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The Radioactive Remains of Pierre and Marie Curie¹

By Joel O. Lubenau and Jean-Luc Pasquier

March 1995, Paris

In March 1995, the office of the President of France announced that the mortal remains of Pierre and Marie Curie would be enshrined in the Palace du Pantheon. President François Mitterand stated that in addition to honouring the Curies, transferring their remains to the Pantheon affirmed a faith in science and respect for those who dedicate their lives to science much as Pierre and Marie Curie dedicated theirs. The ceremony would take place on 20 April 1995.

In fact, French scientists would do their part in making the ceremony possible, namely, by ensuring that all those involved in the transfer would not be endangered by residual radioactive material in the remains.

But, the story begins much earlier.

21 April 1906, Sceaux²

Pierre Curie died Thursday afternoon, 19 April 1906 when accidentally struck by a horse-drawn wagon on rue Dauphine in Paris.³ When he learned of son's death, his grief-stricken father asked, "What was he dreaming of this time?"

Marie Curie refused an autopsy of Pierre's body and asked the body be brought to their home. André Debienne, their laboratory collaborator, went the police station to claim the body. The ambulance carrying Pierre Curie's remains arrived in the evening and the body was placed in a ground floor room.

On Saturday morning, he was placed in a coffin. Later, Marie wrote in her mourning diary:

We kissed your cold face for the last time. Then a few periwinkles from the garden on the coffin and the little picture of me that you called "the good little student" that you loved....Your coffin was closed and I could see you no more....They came to get you, a sad company; I looked at them, and did not speak to them. We took you back to Sceaux, and we saw you go down into the big deep hole. Then the

¹ © Joel O. Lubenau, Lititz, PA, U.S. 28 May 2013

² Except as noted, the account of Pierre's death and burial is from "Marie Curie – A Biography by Eve Curie," translated by Vincent Sheean, Country Life Press, Garden City, NY 1937, pp. 246 - 251. See also: Susan Quinn, "Marie Curie, A Life," Simon & Shuster, NY, 1995, pp. 227-246.

³ Anon. "Prof. Curie Killed in a Paris Street," *The New York Times*, 20 April 1906.

dreadful procession of people. They wanted to take us away. Jacques⁴ and I resisted. We wanted to see everything to the end. They filled the grave and put sheaves of flowers on it. Everything is over. Pierre is sleeping his last sleep beneath the earth; it is the end of everything, everything, everything.

In the cemetery but out-of-sight were journalists. One wrote:

Mme. Curie, on her father-in-law's arm, followed her husband's coffin to the tomb hollowed out at the foot of the wall of the enclosure in the shadow of the chestnut trees. There she remained motionless for a moment, always with the same fixed, hard gaze; but when a sheaf of flowers was brought near the tomb, she seized it with a sudden movement and began to detach the flowers one by one to scatter them on the coffin.

She did this slowly, composedly, and seemed to have totally forgotten the audience, which, profoundly struck, made no noise, no murmur.

The master of ceremonies, nevertheless, thought he must ask Mme. Curie to receive the condolences of the persons present. Then, allowing the bouquet she held to fall to the earth, she left the tomb without saying a word and re-joined her father-in-law.

6 July 1934, Sceaux

On 5 July 1934, *The New York Times* reported the death of Marie Curie⁵ and the following day reported her body had been taken to Sceaux, near Paris, for burial and speculated the body would be cremated.⁶ However, the *Time's* report of the burial rites on the next day made no reference to cremation:

Mme. Marie Curie was buried today as she lived, in the utmost simplicity.

There was a brief ceremony without a civil or religious ritual. Her frail, wasted body, which she had devoted to science, was lowered in a plain oak coffin in the same grave with her husband in a crowded and inexpensive part of the little village cemetery.

Roses were distributed to each of the twenty-five laboratory associates and 150 friends and scientists who were there when an automobile hearse brought the coffin at 11:30 A.M. The mourners formed a line and each placed a rose on the closed coffin in walking by.

⁴ Pierre's brother.

