he was succeeded by Samuel Devons from 1955 – 1960. Devons died only recently in 2006, but unfortunately I missed the opportunity to interview him. Although I have made contact with his daughter I have not been able to find any reference to contamination at Manchester. I have been able, however, to interview Professor Henry Hall who arrived in Manchester towards the end of Devon's time. During the interview he recalled that there were a few rooms that were locked due to concerns about contamination. One of the locked rooms was in the basement and another was at the top of the building, but he didn't recall where exactly.

In the early 1960s EB Paul was appointed to complete the building of particle accelerators started by Devons and he occupied the Laboratory Director's Office on the first floor of the 1900 building, which had previously occupied by Rutherford, Bragg, Blackett and Devons. Between 1961 – 1964 the Departmental Reports were co-written by Henry Hall and EB Paul. According to correspondence received by Professor Coggon, Paul found his office to be contaminated after his badge monitor showed unusual levels of radiation. Consequently he vacated the room while remediation took place, which included replastering and repainting. Four years after Paul's departure the Department of Physics moved to the new Schuster Building.

Summary
The evidence that is available is consistent with the view that the contamination which occurred during the Schuster and Rutherford years of experimentation with radium resulted in radiation levels that were significantly higher than the levels reported in the 1999 and subsequent radiological surveys. The levels in 1912 were sufficient to make delicate measurements "difficult, if not impossible" in the main building and required relocation to new rooms 30 yards distance to avoid disturbance. There was at least one round of remediation that took place in the 1960s and it is quite likely that there were previous attempts to clean up the contamination after Rutherford left in 1919. This view throws some doubt on the assumptions made in the risk assessment that there was no prior remediation. These assumptions clearly could have an impact on any estimates of previous levels of exposure.

5. Radium D (Pb210) Contamination
The risk assessment assumes a hotspot level of Pb210 in the contamination scenario based on activity levels of Pb210 found in C1.10. However, as acknowledged, much of the surveying was done with instruments which would not have detected the 46 keV gamma signature of Pb210. In Todd (2008) on p99 I estimated on the basis of the 2000 Wastestream Characterisation [C21 in Churcher et al (2008)] that perhaps 12 MBq of Pb/Bi/Po210 could have remained in the building, since the remediated Pb210 was not in equilibrium with its parent Ra226, and so some Ra222 and hence Pb210 must have escaped. The actual amount of Pb210 could actually be much higher than this as a major source of Pb210 contamination during Rutherford's time was the leak of radium emanation (radon or Rn222), e.g. when an emanation tube was broken. Such accidents happened from time to time and are well-documented in the historical material (Todd 2008, 2009c). On such occasions the entire laboratory was put out of action for several hours. This contamination mechanism was recognised by Rutherford early on as one which if unchecked could lead to the permanent contamination of a laboratory, as happened at his Montreal Laboratory (Todd 2008, 2009c).

A single tube might contain as much as 100 mCi or 3.7 GBq. With a half-life of 22 years even after 100 years this would still have an activity of 0.174 GBq. If there were say five such accidents over the Rutherford period before WWI between 1908 and 1914, then the total residual Pb210 in 2012 would be nearly 1 GBq. Spread over an area of 200 m2 this comes to about 500 Bq cm-2. These activities would of course be much higher at earlier dates. In 1950 after 40 years, the Pb210 from a 100 mCi tube would have decayed to 1.1 GBq. Pb210 from five such tubes spread over 200 m2 comes to about 2700 Bq cm-2 in 1950. Considerations such as these could easily produce a different outcome in a risk assessment as the Pb210 (and hence Bi/Po210) would be much more widely distributed than assumed in a hotspot model. The surface contamination levels would though depend on assumptions made about which surfaces were affected, i.e. walls, floors and/or ceilings.

6. Distribution of Contamination
As well as assuming a 1% loss rate for Ra226, as discussed in 2 and 3 above, the risk assessment also assumes that it is distributed homogeneously "across a total floor area equivalent to a 1 metre diameter circle in each of 20 rooms". This assumption seems to be inconsistent with the facts concerning the known distribution of contamination where there is a clear heterogeny. There is a small number of key rooms which were

significantly more contaminated than others, e.g. the Radium Room, the Preparation Room and the Ground Floor Lab, and this correlates with the activities which we know took place in them (Todd 2008, 2009c). A "worst case" scenario based on a heterogenous distribution would likely give a different outcome. If say it was assumed that of the total spilled radium, 20% was spilled in one room, 10% in the next two and that the remaining 70% was distributed in 17 rooms, giving 4% each, then an occupant of the most contaminated room would receive a dose five times that of the least. Combined with the higher loss rate suggested above, this would result in a dose of up to 15 times higher than estimated in the risk assessment.

