The Invisible Light

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Contents

Editorial

I hope you like this issue of The Invisible Light. There is an article by Dick Mould about Chernobyl and about Marie Curie in the USA by Joel Lubenau. To accompany these papers I have a note about the horror film Chernobyl diaries and a stunning painting of Marie Curie by Josef Hilpert.

There are several recent interesting articles on Aunt Minnie Europe.
Radiology's graveyard: Extinct exams you may not know about. (July 23, 2012)
http://www.auntminnieeurope.com/index.aspx?sec=sup&sub=wom&pag=dis&ItemID=606903
Teleradiology flourishes from humble beginnings. (23 September 2012)
http://www.auntminnieeurope.com/index.aspx?sec=sup&sub=ris&pag=dis&ItemID=607145
Why jokes still have a place in medical imaging. (5 November 2012)
http://www.auntminnieeurope.com/index.aspx?sec=sup&sub=xra&pag=dis&ItemID=607289

This year we celebrate 40 years of the CT scanner. This was the theme of the BIR Presidents Conference for 2012. Below are the links to the talks that Liz Beckmann and myself gave.
Adrian Thomas - CT - A Historical Perspective: http://www.youtube.com/watch?v=-b4uRgUhR4E&feature=relmfu
Liz Beckmann - A Tribute to Godfrey Hounsfield. http://www.youtube.com/watch?v=WW4X-Jn-yWI&feature=relmfu

The International Society for the History of Radiology will be meeting in ECR in Vienna next year. I am delighted to announce that our Annual Lecture is to be given by Dr Stephen Golding from the University of Oxford. Do come along and join us for the session, which will be on the Saturday afternoon. ISHRAD has a Facebook page!

There are details in this journal of our Annual Lecture, which is to be given by Wade Allison. Wade is a great speaker so do come an=d listen. Finally we have the Congress of the British Society for the History of Medicine next year. I will be the President and a strong theme will be the history of technology. Do consider presenting a paper on the history of radiology. The meeting is in a stunning location at Canterbury Lodge in the Grounds of Canterbury Cathedral!

Best wishes
Adrian

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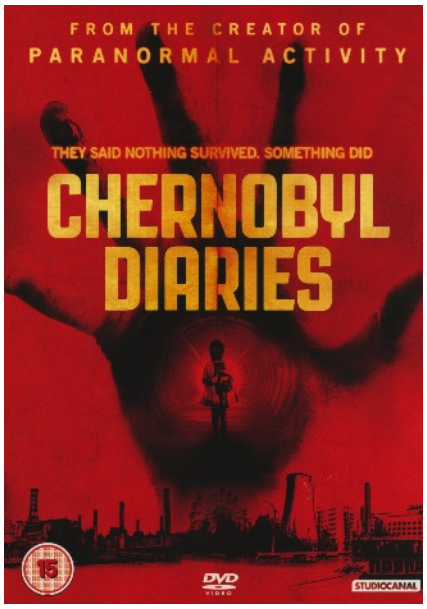
Chernobyl Diaries [DVD]



This is a strange film about Chernobyl. It stars Jesse McCartney (Actor), Jonathan Sadowski (Actor), and Bradley Parker (Director) | It is rated as suitable for 15 years and over. The film is the creator of the film Paranormal Activity, and is described as 'a terrifying new thriller set on the site of the world's most horrific nuclear disaster.'

The film Chernobyl Diaries follows a group of six young American vacationers in Europe who, looking to go off the beaten path, hire an 'extreme tour guide.' Ignoring warnings, the takes them into the city of Pripyat, which is the former home to the workers of the Chernobyl nuclear reactor, but is now a deserted town since the disaster, now more than 25 years ago. After a brief exploration of the abandoned city, however, the group soon finds themselves stranded, only to discover that they are not alone……..

So what's not to like? We have mutant zombies in a deserted town. I'm not quite sure that this is a film that Dick Mould would approve of, and Dick does not mention it in his article. It is certainly not a film that gives a balanced view of the use of radiation, and as such it promotes an irrational fear of radiation.

Trips to Chernobyl may be made in reality and there are many guides. An example is:

Pripyat - Chernobyl Tour: http://www.ukrainianweb.com/chernobyl_ukraine.htm

They say that: 'According to the current requirements of the Ministry of Emergency Situations of Ukraine, the exclusive operator of the Chernobyl tours, a formal application (booking request) has to be submitted in advance. The Chernobyl tour is a strictly regulated operation. A fairly limited number of individuals can visit Chernobyl and Pripyat on a given day. Make sure to plan/book your trip well in advance and contact us at least 10 days prior to the date of your tour.'

The tour includes:

- Duration of the Chernobyl and Pripyat tour: 1 day - leaving Kyiv at 9:00 in the morning and returning from the trip to Kyiv at 6:00 in the evening. (Optional: visiting the Chornobyl Museum in Kiev the day before the tour.)
- Arrival at the town of Chernobyl. Meeting with the authorities of "Chernobyl Interinform" agency
- Transfer to the Chernobyl Nuclear Power Station and sightseeing of Reactor 4.
- Visit to Pripyat (Prypiat), a highlight of your trip.
- Sightseeing of "The Dead (Ghost) Town" - swimming pool area, Ferris wheel, riverboat, abandoned buildings.
- Visit to the Chernobyl Scientific Center: physical and radiochemical laboratories, other.

Being attacked by mutant zombies is not mentioned in the itinerary, which is a little disappointing.

Nikola Tesla http://theoatmeal.com/comics/tesla

This is a curious web page about Nikola Tesla. I suppose that 'geeks' are now fashionable and Tesla seems the inspire his supporters in a way not done by either Röntgen or Becquerel. This web page sees Tesla as the greatest geek who ever lived and is quite interesting. It states that Wilhelm Röntgen is typically credited as the discoverer of X-rays. We are asked "Can you guess the mustache-donning inventor who beat him to it and got basically zero credit? So we are told it's Nikola *Goddamn* Tesla. I am not quite sure what his moustache has to do with it. Personally I believe that X-rays were discovered by Wilhelm Goddamn Röntgen with his beard. I supposed it's the beard that made the difference!

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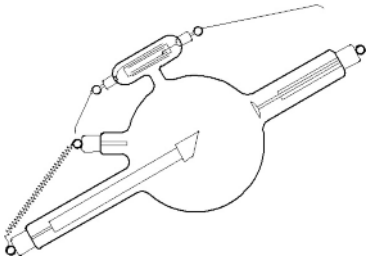

ANNUAL LECTURE

OPEN TO ALL

"Radiological Protection:

The perspectives of Adam Smith, Charles Darwin & Florence Nightingale"

Speaker: Professor Wade Allison, MA DPhil

Emeritus Fellow, Keble College, Oxford

The Robens Suite, 29th Floor, Tower Wing

Guy's Hospital, London, SE1 9RT

25th February 2013

Light refreshments from 6pm. Annual General Meeting (BSHR members only) 6.30pm

Lecture 7pm

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Dr Arpan K Banerjee

Consultant Radiologist

by email

arpan.banerjee@heartofengland.nhs.uk

NO LATER THAN FEBRUARY 18, 2013

Tickets are free of charge.

A retiring collection will be taken with a suggested donation of £5 – £10

Chernobyl bibliography of books & reports 1986-2011
and follow-up on thyroid cancer & leukaemia

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Abstract

This article updates an earlier review [1] which was published in 1999. The bibliography of selected books and reports in the Chernobyl literature, which is not directly available on the Internet, is referenced in chronological order and will provide a useful source on how the post-accident knowledge has progressed in the 25 years after April 1986. The causes of the accident are summarised as is the survival of the 203 persons who suffered acute radiation syndrome (ARS) at the time of the accident and bone marrow transplant results. Selected recent journal papers on thyroid cancer, leukaemia and retrospective dosimetry techniques are also included.

Key words: Chernobyl, thyroid cancer, leukaemia, nuclear power plants, retrospective radiation dosimetry, acute radiation syndrome, bone marrow transplant

Figure 1. The Chernobyl nuclear plant photographed in May 1986. (Courtesy: TASS)

Introduction

It will become clear from this bibliography that as time has passed the publication of entire books and of lengthy reports by organisations such as the IAEA and WHO have virtually ceased, with all that remains being epidemiological, clinical and environmental research papers. Anniversaries, such as the 25th in 2011, show an increase in articles, with a few entire issues of journals devoted to Chernobyl. This bibliography can therefore be considered to probably represent the best overview reference sources on the catastrophe which have been published over a quarter of a century since 26 April 1986.

Causes of the accident 1986.

The accident (**Figure 1**) occurred during a planned test procedure which involved shutting down the turbine generator of nuclear power plant (NPP) number 4 for the purpose of studying the efficiency of inertia rotation. That is, to test the ability of the turbine generator to power certain of the cooling pumps whilst the generator was freewheeling to a standstill after its steam supply had been cut off. This would determine whether the power requirement of NPP4 could be sustained for a short time during a power failure. The actions for the experiment began at *0100* hours on 25 April 1986.