⁵ Anon. "Mme. Curie is Dead; Martyr to Science," *The New York Times*, 5 July 1934.

⁶ Anon. "Mme. Curie's Body is Taken to Paris," *The New York Times*, 6 July 1934.

Mme. Curie's two daughters, heavily veiled and wearing black, and a son-in-law stood near by and received condolences. They shook hands with the other mourners as all passed by and out of the cemetery.

The flower ceremony was conducted without a word being spoken. But the human silence was broken by the constant singing of hundreds of birds perched in nearby trees and the intermittent drone of a buzz saw a few feet away on the other side of the wall.

Four of the family's graves are there now – Professor Pierre Curie, husband of Mme. Curie and co-discoverer with her of radium, who was killed when struck by a truck in 1906, and his father and mother. The graves are placed against a moss-covered stone wall, bordered by a row of beeches.

At the head of Prof. Curie's grave is a rambler rose bush planted twenty-eight years ago by Mme. Curie. It is now in gorgeous bloom for the first time since it was planted, villagers said.

Beside the coffin were laid wreaths from the French government, the President of Poland, the Polish Ambassador and probably all radium laboratories in the world, including those in the United States and Canada.

The coffin had a small plain silver plate bearing her name and the dates of her birth and death. Wreaths of roses were placed on top the coffin.

It was just ten minutes from the time the coffin arrived until all had gone.⁷

6 April 1995, A Simple Request and Complications⁸

When the decision was made to transfer the bodies from Sceaux to the Pantheon there was no reliable information about their radiological condition. Accordingly, on 6 April 1995, the official responsible for the transfer contacted the French radiation protection agency, l'Office de Protection

⁷ Anon. "Mme. Curie Buried With Simple Rites," *The New York Times*, 7 July 1934.

⁸ The account that follows is based upon a blog posted by Jean-Luc Pasquier on 28 December 2011 at <http://6bisruedemessine.wordpress.com/2011/12/28/marie-curie-une-physicienne-au-pantheon/> (accessed 10 March 2013) and translated, in part, by Laurent Kueny and, in part, by computer translation programs available on the web. Supplementary information provided by M. Pasquier via electronic correspondence has been incorporated into this account.

contre les Rayonnements ionisants (OPRI)⁹ expressing concern about residual radioactivity in the bodies that could be hazardous to workers at the cemetery. OPRI was informed that the French President's office directed that radiation measurements be taken during the exhumation and a radiation protection program provided for workers carrying out the exhumation. Others involved in the transfer should be advised of precautions that might be necessary.

OPRI assigned these tasks to Jean Blanc, head of the OPRI Division of Intervention, and Jean-Luc Pasquier, Scientific Director. Upon meeting with the head of the funeral they learned that the bodies were believed to be inside a vault under the planter bed in front of the tombstone, a circumstance, if true, that would simplify the proceedings (Figure 1).

On other fronts, however, matters quickly became complicated. OPRI learned that, in the meantime, the mayor of Sceaux requested the nearby nuclear research centre at Fontenay-aux-Roses to provide radiological controls, a development that would swell the number of personnel at the cemetery. Additionally, a representative of the Ministry of Culture advised M. Pasquier that no exhumation should be allowed and the Curie family did not wish photographs taken.

OPRI President Roland Masse and Fontenay-aux-Roses Director M. Debiar met to resolve these issues. A joint radiation protection protocol for the exhumation was agreed upon. It was also agreed that the exhumation would proceed despite the reluctance of the Ministry of Culture. The exhumation was scheduled for April 14th.



Fig 1: The Sceaux Cemetery plot for the Curie family. The vault lay under the planter bed. The marker in front was added after the remains of Pierre and Marie Curie were moved to the Pantheon.

⁹ In 2002, OPRI was replaced by Autorité de Sûreté Nucléaire (ASN) and the Institut de Radioprotection et de Sûreté Nucléaire (IRSN) (translator's note).