7. Radiological data from the Old Cavendish Laboratory

Although there are no surviving records from Manchester prior to 1999, there are records of remediations carried out at the Old Cavendish to deal with both mercury and radioactive contamination. As described in Todd (2009a and 2009c) I have been able to trace a history of Rutherford's radium after he left Manchester in 1919. It appears the Austrian radium was put back into solution in a room at the top of the Cavendish towers. This became the Radium Room at the Cavendish, equivalent to Manchester's Radium Room on the 2nd floor in the old Schuster Laboratory. The Austrian radium probably remained in the tower after Rutherford's death in 1937 and was effectively forgotten about during the WWII. It probably stayed there until 1958 when the room was cleared out. According to the records, decontamination work took place in September/October 1958 by a team from Harwell consisting of members of the Health Physics Group and the Industrial Chemistry Group (ICG). A good description of the state of the room is given*.

"The laboratory was situated at the top of a flight of narrow stairs and constituted two small rooms, both of which contained a large amount of old equipment, benches, cupboards, etc. The whole was extremely dirty, dust lying thickly overall articles; in addition, large quantities of mercury had been spilt in various places on the floor. Several large radium sources (about 480 mg) were on a wooden window sill in the inner room with very little shielding … and there were a number of smaller sources – probably radium and thorium – scattered around both rooms.
Before a contamination survey was carried out it was necessary to remove all known sources and an air sample at floor level in the inner room showed 1700 dpm/m3. The rapid decay of this sample indicated the presence of radon and daughters. A first survey of the area showed levels of activity on chairs, benches, equipment, floor and walls of up to several thousand counts per second."

According to the associated ICG report of 23rd September*

"On Wednesday 24th September 1958, the party returned to Cavendish with appropriate active waste containers, protective clothing, breathing apparatus and decontamination kit, complete with tools for breaking laboratory benches etc. Four days work was required to strip the rooms of contents. Glassware and general trash was broken and sealed in large fibre drums. … All bottles containing solutions were packed in vermiculite and sealed in fibre drums. A three ton Bedford and 15 Cwt Ford Van were escorted on the return journey to AERE with this load of active waste on 27th September 1958."

* "Decontamination of Tower Rooms, Cavendish Laboratory, Cambridge". Mr R H Burns Industrial Chemistry Group, Building 175.

At this time no records of the arrival of the tower waste can be located in the archives, although there are records of general activities of the ICG and Health Physics Division. The Health Physics Group at this time were based in Building 364 of the Harwell campus, as they are today, while the ICG were based in Building 175 in the north part of the campus, very close to where Nirex UK and the Nuclear Decommissioning Authority (NDA) are currently located.

Although this room had been neglected for some time and was used for preparing radioactive sources, as well as storing radioactive substances, it gives us an insight into the condition (including mercury) which might have prevailed at Manchester when Rutherford cleared out his old Radium Room in 1919. This, it would appear to me, is as good a model as any for estimating historic levels of levels of contamination at Manchester.

Conclusions
After reviewing the Provisional Report and associated HPA and HSL reports I am of the opinion that some of the assumptions made in calculating health risks could be in error.

(1) The assumed 1% loss rate underestimates the unaccounted for Schuster radium
.
With one exception, forward estimates of historical contamination were used only as a crude check on the plausibility of backward estimates (see above). The figure of 1% for loss through spillage was given only as part of a crude check on the plausibility of backward estimates of exposure. There are other uncertainties in this check, which are now made clearer in the report. The value of 1% is not critical to the risk assessment.

(2) The historical evidence strongly indicates that significant remediation did take place before 1999, contrary to the assumed absence of prior remediation.

The possibility of reductions in exposure through undocumented building work before 1999 was acknowledged in the provisional report, and taken into account in its conclusions. Text has now been added referring specifically to the anecdotal report of limited remediation in rooms that were found to be contaminated in the 1960s, and to new evidence of expenditure on refurbishment in that decade. However, this does not alter the assessment of risk.

(3) The historical evidence also indicates that prior levels of contamination were significantly higher than has been assumed.