Several major faults occurred within the procedure, which if they had been properly noted, the test could have been aborted. For example at *0028* hours on 26 April when proceeding to lower power (the test was planned to be performed at between 700 MW and 1000 MW thermal power) the set of control rods used to control reactor power at high powers, and called local automatic control rods (LACs), were switched out and a set of control rods called the automatic control rods (ACs) were switched in. However, (a major fault) the operators failed to reset the set point for the ACs and because of this were unable to prevent the reactor's thermal power falling to 30 MW. The operators by *0100* hours had managed to obtain stability but only at 200 MW thermal power which was well below the required power level and so the experiment should have been stopped: but it was not. Indeed this 200 MW power level was only achieved by removing control rods from the core of the reactor. At this time, due to the low power of 200 MW and the very high (115%-120% of normal) coolant flow rate through the core due to all eight pumps functioning some pumps were operating beyond their permitted regimes (another major fault). Then by *0119* hours the water in the coolant circuit was now nearly at boiling point.

At *0122.30* hours a most serious fault occurred when a printout of the reactor system parameters showed that there were then only six, seven or eight control rods in the reactor core: representing less than half the design safety minimum of 15, and less than one-quarter the minimum number of 30 control rods given in the operator's manual.

Then at *0123.04* hours the critical major fault occurred. The automatic safety protection system which trips the reactor when both turbine generators are tripped was deliberately disengaged by the operators: although this instruction was not included in the experimental schedule.

What then followed was that the reactor power began to rise slowly from 200 MW; the ACs are withdrawn; the main coolant flow and feed water flow are recued causing an increase in the temperature of the water entering the reactor; a reactor power steep rise (a *prompt critical excursion*) was experienced and the NPP4 shift foreman ordered a full emergency shutdown .... but it was too late. *0123.46* saw the onset of nuclear fuel channel rupture and at *0123.48* a thermal explosion occurred, followed at *0123.48* by a hydrogen explosion. Burning debris and sparks shot into the air above the reactor, and some of this fell onto the roof of the machine hall and adjacent buildings and started a fire: which kept burning for two weeks.

Acute radiation syndrome 1986

A major problem with estimating doses received by persons irradiated from the Chernobyl accident is of course the fact that they must by *retrospective*. This problem began with the initial population of nuclear power plant (NPP) workers and liquidators who experienced acute radiation syndrome (ARS), **Table I**, and work on this topic continues to this day.

Table I. The 203 cases originally diagnosed with ARS.

Degree of ARS	Dose range (Gy)	No. of patients hospitalised Kiev	Moscow	No. of deaths	Survival time (days)
4th	6-16	2	20	20	10, 14, 14, 14, 15, 17, 17, 18, 18, 18, 20, 21, 23, 24, 24, 25, 30, 48, 86, 91
3rd	4-6	2	21	7	16, 18, 21, 23, 32, 34, 48
2nd	2-4 10 43 1 96				
1st	1-2	74	31	0	

Bone marrow transplantation 1989

The most recent detailed report on bone marrow transplant results for Chernobyl victims is now several years old, and is found in a 1989 paper by Alexander Baronov, Robert Gale and co-authors published in the *New England Journal of Medicine* [2]. Bone marrow transplants for 13 recipients are reported. Dose estimates based

on neutrophil kinetics were in the range 4.4-9.5 Gy (median 8.1), those based on lymphocyte kinetics 4.7-13.4 Gy (median 7), and those based on analyses of dicentric chromosomes 4.4-11.9 Gy (median 8.3).

Bibliography of books & reports 1986-2011

These selected references are mainly books and reports but also include a few papers and presentations. It should be noted that reports from various organisations, including the International Atomic Energy Agency (IAEA) are now published only on the Internet. This publication policy is for reasons of economy and for example, the last printed paper publication by the IAEA on Chernobyl was in 2005 [3]. The most recent IAEA references [4-6] includes a series of stories, photographs and videos that depict the current environmental, social and technical aspects of the affected regions of Belarus and Ukraine [6]. The World Health Organisation (WHO) also communicates via the internet [7].

It is noted that most books and reports were published within the first 2-3 years (**Figure 2**) following the accident and for the 10^{th} and 15^{th} and 20^{th} anniversaries. The selected references include some newspaper colour sections and some magazines which have published good quality photographs relating to the accident and its effects. This selected bibliography for 1986-2011 listing titles and authors is given below in chronological order [8-48], with the full references details at the end of this paper.

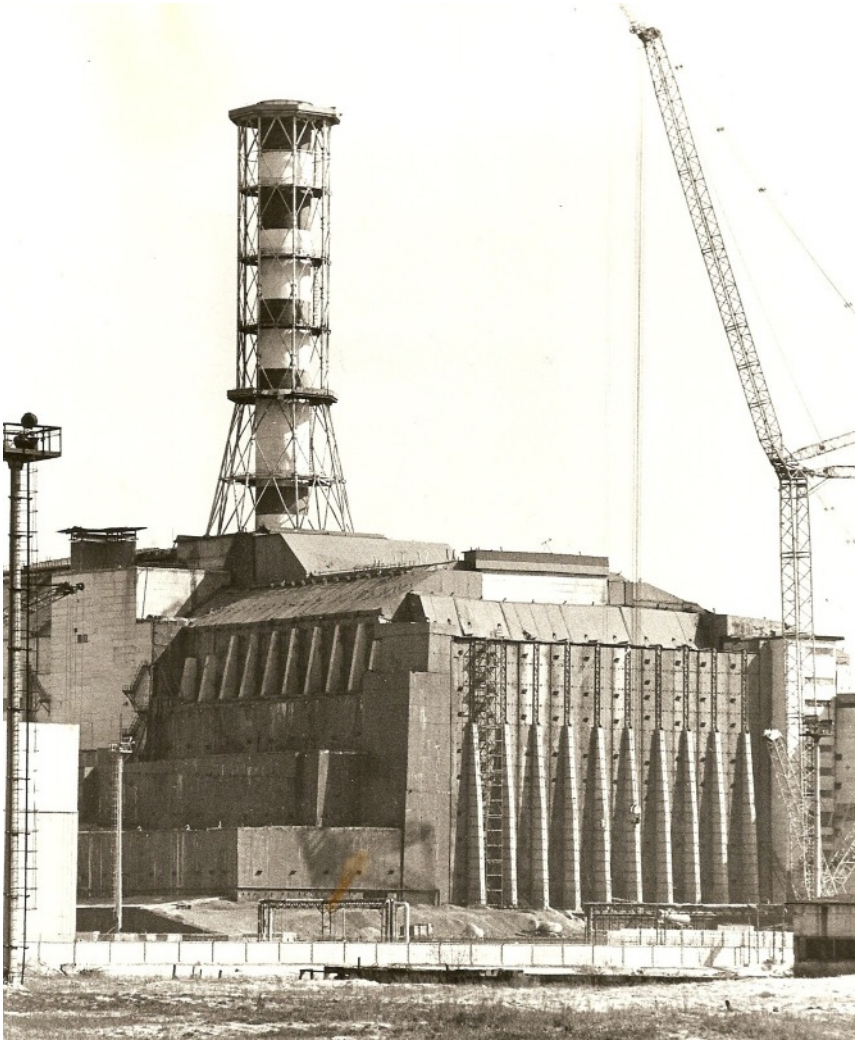

Figure 2. The Sarcophagus. May 1989. (Courtesy: TASS)

1986
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1988
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1991
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1992
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■ Ukraine MinChernobyl, Academy of Sciences of Ukraine. *Description of the Ukritiye Encasement and Requirements for its Conversion*. [20]

1993
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1994
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1995
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1997

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2000

■ Mould RF. *Chernobyl Record*. [40]
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2001

■ Clark S, Moreau J-L. To them, it's just another day at the plant. To us it's risking their lives cleaning up Chernobyl. *Sunday Times Magazine.* [42]

2005

■ Chernobyl Forum. *Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine*. IAEA. [3]

2006

■ Alexievich S. *Voices from Chernobyl*. *The Oral History of a Nuclear Disaster*. [43] ■ Stone R, Ludwig G. Inside Chernobyl. *National Geographic*. [44]

2011

■ Dubrova Yuri E. Germline mutation after Chernobyl – what is known and what is not. *Presentation at British Institute of Radiology meeting 12 December 2011*: Chernobyl 25 years on: consequences, actions and thoughts for the future. [45]
■ Likhtarov I, Kovgan L, Chepurny M et al. Estimation of the thyroid doses for Ukranian children exposed in utero after the Chernobyl accident. *Health Physics*. [46]
■ Rothkamm Kai. Biomarkers for radiation exposure and effect. *Presentation at British Institute of Radiology meeting 12 December 2011*: Chernobyl 25 years on: consequences, actions and thoughts for the future. [47]
■Thomas GA, ed. The Radiobiological Consequences of the Chernobyl Accident 25 Years On: April 2011. *Clinical Oncology*. [48]

Retrospective dosimetry 2011

An excellent review of retrospective dosimetry techniques written by co-authors from many countries {United Kingdom, Ukraine, Spain, Italy, Netherlands, France, Turkey, Norway, Germany, Finland, Portugal, Serbia and Belgium}, with a bibliography of 129 references, was published in 2011 of retrospective dosimetry techniques for external ionising radiation exposures [49]. The methods reviewed are listed in **Table II**.