14 April 1995, Sceaux

At 7:15 am, Msrs. Blanc and Pasquier arrived at the cemetery and began taking background radiation measurements in and around the cemetery. Outside the cemetery dose rates were between 60 and 70 nGy/h. Inside the cemetery dose rates varied from 90 to 500 nGy/h and averaged about 200 nGy/h. M. Pasquier attributed the increased levels inside the cemetery to the presence of uranium in the many stone monuments and stone pavers.

A radon measurement at the cemetery entrance indicated a concentration of 13 Bq/m³, a value commonly found in football stadia in the Paris region.

After the arrival of OPRI President Masse and the police officer, exhumation began. The initial radiation level at the gravesite was 150 nGy/h.

After unsealing the tomb by tipping the tombstone upward slightly, a radiation level measurement and an air sample were made inside the vault. At 1.5 m depth, 100 nGy/h was measured. The radon level was 18 Bq/m³ a level that allowed workers to proceed to the next stage without having to wear respiratory protection.

After fully opening the vault, the stone slabs covering Marie Curie's wood coffin were removed. The radiation level outside the wood coffin was 170 nGy/h. The wood showed signs of decay but a metal plate identified the coffin's content. Upon opening the wooden coffin, workers found inside an intact lead coffin. Four workers lifted the lead coffin and placed it on a vinyl sheet. Inspection revealed that lead thickness to be about 2.5mm. The only damage was four small holes that were made to hook anchors for the lift. Inspection through the holes revealed a white wooden coffin inside. Radiation levels outside the lead coffin were about 90 nGy/h. There was no measurable alpha and beta contamination on the lead coffin exterior (<0.3Bq/cm² beta and < 0.1 Bq/cm² alpha). Samples of the air space inside the lead coffin indicated radon levels of 257 – 360 Bq/m³.

Funeral workers arrived bringing the coffins in which the Curies were to be taken to the Pantheon. These were configured to match the niches of the Pantheon. Upon examination, workers found that Marie Curie's lead coffin would not fit into the Pantheon coffin so it would be necessary to open the lead coffin and transfer her remains to the Pantheon coffin.

While they watched, funeral officials speculated that given the lead coffin was sealed opening it might yield surprises despite the 61 year interval after burial.

At 9 am, the lead coffin was opened. Inside was neither a skeleton nor dust. Marie Curie's body was well preserved. Her face was recognizable. Examination of her hands, said to bear scars from exposure to radiation,

revealed no marks. Stems and petals of roses that had been placed upon her body were still there, blackened but visible.

Alpha and beta survey meter measurements taken in close proximity to the body showed slight alpha and beta contamination about the bone masses of the feet, hips and skull, 0.2 Bq/cm² beta and 0.5 Bq/cm² alpha. Laboratory analyses by OPRI of fragments of the wood coffin disclosed less than detectable levels of Ra²²⁶ and Bi²¹⁴ (Figure 2).



Figure 2: Fragments of the wood coffin for Marie Curie and the results of the OPRI laboratory analyses.

At 9:15 am, her body was gently transferred to the Pantheon coffin. It was then closed with all present having paid their respects, not without emotion.

The exhumation of Pierre Curie followed. A copper plate on the decayed wooded coffin identified the occupant as Pierre Curie. However, only a few bones, humerus and fragments of tibia and pelvis, and dust remained. There was no sign of the skull that had been struck by the wagon wheel in the accident at rue Dauphine in Paris on 19 April 1906. The photograph of Marie Curie that she placed in the coffin could not be found. The gamma dose rate at the level of the remains was 240nGy/h, significantly higher than the surrounding background. Surface contamination was found on the bones and later estimated to reflect a Ra²²⁶ content of 287 Bq/kg. OPRI laboratory analyses of the fragments of the coffin disclosed contamination levels of 40 Bq/Kg Ra²²⁶ and 20 Bq/Kg of Bi²¹⁴ (Figure 3).



Fig 3: Fragments of the wood coffin for Pierre Curie and the results of the OPRI laboratory analyses.

At 9:30am, the mortal remains of Pierre Curie were placed into the Pantheon coffin.