The risk assessment presented does not depend on assumed levels of historical contamination (except for an assumption that spillage of nuclides in the uranium-235 decay chain was in similar proportion to that for radium-226). Forward estimation of exposures from estimates of amounts of materials handled and spilt was used only as a rough check on the plausibility of backward estimates. Moreover, there are other important sources of

uncertainty in the forward estimation, including the possibility of clean-up before 1950. This is now made clearer in the report.

(4) In addition to known hotspots of Pb210, there was likely to be a wider more diffuse Pb210 contamination, due to leak of radium emanation with tube breakage, which is not included in the contamination scenario. This issue could be resolved if further measurements were made using appropriate instruments, i.e. which were sensitive to low-energy gamma-rays. The currently planned further remediation work in 2.62/2.63 provides an opportunity for this to be done.

See HPA response.

(5) The contamination was heterogeneously distributed contrary to the homogeneity assumption in the risk assessment.

See HPA response.

(6) Data from decommissioning of the Cavendish Laboratory Radium Room in 1958 provide a good model for estimating contamination levels in the Manchester Radium Room in 1919.

Estimates of contamination in the Manchester radium room in 1919 are not directly relevant to this risk assessment.

Taken together these potential errors could significantly alter the outcomes of the risk assessment. Given this possibility it would be sensible to conduct some further tests to resolve these issues. Clearly, one outstanding issue is the contribution of the Schuster radium to the contamination. A mass spectrometry analysis of the waste currently held by the University could potentially discriminate between Schuster's pure RaBr2 and Rutherford's impure RaBaCl2.

For the reasons given above, I do not think the points raised call into question the conclusions of the risk assessment, which took into account the major uncertainties. I do not think that information about the contribution of the Schuster radium to the contamination would refine the risk assessment significantly.

Acknowlegements
I am grateful to the *Royal Society* for providing me a small grant to support the radiological survey of archival papers.

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Comments and questions from an unnamed source

You have said that you looked closely at current and past exposures in the building. The methods used to look at past exposures depend on a number of assumptions about whether there was any attempt, prior to the major works undertaken in the 21st century, to reduce or eliminate contamination from any of the 'candidate exposures'. There was also a dependence on a piece of work by Dr Todd which looked at a limited type of contamination and also at a limited period.

The uncertainties about reductions in contamination from undocumented renovation, especially before 1970, are recognised and taken into account in the risk assessment. The data on possible historical levels of contamination are recognised to be uncertain, and are used principally as a rough check on the plausibility of exposures estimated retrospectively from recent measurements of contamination (see above).

We have tried to clarify the first issue. So far the University has not indicated whether there were any decontamination attempts; but the fact that documents exist which appear to demonstrate that there were at least some, leads us to suggest that it would be preferable not to issue your report as 'final' until that issue has been determined.

It is the nature of any scientific activity that new information may always come to light that necessitates a revision of previous understanding. However, in this case, I do not think there is a sufficient expectation of new information that could impact critically on my conclusions to justify delaying finalisation of my report.

The position in relation to the records of the amount of contamination introduced to the building appears to be that these records are incomplete. We believe that further investigation should take place in this respect.

As indicated above, the risk assessment does not depend critically on data concerning the amount of contamination introduced into the building, estimates of which were used principally to check the plausibility of exposures estimated retrospectively from recent measurements.

There is a third area of investigation which also appears to be incomplete. This relates to the issue of how the combined effects of the various contaminants have been considered in recent research; comprehending also the research into the implications of low-level exposures and also the significance of any ingestion rather than inhalation.

The potential toxicity of contaminants in combination is addressed in Section 5.6, and I do not think that I can add usefully to that. I recognise that one or two scientists have questioned the validity of standard models for estimating cancer risks from low level exposures to radiation, but their position is not

accepted by the very large majority of scientists worldwide who work in this area. Exposures through ingestion were taken into account in the risk assessment performed by HPA (Section 5.4 of their report).

Response to

'Health Risks from Contamination of the Rutherford Buildings, University of Manchester'
by Professor David Coggon, September 2009

From

University of Manchester University and College Union (UMUCU) Executive
11 January 2010

See also report at:
http://www.umucu.org.uk/ucu/UMUCU_Response_to_the_Coggon_Report_11_01_10.pdf

Introduction

UMUCU wish to acknowledge the work which Professor Coggon has undertaken in compiling this report. In particular we appreciate Professor Coggon's efforts to estimate risk in the difficult circumstances of a paucity of certain key data. We also recognise the considerable lengths to which Professor Coggon and his team have gone in order to gather a wide variety of data, including anecdotal evidence from previous occupants and users of the Rutherford Buildings.