Table II. Techniques for retrospective dosimetry. [49]

Cytogenetic techniques
Dicentric chromosome assay Premature chromosome condensation
Micronucleus assay
Fluoroescence in situ hybridisation (FISH)
Genetic techniques
Somatic mutations glycophorin A/hypoxanthine-guanine-phosphoribosyl transferase
Gene expression assays
Haematological techniques
Protein biomarkers
!-H2AX
C-reactive protein
Serum amylase
Physical techniques
Electron paramagnetic resonance (EPR) dosimetry
Luminescence dosimetry
Activation techniques
Computational techniques
Analytical dose reconstruction ('time & motion' calculations)
Dose reconstruction by numerical approaches

Thyroid cancer 1986-2011

One of the most dramatic sets of statistics are for thyroid cancer for Belorussian children 0-14 years old before and after the accident, **Table III**. These were obtained from the Minsk Cancer Registry and I am most grateful to Professor A.G. Mrochek of Minsk for this data. In addition, it is important to record that I personally visited the Minsk Cancer Registry and found that the records had for many years prior to 1986 been carefully recorded in large books (this was not a computerised registry) and can be considered to be accurate. The figures in **Table III** speak for themselves and need no tests for statistical significance [40, 50]! The data covers the entire country of Belarus. Chernobyl, which is in the Ukraine, is adjacent to the border with Gomel oblast. The furthest oblast from Chernobyl is Vitebsk. Even if there was wider diagnostic screening coverage in Belorussia after 1986 this would still not account for the very large differences in **Table III**. The radioactive cloud from Chernobyl passed over Gomel when it was raining and this led to the deposition of high levels of ^{131}Iodine.

Table III. Number of thyroid cancers in Belorussian children 0-14 years old: data for before and after the accident. [40, 50]

Oblast	Number of thyroid cancers		
	1974-85	1986-97	
Gomel	1	305	
Brest	2	135	
Minsk	2	65	Mogilev
	0	30	Grodno
	3	32	Vitebsk
	0	7	
All Belarus	8	574	

In a much later publication, the May 2011 special issue of *Clinical Oncology* [48] which is devoted to the radiobiological consequences of the Chernobyl accident and contains nine overview papers of which 6/9 specifically include the words 'thyroid cancer ' their titles, [51-56]. These overviews contain information on the Chernobyl Tissue Bank, thyroid cancer pathology, gene expression profiles, DNA copy number alterations and on both adult and paediatric thyroid cancers.

The June 2011 issue of *Health Physics* includes information on paediatric thyroid cancer [47]: with an estimation of thyroid doses for children exposed *in utero* after the Chernobyl accident. The October 2011 issue

of this journal [57] is a special issue devoted to radioecology relevant to the Chernobyl accident where radioecology is defined as 'the study of the fate, transport, and potential effects of radionuclides and associated contaminants in the environment'; and that 'in short, it is the science that describes the fundamental connection between environmental health and human health risks'.

The 2011 paper by Zablotska et al from USA and Belarus [58] published results of a study of thyroid cancer risk in Belarus among children and adolescents exposed during the Chernobyl accident. They concluded that '10-15 years after the Chernobyl accident, thyroid cancer risk was significantly increased among individuals exposed to fallout as children or adolescents, but the risk appeared to be lower than in other Chernobyl studies and studies of childhood external irradiation'.

In 2009 in a clinical study performed 1998-2000, published [59] by authors from Germany, Ukraine and the Netherlands on thyroid examination in 99 highly radiation-exposed Chernobyl workers the following was concluded. 'The Chernobyl accident showed surprisingly little impact on the thyroid in the cohort studied. The data suggested an age-dependent heterogeneity in response to short-lived radioisotopes and favours long- term follow-up analysis.' However, the study, although interesting, did not have any control group and the figure of 99 is relatively small. Such problems are also encountered with some other studies.

Leukaemia assessment 2007 & 2008

The induction period for leukaemia (the maximum health effects occur during the first 12 years after exposure) is longer than for thyroid cancer, as seen in data for the Hiroshima and Nagasaki atomic bomb survivors but although adequate time has elapsed since 1986, positive proof of Chernobyl-induced leukaemia cases has not yet been found. For example, Kesminiene & Cardis from the Centre International de Recherche sur le Cancer (IARC) in Lyon, writing in 2007 [60] conclude that 'It is premature to draw conclusions on the risks of cancers other than that of thyroid'. The International Consortium for Research on the Health Effects of Radiation also concludes, 2006 [61] that for children in Belarus, Russia and Ukraine there is 'no convincing evidence of an increased risk of leukaemia as a result of exposure to Chernobyl radiation'. Although they also state that 'the lack of significant dose-responses in Belarus and Russia also cannot convincingly rule out the possibility of an increase in leukaemia risk at low dose levels'.

The Ukranian-American case-control study of leukaemia and related disorders among Chernobyl clean-up workers from the Ukraine, published in 2008 [62] 'found a significant linear dose-response between Chernobyl-related radiation exposure among Ukranian clean-up worker and the risk of leukaemia'.

Viktor Ivanov of the Medical Research Center of the Russian Academy of Medical Sciences (MRRC RAMS) in Obninsk, writing in 2007 [63] which is some 20 years after the accident, concludes the following. 'It is too early to draw definitive conclusions about all health effects of the accident on the emergency workers.' He emphasises that there have only been a limited number of papers published which deal with radiation risks among the liquidators. [64-67]. Thus unlike some early opinions which appeared in newspapers predicting the future, no significant increases in leukaemia incidence have actually been observed amongst liquidators.

US$ 2.5 million Chernobyl project 2009-2012

This US$ 2.5 million project was launched on 24 April 2009 [7, 68], the 23rd anniversary of the accident. This is a three-year initiative which aims to translate the latest scientific information on the consequences of the accident into sound practical advice for residents of the affected territories. It is a joint effort by IAEA, UNDP, UNICEF and WHO. It is supported by a 2007 UN General Assembly resolution and the project, known as the *International Chernobyl Research & Information Network* (ICRIN), is part of a larger effort to help local communities 'return to normal' in the course of the decade that ends in 2016.

UNSCEAR report February 2011

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) released a 173-page report on 28 February 2011, which is the third UNSCEAR report to study the accident [69]. It is in the form of a scientific annex to the second volume of supporting evidence underpinning UNSCEAR's 2008 report to the UN General Assembly. They report that despite new research data becoming available, the major conclusions regarding the scale and nature of the health consequences of the accident are 'essentially consistent with previous assessments'. It was also reported that dose estimates have been extended to over 500,000 workers involved in the recovery after the accident, from 380,000. Also, that the estimation of thyroid doses has been expanded to include 100 million people in Belarus, the Russian Federation and Ukraine, from five million. **Table IV** lists some of the report's major findings.

Table IV. Major findings in the UNSCEAR report of 2011. [69]

[■] 134 plant staff and emergency workers suffered acute radiation syndrome (ARS) from high doses of radiation.
[■] In the first few months 28 of the 134 died.
[■] Although another 19 ARS survivors had died by 2006, those deaths had different causes not usually associated with radiation exposure.
[■] Skin injuries and radiation-related cataracts were among the most common consequences in ARS survivors.
[■] Although several 100,000 people, as well as emergency workers, were involved in recovery operations, there is no consistent evidence of health effects that can be attributed to radiation exposure, apart from indications of increased incidence of leukaemia and of cataracts among those who received higher doses.

All the ARS survivors are under clinical surveillance at hospitals in Moscow or Kiev. Most suffered functional sexual disorders up to 1996; however, 14 normal children were born to survivor families within the first five years of the accident.

Regarding the general public in the three most affected countries, the only evidence of health effects due to radiation is an increase in thyroid cancer among people exposed as children or adolescents in 1986. There were more than 6,000 cases reported 1991-2005 in Belarus, Ukraine and the four most affected regions of the Russian Federation. By 2005 a total of 15 cases had proved fatal. UNSCEAR stated that a 'substantial portion' of the cases could be attributed to drinking milk in 1986 contaminated with short-lived ^{131}Iodine from the accident.