At 9:45 am, an unmarked van carrying the funeral coffins, now covered by French flags, left the cemetery. The OPRI and Fontenay-aux-Roses teams then met to process their data and prepare a joint statement:

The exhumation of Pierre and Marie Curie was conducted Friday, 14 April 1995 and lasted 1 hour and 30 minutes. OPRI and Fontenay-aux-Roses scientists carried out radiological monitoring and controls during the exhumation. Dose rate measurements, air sampling, and analysis of the wood coffins did not show the presence of significant radioactivity. The results confirmed the absence of radiological risk for workers, public and environment. As might be expected, traces of radium-226 have been detected at the coffins of Pierre and Marie Curie, less than 0.5 Bq/cm² in a few points.

20 April 1995, Palace du Pantheon

On 20 April 1995, a French Tricolour banner was draped over the entrance to the Pantheon (Figure 4). A temporary stand was built at the entrance to accommodate the distinguished invited guests and speakers. In front the caskets of Pierre and Marie Curie rested on biers (Figure 5). At 5 pm, the formal ceremony began.¹⁰ After completion of the remarks marking the occasion, the great doors of the Pantheon were opened. French soldiers bearing the caskets on their shoulders solemnly carried them inside (Figure 6) immediately followed by the Curies' daughter Eve Curie Labouisse (90 years

¹⁰ A French television news report of the ceremony is available at <http://www.ina.fr/video/CAB95027036> (accessed 28 March 2013).

of age), French President François Mitterrand, and Polish President and Nobel Laureate Lech Walesa (Figure 7). The caskets were rested on biers under the dome until they were placed in the Pantheon niche.

Figure 4: The Pantheon decorated for the April 20, 1995 ceremony. The temporary stand in front provided seats for honoured guests and speakers.



Figure 5: During the ceremony the caskets of Pierre and Marie Curie rested on biers in front of the Pantheon.

Fig 6: The caskets of Pierre and Marie Curie being carried into the Pantheon.





Fig 7: Following the caskets were Eve Curie Labouisse, French President François Mitterrand, and Polish President Lech Walesa.

Discussion:

Were the Remains of the Curies Cremated?

The remains of the Curies were found in their graves in Sceaux in 1995 so they were not cremated after their deaths in 1906 and 1934. In 1995, after exhumation, they were placed in coffins specifically made fit the niches in the Pantheon. They were not cremated.

But, there is confusion in the English-speaking world on this point. The statement about cremation plans for the body of Marie Curie in the 6 July 1934 New York Times article (footnote 7) is an early source of the confusion. More confusion resulted from a 1995 account in a leading American newspaper that referred to the "ashes of Marie Curie" having been enshrined in the Pantheon.¹¹

In French, "les cendres" was used to describe the remains of the Curies. It translates to mean "ashes." In the American vernacular, "ashes" when applied to a person's remains is usually understood to mean the ashes from cremation. But, in French, "les cendres" when applied to a person's mortal remains means only the remains of the body with no implication that it had been cremated.

Were the Remains Radioactive?

In his 28 December 2011 blog on this matter, M. Pasquier, after considering the inherent uncertainties of the field measurements of the gamma and contamination levels, concluded it was not possible to come to a definitive answer *from the field measurements* regarding the residual contamination of Marie Curie. However, given her extensive early work with radium she must

¹¹ Anon. "Marie Curie Enshrined in Pantheon," *The New York Times*, 21 April 1995.

have been contaminated by it. In the early 2000s, M. Pasquier and a colleague, Jean Pierre Vidal, made radiation surveys of scientific equipment used by the Curies (Figure 8) that showed extensive radium contamination. Autoradiography of Marie Curie's laboratory notebook revealed clear evidence of contamination (Figure 9).