We fully support and endorse Professor Coggon's recommendations that there be further exploration of the mercury contamination of 2004-2006, and additional monitoring of mercury levels in the air; and of a need for comprehensive risk assessments in the case of any further building work.

In addition we wish to make the following comments:

Data Gathering

While considerable efforts were made to gather data from a range of people who had worked in, or who were otherwise involved in, the Rutherford Building, there is little explicit reference to, and use of, these data in the report. These data may be extremely important given the loss by the University of some of the health and safety-related records for the Rutherford Buildings. These more anecdotal data may give insight into the actual working practices in the buildings, in contrast to official processes, which may, or may not, have been followed at all times.

Anecdotal data have been included where they impact on conclusions. A report of limited remedial work in some rooms in the 1960s has now been added.

While we note that many additional reports and data pertaining to the Rutherford Buildings are now available on the website http://www.manchester.ac.uk/rutherfordreview/, we ask that the more anecdotal data

are also archived and preserved in case of opportunity, or need, for further analysis in the future. As a Union we would also be interested to see any other documentation used in the preparation of the report which may not be posted on the website.

The anecdotal information received will certainly be retained. However, much of it is personal, and could not reasonably be made publicly available. I have encouraged the University to make publicly available relevant records that do not contain personal information.

Input from Stakeholders

While we recognise that Professor Coggon was responding directly to the Terms of Reference (p.7), we do think it extremely important to highlight that one of the challenges in producing the report was the loss of certain key data by the University. Hence we think that, as well as calling for further examination of mercury etc, it is equally important that the University introduce mechanisms which would prevent such a loss of data, or failure to maintain appropriate records, from happening again.

This is a matter for the University. However, the general trend is towards better documentation and retention of records than in the past.

In addition the University needs to develop more substantive communication processes around Health and Safety with the trade unions. Although the University does consult with the Unions through the various Health and Safety Advisory groups and the Health and Safety Committee we believe that the University should learn wider lessons about the role of Unions in the management of Health and Safety issues. Specifically Union representatives should be fully involved in accident investigations and the preparation of reports pertaining to these investigations. They should also be involved in Health and Safety inspections around the University, particularly in those schools where Safety Reps have been identified to the Heads of School since this only serves to enhance the University's image as an employer which values the input of its employees in Health and Safety matters.

This again is a matter for the University, which is subject to the requirements of health and safety legislation, and should aspire to good employment practice.

'Chance Coincidence' and the Question of Epidemiology

1. The report states that 'epidemiological research to clarify further risks is not a scientific priority' (p.5; see also p.9; p.33 for example). While we are prepared to accept that epidemiological research may not be seen as a *scientific* priority, and may be of limited use in clarifying risks, there may nonetheless be other benefits of an epidemiological study (or other study of morbidity and mortality) of previous and current occupants of the building. Should there be any further fatalities from brain or pancreatic cancers, or even other deaths or serious illnesses among occupants of the building, there would be considerable concern among members of the University as

well as the wider public. Tracking the health of those who have used the building could be seen as an important part of the University's duty of care to its employees.

I have expanded the text to explain further why I do not think that an epidemiological study is warranted.

2. Professor Coggon has suggested that the emergence of any future cases of cancers would not alter his risk calculations, and the conclusions of 'chance coincidence' as the explanation for the cluster of cancers in the building. However, while recognising that it may never be possible to draw firm conclusions (given the statistical limitations imposed by the relatively small number of people who have worked in the building), we suggest that some indication needs to be given of approximately what number of additional cancer cases could occur and still reasonably be considered to lie within the realms of 'chance coincidence', i.e. without triggering the need for further risk evaluation – as this question would inevitably be asked, in the event that any further cancers cases emerge.

I do not think that a simple answer can be given to this question. It would depend not only on the number of additional cases, but also on exactly what they had in common (e.g. when and where they worked in the Rutherford Buildings, and what they did there). However, in light of the investigation that has been conducted, there is no indication that an exposure associated with work in the Rutherford Buildings has caused pancreatic cancer (or any other disease). Thus, there is no stronger scientific case for carrying out an epidemiological study of staff who have worked there than for any other department in the University.

3. The report suggests that the findings of an epidemiological study would be subject to 'substantial statistical uncertainty' (p.9). However we suggest that this is also the case for the findings of the risk assessment, given the necessary reliance at times on hypothetical estimates of spillages of radionuclides and mercury. For example, how would the risk estimation differ if, say 5-10% of radionuclides were spilled during the early years of the buildings use, rather than the 1% figure cited in the report?