UNSCEAR also reported that it is not possible to state scientifically that radiation caused a particular cancer in an individual. 'This means that in terms of specific individuals, it is impossible to determine whether their cancers are due to effects of radiation or to other causes, or moreover, whether they are due to the accident or to background radiation' [69].

Morbidity & mortality statistics, IAEA Director-General April 2011

Obtaining accurate statistics in the early years post-accident was extremely difficult for those affected by the Chernobyl accident. For example, at the time of the accident, there was no collaboration (except between attendees at international conferences .... this was noted personally) between the three countries Ukraine, Belarus and Russia. Although the first two of these countries often published results in the same publication, Russia always seemed to publish separately. There was also no joint population registry for the three countries but such a problem tended to be ignored! The statistics produced can therefore be considered to be best estimates but if political will had been present in 1986 and thereafter in the 1980s and 1990s much better statistics for the understanding of the effects of the catastrophe would have been possible. The statistics in **Table V** are from 20 April 2011 when the IAEA Director General Yukiya Amano together with the UN Secretary General visited the Chernobyl NPP on the occasion of an *International Conference on Chernobyl: 25 Years On –Safety for the Future* [4].

Table V. Mortality, morbidity and environmental statistics. [4]

[■] Deaths from radiation sickness of around 50 people engaged in the immediate emergency and recovery operations, {i.e., the so-called 'liquidators'}.
[■] Some 600,000 people were affected by high radiation doses of whom around 4,000 may die prematurely as a result of their exposure.
[■] More than 100,000 people were evacuated from their homes immediately after the accident and the total number of evacuees from severely contaminated areas eventually reached 350,000.
[■] Since 1986 radiation levels in the environment have fallen by a factor of several hundred, due to natural processes and countermeasures. Most of the land contaminated with radionuclides has been made safe and returned to economic activity.

Chernobyl tourism 2012

As a concluding comment it was interesting to see a United Kingdom newspaper report of 18 June 2012 which indicates most clearly how access to Chernobyl has changed from the early post-1986 years. Under the heading

Tourist trade cashes in on disaster as England fans flock to Chernobyl in the Sport Section of the newspaper covering the European Football Championships of 2012 in Poland & Ukraine, the following is to be found. 'For around £100, tourists can visit the power station itself, the abandoned town of Pripyat and the Red Forest where radiation levels became so high that the trees died.' However, the Sarcophagus is only viewed from the outside and tourists are not permitted to enter this structure.

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Submitted: 19 August 2012

Tired, Tenacious, Triumphant: Marie Curie Visits the United States in 1921.

Joel O. Lubenau[v]

The primary purpose of Marie Curie's visit to the United States in 1921 was to accept a gift of a gram of radium. The trip also provided an opportunity for her to visit American academic, medical and government institutions, the plants of the company that produced the radium, and some of the scenic sights of the country. A copy of her itinerary, its rarity and significance only recently recognized, sets out a tight, exhausting schedule that called for 30 stops in towns and cities across the United States in 46 days. Contemporary newspapers closely followed Curie's travel reporting her frequent bouts of exhaustion and reported medical details that were provided by the physician that accompanied her. At one point, there was consideration of terminating her trip ahead of schedule. The newspaper accounts show that, to accommodate Curie's frail health, numerous changes in the itinerary were made, some events were cancelled, and, in other instances, her daughters stood in for her while she convalesced. Despite these difficulties, Marie Curie persevered, accomplished the main objectives of her trip, and returned to France enriched by the experience and financially rewarded as well.

Key Words: Marie Curie, Warren G. Harding, Marie Mattingly Meloney Brown, radium, carnotite, Standard Chemical Company, American radium industry

Introduction

In May 1921, Marie Curie journeyed to the United States to accept a gift of a gram of radium from the women of America. President Harding presented a Certificate of Gift to her at the White House. Accompanied by her daughters, Irene and Eve, her stay in the US lasted six and one-half weeks during which she was the recipient of many honours and visited numerous academic, medical, commercial, and government institutions.

The primary purpose of the trip was to accept the gift of radium. But, her itinerary was expanded to permit American institutions to recognize her scientific accomplishments and to enable Marie Curie to gain insights into and encourage American college education of women, to see first hand the production facilities of the American company that had produced over half of the world's supply of radium, and gain an appreciation of the vastness and variety of the American landscape.

To do this required an itinerary that was tightly scheduled and exhausting. Contemporary newspaper accounts of her trip reveal that the demands of her itinerary schedule coupled with her fragile health resulted in frequent curtailments and cancellations of scheduled events and her journey almost ended at the one-third point because of extreme exhaustion. That she was able to complete the tour in spite of her frailty is testimony to her powers of recovery, her tenacity, and the care and attention of the individuals that accompanied her, especially her daughters. Table 1 lists the planned stops during her visit.

The Genesis

The beginning of the story of Curie's visit is well documented by her own account and the biographies by her daughter, Eve, and Susan Quinn [1-3]: Marie ("Missy") Mattingly Meloney Brown, journalist and editor of the women's magazine, *The Delineator,* had repeatedly requested an interview of Marie Curie. Mme. Curie's acquiescence led to the initiation of an astonishing sequence of events orchestrated by Mrs. Meloney Brown culminating in the raising – in the name of American women - $100,000 to purchase a gram of radium for Mme. Curie to further her research. The White House offered to host a ceremony in which President Harding would present the gift to Mme. Curie. After much persuasion, she agreed to this and to a trip itinerary that was expanded to six and one-half weeks, not counting trans-Atlantic travel time. She asked that her itinerary include visits to the Niagara Falls, New York, the Grand Canyon, Arizona, and the plants in western Pennsylvania of the

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company that produced the gram of radium, the Standard Chemical Company. The company had produced 72 grams of radium, approximately half of the world's radium at that time [4]. Accompanying Mme. Curie were her daughters, Irene and Eve, Mrs. Meloney Brown, and a New York City physician, Edward H. Rogers.[1]

Curie departed Le Havre France on the morning of May 4, 1921 on the White Star liner, *Olympic*, a sister ship of the *Titanic* (Figure 1), and arrived in New York City on Wednesday afternoon, May 11th [5,6]. But, she had been 'frightfully seasick' the whole voyage and had to lie in her cabin for two hours after docking before she felt well enough to meet the press and face a battery of photographers and movie news cameramen. It was a foreboding start.

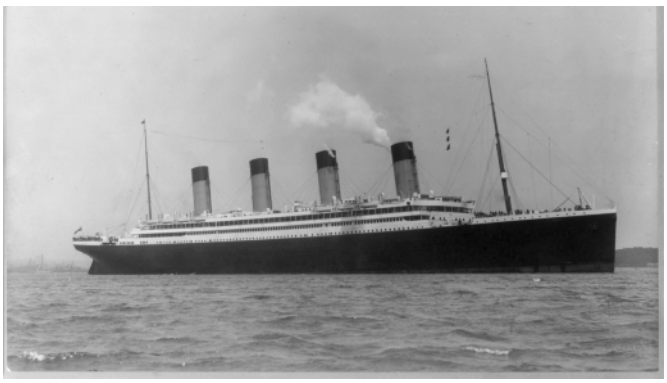


Figure 1. The *Olympic's* keel was laid in 1908 and was the first of a trio of a new class of liners built for the White Star Line (later Cunard-White Star), the others being the *Titanic* and *Britannic*. In appearance, the *Olympic* closely resembled the *Titanic*. In 1912 the *Titanic* was lost after striking an iceberg and in 1916 the *Britannic* sank while in wartime service after a torpedo or mine hit it. The *Olympic* was retired in 1935.

The following day, Mrs. Andrew Carnegie hosted a lunch for her at the Carnegie residence on the corner of Fifth Avenue and 91st Street [7].[2] The Carnegie-Curie connection dated to 1905 when Andrew Carnegie provided a grant to an early American radium physician, William Duane, to continue his studies with Pierre and Marie Curie. In 1907, Carnegie placed at the disposal of the Curie laboratory in Paris specific grants to support up to six researchers annually. This led to other grants to the laboratory from others, e.g., the Lazard Brothers Bank and Baron Henri de Rothchild [8].

On May 14th, an updated copy of Curie's itinerary was mailed by a representative of the Marie Curie Radium Fund, headquartered in New York City, to Dr. William J. Holland. Prof. Holland was an eminent zoologist and paleontologist, minister, past Chancellor of the University of Pittsburgh and Director of the Carnegie Museum. He also was a prominent member of the Committee of Scientists of the Marie Curie Radium Fund and played a key role in organizing the Pittsburgh segment of the itinerary. The itinerary now resides in the archives of the Senator John Heinz History Center, Pittsburgh, Pennsylvania [9].

[1] A graduate of the University of Wisconsin Rogers received his medical degree in 1892 from the College of Physicians and Surgeons of Columbia University, interned at St. Luke's Hospital, New York City and then entered private practice in the city. He later became medical director of the Knickerbocker Hospital.