Why was there so little evidence of radium in her remains? M. Pasquier speculated that in her later years she was less exposed to radium in part due to improved protective measures in her laboratory, in part because of being diverted to other work, notably developing portable medical x-ray services for the military (the "petite Curies"), and in part because of biological elimination of the radium in her later life. The biological half-lives of radium are 900 days in the whole body and 5.5 years in the bone. Dr. Richard Toohey suggested an additional factor - in a menopausal woman, osteoporosis would have accelerated elimination of the radium from the bone.¹²



Fig 8: Laboratory instruments used by the Curies that are contaminated with radium.



Fig 9: An autoradiograph of a page of Marie Curie's laboratory notebook.

¹² Personal communication dated 30 March 2013.

The lead that contained Marie Curie's body coffin may have been used because of concern in 1934 about radium contamination of her body, but this point has not been verified.

In contrast to the findings for Marie Curie a definitive positive conclusion could be made regarding Pierre Curie's remains. Given his death in the traffic accident in 1906 there was no opportunity for elimination of the radium body burden in later life as was the case of Marie Curie.

He was, in fact, seriously contaminated with radium. His obituary in *The New York Times* stated:

The professor was frequently forced to delay his tests for three or four hours, by reason of the fact that he had been exposed to radium and that his clothes had become so radioactive as to prevent him from going near his instruments. The Curies' laboratory became so thoroughly impregnated with radium that they had to move into another place for their experiments. Both the professor and his wife recently became ill through the effects of radium.¹⁴

But, the possibility that this contamination could be hazardous to others was not recognized at the time and this would explain the absence of a lead coffin for him when buried in 1906.

In any event, the residual radioactivity of the Curies' remains was not a danger to the workers at the cemetery or to others involved in the transfer of the remains to their final resting place in the Palace du Pantheon.

Did Radium Cause Marie Curie's Fatal Illness?

Given the low levels of radioactivity in the remains of Marie Curie, M. Pasquier suggested that Marie Curie's fatal illness was less attributable to radium and

¹³ Personal communication dated 30 March 2013.

¹⁴ Anon. "Prof. Curie Killed in a Paris Street," *The New York Times*, 20 April 1906.

more to her work during World War I developing a program to provide the French military field medical X-ray services, the "petite Curies".

In 1921, Marie Curie herself blamed both for her inability to fulfil her travel commitments during her visit to America that year. During that visit she accepted a gift of a gram of radium from the Women of America and spent six and one-half week touring the country. Repeatedly, she was felled by fatigue and anaemia leading to curtailment and cancellations of scheduled events. At her final meeting with the press before returning to France she expressed regret that her illness had interfered with the schedule attributing it to her work with radium and work during the war:

*My work with radium, and especially during the war, has so damaged my health as to make it impossible for me to see many of the laboratories and colleges in which I have a genuine interest.*¹⁵

Dr. Pierre Radvanyi suggested a third source of radiation exposure of Marie Curie, namely, her extensive work with polonium, a notoriously dangerous material that contributed to the death of her daughter, Irene.¹⁶ Dr. Richard F. Mould noted Marie Curie spent 1903-1906 mainly studying polonium and from 1909-1911 spent additional time studying its properties along with those of radium.¹⁷

What caused the radiation damage to the health of Marie Curie? Probably three sources – her work with radium, her work with the "petites Curies" during World War I, and her work with polonium.

Conclusions

In 1906, when Pierre Curie was buried, there was no concern about possible hazards from radium contamination of his body even though it was known he and the Curie's laboratory were contaminated.

In 1934, when Marie Curie was buried, there may have been concern about radium contamination of her body; this has not been verified.

In 1995, when transfer of their remains to the Pantheon was announced there was concern about radium contamination of their remains.

French scientists responded and, while they determined the body of Pierre Curie was definitely contaminated and that of Marie Curie possibly

¹⁵ Anon., "Mme. Curie Finds America a Marvel." *The New York Times* 25 June 1921. See also Lubenau, J.O., "Tired, Tenacious, Triumphant: Marie Curie Visits the United States in 1921," *The Invisible Light* No. 36 (December 2012), ISSN 1479-6945 (print), ISSN 1470-6953 (online).

¹⁶ Personal communications 17 and 19 March 2013.