The risk assessment does not rely on hypothetical estimates of spillages of radionuclides and mercury. Rather, it is based on exposures estimated from measured levels of contamination. Data on possible levels of spillage of radioactive substances have been used principally to check the plausibility of these exposure estimates (see above). There are other important sources of uncertainty, which are acknowledged, and have been taken into account in forming conclusions. Even if exposures to radiation were 10 times the maximum assumed, they would cause only a small increase in the risk of cancer, and would not account for the cases of pancreatic cancer that have been observed.

Section 6 Conclusions

Following an extensive discussion of the 'sources of uncertainty' in the estimations of risk, this section concludes that '…by far the most likely explanation for the cluster is that it has occurred by chance coincidence' (p.33). As the section notes in its first paragraph there are two main sources of uncertainty, one the limitations of scientific knowledge and secondly the lack of historical data (p.31). While appreciating the care which has been taken in the estimations, UMUCU would call for more precise wording in this case, for instance, the addition of a clause such as '*Given accepted current scientific knowledge, and the limitations of these estimations of risk, the current explanation* for the cluster is that it has occurred by chance coincidence.'

It goes without saying that any risk assessment will always be limited by current scientific knowledge. However, current scientific knowledge on the major health risks from ionising radiation, mercury and asbestos is pretty robust. Uncertainties in the assessment of past exposures are greater, but these have been taken into account in forming conclusions.

In summary, we support Professor Coggon's recommendations for further monitoring, but would wish for the further points raised here to be taken into consideration in the report. From the Union's point of view we would wish to be much more actively involved in Health and Safety issues in order to minimize the chances of a repeat incident, particularly in regard to the loss of key data.

UMUCU Executive

Unite the Union's response to Coggon report.

For our part we thought that the way in which Prof Coggon conducted himself and his report was above board and did not manipulate the facts and figures he had access to. However, it would be interesting to see the facts and figures that he did in fact collate and compile even if it was only to see how many of the workforce actually joined in.

The facts and figures that bear on the assessment of risk are all summarised in my report or in those of HPA and HSL.

His comparisons of radiological facts and figures and the HPA results of the radon and mercury readings taken now should be encouraging and reassuring to the present Rutherford workforce. The extrapolations used in an attempt to assuage the past Rutherford workforce does not appear to have gone very far, or to have been effective. His "magic coincidences" and "Texas sharpshooter" scenario's do little to calm the fear frustration and anger of those like Pat Ryan who have been categorically told that their exposures to radiation in the building renovation were causative to the cancer they suffered.

The aim of my report is to present my assessment of risks and uncertainties, based on the information that is available. It is for others to decide whether or not they accept my reasoning. I am unsure from where the term "magic coincidences" is quoted, but I do not think it comes from me.

The poor showing that the University gave in the record keeping, the communications between management and Unions and workforces is again another matter. The Rutherford discussion that began with the public disclosures were an exposé of miscommunication, poor communication, or outright ignorance on the part of management in relation to the attempt by the pancreatic cancer victims to obtain satisfaction to their condition.

The past performance of the University was not part of my remit.

The body of evidence provided was neither substantiated nor denied by the management and subsequently by Coggon's teams. There were large discrepancies in supposed reports on the "hot" conditions and mercury contaminations and remedial work carried out.

It is unclear to what discrepancies this refers.

We are quite satisfied that the chaotic collation of correspondence that made up the body of the report was made public to embarrass the University and identify its management's incompetence, and this was carried out quite effectively. However, we would also like to think that the management can take stock and learn from this and

progress with a transparent Health and Safety modus operandi, one in which the management and unions are working hand in hand to provide a clear and open account of the University Health and Safety policy and procedures, and especially record keeping.

Again, this goes beyond my remit, although I am unclear what "chaotic collation of correspondence" is thought to make up the body of my report.

Finally we would like to point out that just as this event was being drawn to a close the Health and Safety management employed a new officer within their ranks. The Health and Safety legislation clearly states that the TU Safety reps should be involved at the interviewing stages and this was not done. Was it that we were not supposed to be aware of this legislation or that the TU involvement, as the UCU suspect, is a lip-service?

Again, this matter is outside the scope of my remit.

For and on behalf of Unite the Union

Dave Jones,
Branch Secretary,
Unite the Union,
Manchester University.