[2] The residence is now the Cooper-Hewitt National Design Museum, part of the Smithsonian Institution.

Marie Curie Visits American Women's Colleges

Curie began her American tour with visits to three women's colleges - Smith College which bestowed its first honorary Doctor of Science degree on Curie (Figure 2) [10] and Mt. Holyoke College [11], both in Massachusetts, and Vassar College in New York. Although not stated in the itinerary, Curie spoke at Vassar College [12]. It was her first public address in the U.S. and the only occasion that she spoke at length [13]. The Chairman of Vassar's Department of Physics, Edna Carter, arranged publication, using the title "The Discovery of Radium," as the second monograph in the College's series of Ellen S. Richards monographs. It was given specifically for the audience of college students.

Figure 2. Smith College was the first stop of Marie Curie's visit and the first of seven women's colleges she visited. College President William Neilson accompanies her to the May 13, 1921 convocation conferring an honorary Doctor of Science.

The speech was noteworthy for its concluding message to the Vassar women:

> It is my earnest desire that some of you should carry on this scientific work and keep for your ambition the determination to make a permanent contribution to science.

Curie visited four other women's colleges - Women's Medical College of Pennsylvania which bestowed an honorary Doctor of Medicine and Bryn Mawr College, both in Pennsylvania, Wellesley College, Massachusetts (bestowing an honorary Doctor of Sciences), and Hunter College in New York City. Hunter College was not on her itinerary but she made a surprise visit on May 19, 1921, in spite of her doctor's orders for rest, to call on her daughter, Irene, herself a surprise visitor there who gave a lecture [14,15,16]. At some point Barnard College in New York City was added as a speaking engagement but Curie subsequently had to cancel [17]

It is unclear if Curie visited two other women's colleges, Radcliffe and Simmons. Eve Curie [2] stated she did but these are not on the itinerary and these institutions have no records of Marie Curie visiting them [18,19]. However, according to Harvard University's newspaper, the heads of Radcliffe and Simmons Colleges were to take part in a welcome of Marie Curie on June 20, 1921 at the Sanders Theater in Cambridge, Massachusetts [20]. This event is *not* on the itinerary but it became a part of her trip.

On Wednesday, May 18th, the Association of American University Women (AAUW) hosted an official reception for Marie Curie at Carnegie Hall, New York. Three thousand and five hundred members crowded into the hall to greet her and award her a $2,000 prize [21,22].

A Tight, Exhausting Schedule

By this time the demands of her visit had begun taking a toll. Dr. Rogers recommended against attending the AAUW reception and visiting Hunter College advising instead complete rest [15,16,22].

Dr. Ann Lewicki described her trip as 'tightly scheduled' and 'exhausting and difficult' [23]. Concern about Marie Curie's fragile health is evident on the very first page of the itinerary: Her schedule at Smith College, her first stop, called for attending a special convocation followed by a tour of the school's laboratories, a reception, and an outdoor student choral concert. A prescient note was added, 'If tired Mme. Curie need not attend the singing.'

In fact, Curie's health had been a constant concern since her student days when she was admonished for not eating [2,3]. Her health took an especially serious turn in December 1911 when she was taken by ambulance to a hospital where she was diagnosed with a kidney infection [3]. She hoped to avoid surgery and returned home but in March 1912 was back in the hospital so ill she thought death a possibility. Surgery was performed but her convalescence was long and she never completely recovered her strength. She suffered from low blood pressure, dizziness and anaemia and her periodic health problems were, at least in part, related to her exposure to radiation [3].

Her tour called for 30 stops in towns and cities in 46 days plus overnight travel on trains [Table 1]. As will be seen, events were curtailed, postponed, or cancelled when Curie was physically overwhelmed; on other occasions, Irene and Eve substituted for their mother. In retrospect, the itinerary would have been a challenge for a robust 53 year-old person let alone one with Curie's medical history.

Following the meetings, receptions and honorary dinners in New York City from May 17 to 19, she departed for Washington shortly after midnight of the 19th. On Friday, May 20th, at 6:30 am she arrived in Washington where a reception committee welcomed her. That afternoon, at 4 pm, President Harding presented her a Certificate of Gift of the radium (Figure 3) [24]. For that evening, her itinerary called for a 9 pm meeting in her honour at the National Museum. That is a long day!

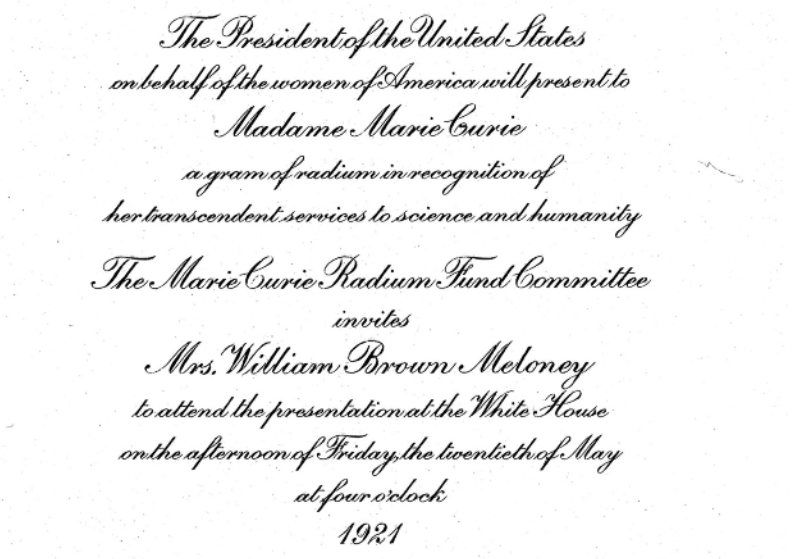

The President of the United States
on behalf of the women of America will present to
Madame Marie Curie
a gram of radium in recognition of
her transcendent services to science and humanity
The Marie Curie Radium Fund Committee
invites
Mrs. William Brown Meloney
to attend the presentation at the White House
on the afternoon of Friday, the twentieth of May
at four o'clock
1921

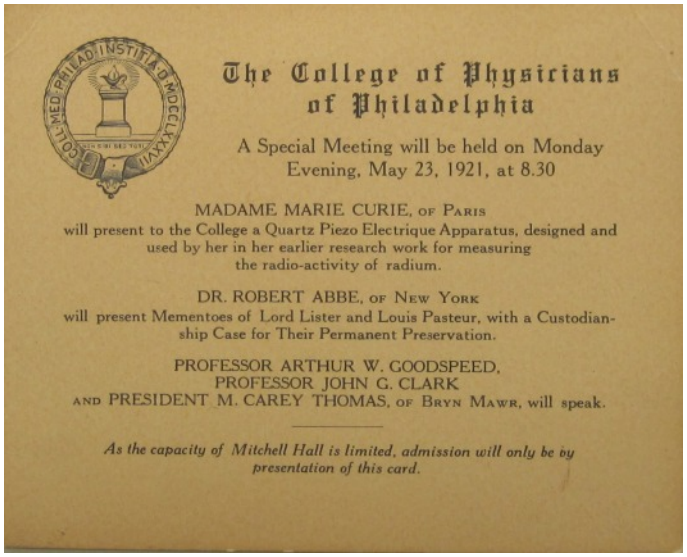
Figure 3. White House Invitation Card to Mrs. William Meloney Brown to attend Marie Curie ceremony, May 20, 1921.

May 21st and 22nd were spent in Washington visiting government laboratories and attending official functions [25]. She was fatigued but recovered sufficiently to keep her engagements including a dinner given in her honour by the Polish Legation [26]. At 9 am on May 23rd, she was scheduled to leave Washington for Philadelphia where she would attend a 1 pm luncheon and then travel by car to the Woman's Medical College of Pennsylvania to receive an honorary Doctor of Medicine. S*till ahead of her that day* was a late afternoon visit to the University of Pennsylvania to receive another honorary degree followed that evening by an assembly of

the College of Physicians of Philadelphia where she would present an original piece of laboratory equipment made by Pierre Curie.

Fatigue altered plans. She stayed in Washington to rest in a private residence and sent her daughters ahead to accept the honorary degrees on her behalf [27]. Irene and Eve did so on May 23rd at the University of Pennsylvania [28,29]. At the Woman's Medical College of Pennsylvania, Irene accepted the degree and conveyed her mother's thanks [29, 30]. Meanwhile, a concerned Dr. Rogers publicly expressed a desire to limit Marie Curie's activities even preferring to send her back to France 'on the first boat to sail' [31].

Marie Curie arrived in Philadelphia late that day and, somewhat recovered, that evening presented to the College of Physicians of Philadelphia a piezo-electrometer made by Pierre Curie and used by the Curies in their studies of radioactivity that led to the discoveries of polonium and radium (Figure 4). [32,33].