¹⁷ Mould, R.F., "Radium History Mosaic," *Nowotwory* v. 57, supplement 4, 2007, p. 42.

contaminated, they concluded the radium contamination of their remains did not constitute a risk to the workers, the public, and the environment.

In the 2000s, surveys by French scientists of the Curie's laboratory equipment and notebooks confirmed what was known in 1906 - their laboratories were contaminated.

The low level of radium found in Marie Curie's remains is explained by normal biological elimination of radium from her body after her exposure to radium had lessened, a process that may have been accelerated by osteoporosis in her post-menopausal years.

Marie Curie was aware of the likely connection between her work with radium and X-rays and her chronic fatigue and anaemia. But, her work with polonium may have constituted a third source of damaging radiation exposure.

Figure Credits

Jean-Luc Pasquier Figures 1, 2, 3, 4, 8, 9, 11

Richard F. Mould Figures 5, 6, 7

Joel O. Lubenau Figure 10

Afterword by Joel O. Lubenau

On 9 November 2012, the Delaware Valley Society for Radiation Safety sponsored a symposium, "Marie Curie, Radium, and Women in Science," hosted by the College of Physicians of Philadelphia Mutter Museum.¹⁸ An added attraction was the display of a special traveling exhibit about the life of Marie Curie sponsored by the Embassy of the Republic of Poland (Figure 10). A discussion of the transfer of the Curies' "ashes" to the Pantheon in 1995 led to a query, were their remains radioactive?

It is an obvious question to ask but the answer initially proved elusive. It was found in M. Jean-Luc Pasquier's blog of his recollections of the events of April 1995 (see footnote 8). M. Laurent Kueny, French Counsellor for Nuclear Safety, Permanent Mission of France to the United Nations and International Organizations in Vienna, brought M. Pasquier's blog to my attention, translated those portions of the blog dealing with the radiological aspects, and provided contact information.

¹⁸ Lubenau, J. O., Allard, D. J., "Mütter Museum Hosts DVRSRS Symposium," *Health Physics News* 41:1 (January 2013)

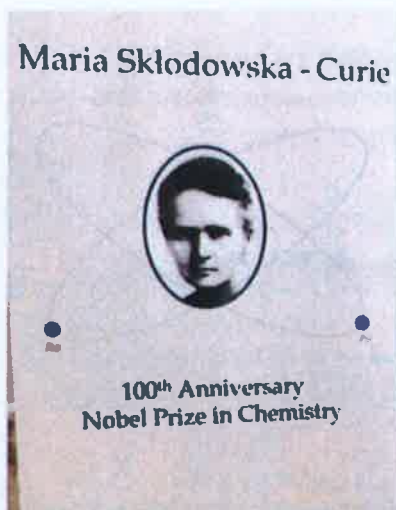


Fig 10: The introductory panel of a traveling exhibit celebrating the 100th anniversary of Marie Curie receiving the Nobel Prize in Chemistry. It was brought to the United States with the support of the Embassy of the Republic of Poland and from November 2012 to January 2013 was displayed at the College of Physicians of Philadelphia Mutter Museum.



Fig 11: A blossom of the Marie Curie rose in M. Jean-Luc Pasquier's garden.

Dr. Pierre Radvanyi, Emeritus Director of Research, Institut de physique nucléaire, Orsay offered insightful comments on the multiple sources of radiation exposure of Marie Curie.

Dr. Richard Toohey, Consulting Health Physicist, M. H. Chew & Associates, provided technical comments on the radiobiological aspects of internal exposures to radium and polonium.

Dr. Richard F. Mould, medical radiological physicist and historian, made available photographs from his collection and provided comments on this paper.

To all, merci beaucoup!

Lastly, the digital archive of *The New York Times* provided contemporary accounts of the events in this story that added historical perspectives. The *Times*' archive is a valued collection of the "first drafts of history."

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**"The past is always there, it never goes away,
but you can select what is best from the
past to help you to go forward to the future."**

Aung San Suu Kyi, Oxford 2012.