The College of Physicians of Philadelphia

A Special Meeting will be held on Monday Evening, May 23, 1921, at 8.30

MADAME MARIE CURIE, of Paris
will present to the College a Quartz Piezo Electrique Apparatus, designed and used by her in her earlier research work for measuring the radio-activity of radium.

DR. ROBERT ABBE, of New York
will present Mementoes of Lord Lister and Louis Pasteur, with a Custodianship Case for Their Permanent Preservation.

PROFESSOR ARTHUR W. GOODSPEED,
PROFESSOR JOHN G. CLARK
and PRESIDENT M. CAREY THOMAS, of Bryn Mawr, will speak.

As the capacity of Mitchell Hall is limited, admission will only be by presentation of this card.

Figure 4. College of Physicians of Philadelphia Invitation Card to attend the Marie Curie reception, May 23, 1921.

Overnight, she was a guest at the Dean's residence at Bryn Mawr college, outside Philadelphia.

The following day, May 24th, Mme. Curie amended her schedule so she could visit the Dean of the Woman's Medical College, Dr. Martha Tracy, to personally thank her (Figure 5). The rest of the day was spent visiting the Welsbach Company in Gloucester, New Jersey where she was presented with 50 milligrams of mesothorium (radium-224) [34,35]. That evening she was a guest of the American Philosophical Society where she was inducted as a member and awarded the John Scott Medal and $800 prize that accompanied it [36].

Figure 5. Woman's Medical College of Pennsylvania awarded an honorary Doctor of Medicine but Marie Curie was to weak to attend the ceremony. The following day, May 24, 1921, somewhat recovered, she stopped by the college to thank Dean Martha Tracy, M.D.

Although not on the itinerary, Mme. Curie evidently had agreed to speak that day to the student body at Bryn Mawr College but was too weak to do so. Irene stepped in and described her mother's experimental work [37].

So, it was another long day. Late that evening, 11:10 pm, she and her party boarded a private railroad car that was attached to a Pennsylvania Railroad train to Pittsburgh.[3]

On the morning of the 25th, Marie Curie arrived in Pittsburgh, utterly exhausted.

Too Much Hospitality

Local newspapers reported that because of ill health and weariness her trips to the Standard Chemical Company plants in Pittsburgh and Canonsburg would be cancelled as well as her projected western tour [39,40].

During her time in Pittsburgh she stayed at the estate of Mrs. Henry R. Rea in Sewickley, an upmarket suburb west of Pittsburgh. The 99-room mansion and surrounding grounds were far more ostentatious than Marie Curie would have preferred but the pleasant surroundings must have had a beneficial effect. Feeling better, a planned convocation by the University of Pittsburgh to confer an honorary Doctor of Laws remained on schedule for Thursday, May 26th but it was curtailed to 15 minutes to conserve her energy. She was presented a bouquet of flowers from women and undergraduates of the Pennsylvania College for Women, The Margaret Morrison Carnegie School for Women, Carnegie Institute of Technology and the women of the University of Pittsburgh. After the ceremony, she received a visit at the Carnegie Music Hall by a delegation of Polish women and children. Curie was too fatigued to attend a reception at the Carnegie Institute; Irene and Eve received visitors on their mother's behalf [41,42,43].

---

[3] The private railroad car was an observation car named 'Adventurer' built in 1913 by the Pullman Manufacturing Company for New York financier James Cox Brady. Brady placed the car at Marie Curie's disposal. It had a combination observation and dining room, four staterooms, two bathrooms with showers, kitchen, and quarters for the crew. [38]. Most likely, the four staterooms were assigned to Marie Curie, to her daughters, to Mrs. Meloney and to Dr. Rogers. Although the car's opulence may have exceeded Curie's taste a private car afforded her a measure of convenience and privacy for travel not available in public accommodations.

Prior to the convocation, Curie made a tour of the Standard Chemical Company refining laboratory in the Vanadium Building in Pittsburgh. [42]. Curie had been scheduled to visit the laboratories of the company in Pittsburgh and in Canonsburg (south of Pittsburgh) the following day. The Pittsburgh laboratories were close by the university so it made sense to visit the laboratories the day of the convocation and spare her a second trip to Pittsburgh. Her laboratory visit lasted an hour and a half and 'among retorts and test tubes, she seemed to forget her weariness' [42]. This experience was to be repeated when she visited the company's plant in Canonsburg, south of Pittsburgh, the following day, May 27th.

Marie Curie had made clear to Dr. Rogers her strong desire to visit the Canonsburg plant and so, accompanied by Irene and others, she travelled to the plant by automobile [43,44,45]. Following an informal lunch, James C. Gray, company president, and Louis F. Vogt, plant manager, served as tour guides. For Curie, this became a highlight of her trip:

> Between vast tanks, containing 27 tank-carloads of muriatic acid, past steaming press filtration rooms, where fumes rising from the liquid almost gag one, in the carbonating department where the raw ore is treated in a soda ash wash; even in the smelter room where a cupola of vanadium by-product was tapped into ladles, Mme. Curie seemed strangely in place.
>
> Bareheaded, with wisps of gray hair blowing about her anxiously wrinkled forehead, dressed simply in black, Mme. Curie seemed entirely in her own element, as sh[e] has not appeared since coming to America. One could not help but realize how much more stimulating and satisfactory to her was the visit…than the many social and official functions which she has graciously attended.
>
> No pair of steps was too arduous, no tank of acid too malodorous, nor was the distance through the many buildings of the plant too long for this scientist, who came to the plant obviously a travel and reception-worn woman, seemingly too tired to walk even a short distance. After delving into every phase of the process, which would have tired a strong man were he not interested, Mme. Curie asked for a few moments with Mr. Vogt, who has been connected with the Standard Chemical Company since the start of the plant and knows more about radium extraction. At the end of 15 minutes, during which time the visiting scientist asked a multitude of questions and did a vast amount of figuring, she emerged fresh and radiant. It was a remarkable exhibition of the ascendency of the technical and scientific mind over the frail and weary body (Figures 6,7) [45].

Figure 6. In this widely published photo of her May 27, 1921 visit to the Canonsburg, Pennsylvania radium plant, a visibly frail Marie Curie is on the arm of company president James Gray. Plant manager Louis Vogt is facing her and in the doorway is Joseph Flannery, Jr., son of the company's founder.

Figure 7. A rare photograph of Marie Curie – she is smiling, perhaps laughing. Louis Vogt is leading the way for her and James Gray. In the doorway is Lyle Wallace, plant process manager.

At the end of the visit, company president James Gray presented her a 3½ pound specimen of 'the purest carnotite ore in existence'[45].

On May 28th, Curie was scheduled to visit a "New Plant in Suburbs." This would have been the Keystone Metals Reduction Company facility in Cheswick that had started producing radium just recently [46]. The trip was cancelled and instead she left for New York City where she was scheduled to visit President Theodore Roosevelt's grave, local laboratories, and attend a dinner at the Hotel Astor sponsored by a Polish American organization.

Again suffering from exhaustion, she went to the home of Mrs. Meloney Brown to rest. On May 29th, it was announced that her trip to the west coast was cancelled, she would not visit the carnotite mines in Colorado, and the rest of the trip would be curtailed [47]. 'Too Much Hospitality' headlined one newspaper [2].

After resting at Mrs. Meloney Brown's home Curie left 'to have a few hours of pure pleasure inspecting the radium laboratories in the Memorial Hospital' in New York City and afterwards travelled to Manhasset on Long Island, New York to spend the weekend at a private home [47,48,49].

During the visit to Memorial Hospital, Dr. Rogers was asked about a report that Curie's health had been injured by her use of radium:

> There is not a word of truth in it, he said. There is nothing the matter with Mme. Curie at all except that she has been trying to do too much. She has been confined most of her life to work in the laboratory. She is a woman of 53 years. With a delicate physique and unaccustomed to outdoor life, she has been attempting to put through a strenuous program in this country and it has tired her.
>
> But she is better today than she was a week ago. I was yesterday in Pittsburgh when she spent four hours going through the plant of the Standard Laboratories Company [sic] climbing up and down stairs in old buildings and inspecting apparatus. After that she went to the country place of Mrs. Henry Rea and spent some time swimming in a private pool.
>
> There is no case on record of any one being injured in health by radium. It caused slight burns – that was the way it was discovered - but these have never had any after effects. Mme. Curie has been working with radium twenty years. Many other have handled it constantly for about the same period. If it had any deleterious effects, they would have been noted long ago. Even those who have in the past opposed its use have not asserted that it was injurious. Mme. Curie is somewhat anaemic as nearly all

> persons of confined, studious pursuits are. About half of the people are more or less so. She will in all probability go as far west as the Grand Canyon. Both Dr. Lambert and myself have told her there was no reason on earth why she should not go [48].

Notwithstanding his assertion, Drs. Rogers and Lambert had ordered a blood analysis to determine if her fatigue was the result of her work with radium [50]. After the blood labwork was completed, the physicians announced that while Curie was slightly anaemic she was otherwise physically sound but 'Mme. Curie cannot stand the strenuous life of receptions and travel which was planned for her in America'[51].

On June 1st she returned to New York City to receive an honorary Doctor of Sciences from Columbia University [52]. On June 2nd she and her party left for the Grand Canyon [17].

The Grand Canyon

Her itinerary originally called for arriving at Grand Canyon for an overnight stopover and then traveling to Los Angeles and Pasadena to visit the movie studios there [47]. Instead, the west coast part was cancelled enabling an extended stay at the Grand Canyon. What transpired during this extra time? Eve Curie explained:

> But the most intoxicating days were those on the journey to the West. Mrs. Meloney, who had given up the idea of having Marie Curie visit the whole of America, nevertheless wanted to show her the most astonishing marvel of the continent: the Grand Canyon of the Colorado.[4] Marie was too tired to show her pleasure very strongly, but her daughters were carried away by enthusiasm. Everything amused them: the three days on the train by the Santa Fé line, across the sands of Texas, the exquisite meals in solitary stations under a Spanish sun; the hotel at the Grand Canyon[5], an islet of comfort on the edge of that extraordinary fault in the earth's crust – a precipice sixty-five miles long and ten miles wide, of which the first sight, grandiose and almost terrifying, leaves the spectator voiceless.
>
> Irène and Eve, mounted on hard Indian ponies, wandered along the crest of the chasm, and, from on high, watched the motionless chaos of mountains, rocks and sand pass from violet to red, from orange to pale ochre, enriched by rough shadows. Unable to resist, they soon adopted the classic itinerary and went down on mule-back to the bottom of the canyon, where, contested by mud and stones, the young Colorado rolled impetuously [2].

Did Marie Curie visit the Colorado Carnotite District?

Marie Curie was invited by the Standard Chemical Company to include the company's mines in Colorado as part of her tour [53] and the *Denver Post* reported she planned to do so [54]. A local resident claimed to have seen her in 1921 [55].

Such a visit would have required a major detour beginning with Curie leaving her private railroad car, probably in Salida, Colorado, to transfer to the narrow gauge Denver and Rio Grande Railroad to go to Placerville, Colorado, the station closest to the mine district in the Paradox Valley. From there to reach the district would require a 65-mile ride by automobile over an old stagecoach road only recently paved [56].

Although it was not included in her May 14th itinerary such a visit apparently was still under consideration until May 29th when the announcement was made to cancel the trip to the west coast *and* to the mines [47]. Kathleen Bruyn, in her 1955 history of south-western U.S. uranium mining pursued the question of Marie Curie visiting Colorado with Irene Joliet-Curie who flatly declared that her mother paused only at the Grand Canyon during the western trip [56]. More recently, William L. Chenoweth came to the same conclusion [57].

---

[4] The Grand Canyon is in Arizona. The reference to "the Colorado" is to the river.

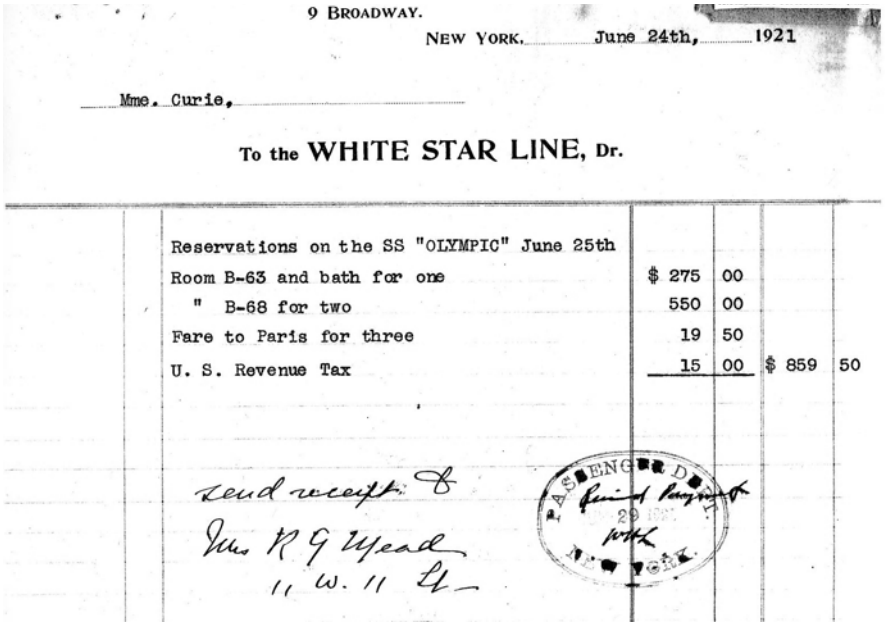
[5] The hotel was the El Tovar, built in 1905 as part of the Harvey House chain. It is located 20 feet from the south rim and remains in use.

Home Stretch

On Monday, June 13th, Marie Curie arrived in Chicago, and resumed her planned itinerary. On June 14th, she received an honorary degree from the University of Chicago and that evening the American Chemical Society awarded her the William Gibbs Medal [58,59]. The following day, Northwestern University bestowed an honorary degree and that evening she left for Niagara Falls, New York [60].

She achieved her desire to visit the Niagara Falls but, then again, fell ill. Events that were planned for her in Buffalo were cancelled and she stayed at the home of a friend to rest [61]. On Saturday, June 18th she travelled to Boston for the final segment of her trip. She was reportedly 'tired but recovered from her recent indisposition' and after arrival went to the home of Dr. William Duane [62]. In Cambridge, Harvard President A. Lawrence Lowell presided over a reception at the Sanders Theatre attended by a thousand students and contributors to the radium fund [63]. She visited one more women's college, Wellesley that conferred on her its first honorary degree [64]. Sunday, June 19th was to be devoted to 'Rest and Sightseeing' [9].

On June 21st, Marie Curie left for New Haven, Connecticut where she was hosted by Yale University. One more honorary degree was conferred on June 22nd making nine honorary degrees bestowed by American colleges [65].



9 BROADWAY.

NEW YORK. June 24th, 1921

Mme. Curie,

To the WHITE STAR LINE, Dr.

Reservations on the SS "OLYMPIC" June 25th				
Room B-63 and bath for one	$ 275	00		
" B-68 for two	550	00		
Fare to Paris for three	19	50		
U. S. Revenue Tax	15	00	$ 859	50

Send receipt to
Mrs R G Mead
11 W. 11 St

Figure 8. The White Star Line invoice for rooms and fares for Mme. Curie and her daughters, Irene and Eve.

Marie Curie returned to New York City for a bon voyage party and departed for France on the *Olympic* on Saturday, June 25th, the 46th and last day of her time in America (Figure 8) [66]. She arrived in Cherbourg on July 2nd and was greeted by government officials and children carrying flowers. 'A squad of detectives took charge of the gramme of radium presented to Mme. Curie by American women and will take it to Paris' [67].

Adieu

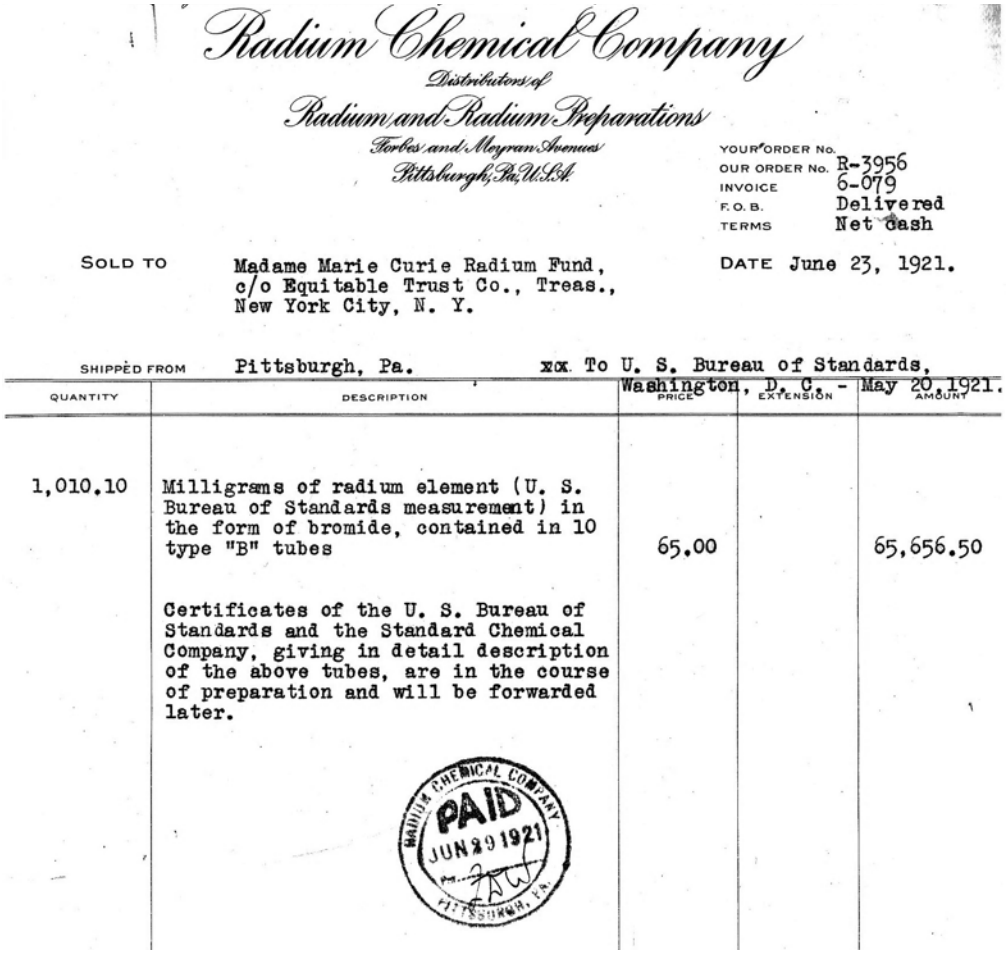
At the time of her visit to the White House, the gram of radium, consisting of 10 glass vials, each containing 100 milligrams of radium, was at the U.S. National Bureau of Standards being calibrated (using a radium standard that had been prepared for the Bureau earlier by Mme. Curie). The radium was then packaged in a mahogany

box containing a lead container and dispatched to New York where it was loaded and secured on the ship returning her to France (Figures 9,10)[6] [66].

Figures 9,10. The shipping cask for the radium and the ten glass vials containing 100 mg each of radium. At the time of the White House ceremony, the radium vials were at the National Bureau of Standards undergoing calibration and a replica set of vials was displayed at the White house.

Subscriptions to the Marie Curie Radium Fund exceeded the $100,000 price quoted by Radium Chemical Company, the marketing subsidiary of Standard Chemical Company. However, the company invoiced the Fund for only $65,656.50[7] (Figure 11) [67]. The additional funds enabled obtaining $22,000 of mesothorium plus valuable ores. On Oct. 5, 1921, the remaining money in the radium fund, $54,956.78 plus $5,000 in notes, was assigned to a trust fund, income from which was paid quarterly to Marie Curie for the remainder of her life [reference 67]. Additionally, she received $6,884 in awards [69] and an advance of $50,000 from an American publisher for a biography of Pierre Curie [70]. Excluding the value of the gram of radium, the awards, publisher's advance, and residual money in the Radium Fund totalled $116,841, the equivalent of $1,495,460 in 2012 dollars.[8]

[6] The shipping cask is displayed in the Musée Curie, Paris, France.
[7] The invoiced amount may represent the actual cost of production of the radium, the company eschewing any profit.
[8] Computed August 19, 2012 using the U.S. Bureau of Labor Statistics Consumer Price Index Inflation Calculator available at http://data.bls.gov/cgi-bin/cpicalc.pl.



Radium Chemical Company

Distributors of

Radium and Radium Preparations

Forbes and Meyran Avenues

Pittsburgh, Pa, U.S.A.

YOUR ORDER No.
OUR ORDER No. R-3956
INVOICE 6-079
F. O. B. Delivered
TERMS Net cash

SOLD TO Madame Marie Curie Radium Fund,
c/o Equitable Trust Co., Treas.,
New York City, N. Y.

DATE June 23, 1921.

SHIPPED FROM Pittsburgh, Pa. xx To U. S. Bureau of Standards, Washington, D. C. - May 20, 1921.

QUANTITY	DESCRIPTION	PRICE	EXTENSION	AMOUNT
1,010.10	Milligrams of radium element (U. S. Bureau of Standards measurement) in the form of bromide, contained in 10 type "B" tubes	65.00		65,656.50
	Certificates of the U. S. Bureau of Standards and the Standard Chemical Company, giving in detail description of the above tubes, are in the course of preparation and will be forwarded later.			

RADIUM CHEMICAL COMPANY PAID JUN 29 1921 PITTSBURGH, PA.

Figure 11. Standard Chemical Company's bid of $100,000 to supply the gram of radium for Marie Curie was less than its market price of $120,000/g. However, Radium Chemical Company, its marketing subsidiary, billed the Radium Fund only $65,656.50, presumably the cost of its production.

A lasting consequence of the trip was a strong friendship with Mrs. Meloney Brown that endured until Mme. Curie succumbed to aplastic anaemia on 4 July 1934 (Figure 12).

Marie Curie granted the press an interview before leaving the U.S. It was held at the New York City home of Mrs. Meloney Brown on June 24th. Her summary of her trip was a mixture of melancholy on account of her frail health that impaired her ability to do all of the things that had been planned and her strong, admiring impressions of the country, its cities and colleges, and the many research institutions she visited. And, it was remarkable for her flat contradiction of Dr. Rogers' assertion that her work with radium had no connection with her fragile health:

> It is with much regret, that I come to the last day of my visit to America….There has been only one disappointment, that has been my physical inability to do all the things I would wish to do and to meet all the American people I much desire to meet.
>
> 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.

I am especially impressed in New York….with the generous opportunities for free education, providing for both men and women. Hunter College, City College, and your other institutions of learning here, where boys and girls may be trained for useful work, even while they support themselves, have commended my admiration. Here, too, in the midst of this great industrial and financial centre, I have noticed that much attention is given to public health, to playgrounds for children and to the pleasures of the people.

Washington, your Capital, is one of the most beautiful cities I have ever seen. The wide streets, the many parks, shade trees and gardens are features which should be planned for all cities. I have especially admired the White House with its dignity and simplicity, a fitting home for the chief of a republic.

Philadelphia was to me like an Old World city. I felt at home and I was sad not to be able to enjoy more of it.

Pittsburgh, of course, had great interest for me, because, among other great industrial enterprises, it is the place where the greatest amount of radium in the world is produced. I was interested to see that the method of extracting radium is the same instituted by me when we discovered radium many years ago.

Chicago is an amazing place. Its wonderful growth both for beauty and permanence in fifty years is more than has ever been accomplished in the history of any other city. It interested me.

In Buffalo I was not well enough to enjoy all that charming city had to offer. I was deeply touched by their consideration of my comfort and I hope some day to be able to visit Buffalo again.

In Boston, I have been especially interested in the chemical laboratories [there]….

The Harkness Quadrangle and Tower at Yale is one of the most beautiful pieces of architecture I have ever seen. I especially appreciated the opportunity of seeing two of the greatest wonders of America, the Grand Canyon, which, despite the heat, was a rare pleasure, and Niagara Falls with its matchless beauty [71].

Figure 12. A formal portrait of Marie Mattingly Meloney Brown and Marie Curie.

Afterword

In November 1996, I came across Marie Curie's 1921 American itinerary in the library of Historical Society of Western Pennsylvania at the Senator John Heinz History Center in Pittsburgh, Pennsylvania. It lay fallow in my files until 2011 when I mentioned it to Dr. Richard F. Mould who remarked he was unaware of any other copy and recommended writing about it, a simple enough suggestion. Thinking that a few contemporary newspaper reports would enhance an otherwise dry account the newspaper accounts revealed far more:

- The itinerary was by no means the final word about where Marie Curie travelled in America.
- Her health became the ruling factor in her trip.
- Still, she was tenacious with respect to her goals for the trip.
- The conflict between Marie Curie and her attending physician became almost palpable when reading the newspaper accounts.
- The lack of privacy with respect to Marie Curie's medical problems is astonishing.

Nonetheless, Marie Curie's visit was a triumph: 'It was a remarkable exhibition of the ascendency of the technical and scientific mind over the frail and weary body' [45].

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Note

In 2011, portions of this paper were accepted for publication in *Nowotwory Journal of Oncology,* at that time a bilingual journal. Unfortunately, a change in ownership and editorial policy resulted in publication in 2012 in Polish only without advance notice to the author who retained the copyright. This paper incorporates additional, significant research findings.

Table 1

Planned stops by Marie Curie During Her 1921 US Visit

According to Itinerary dated May 14, 1921

(Overnight stops in bold letters)

1. **New York, New York**
2. Springfield, Massachusetts
3. **Northampton, Massachusetts (Smith College)**
4. South Hadley, Massachusetts, (Mt. Holyoke College)
5. **Poughkeepsie, New York (Vassar College)**
6. **New York, New York**
7. **Washington, D.C.**
8. Mt. Vernon, Virginia
9. Philadelphia, Pennsylvania
10. **Bryn Mawr, Pennsylvania (Bryn Mawr College)**
11. Gloucester, New Jersey
12. Philadelphia, Pennsylvania
13. **Sewickley, Pennsylvania**
14. Pittsburgh, Pennsylvania
15. Canonsburg, Pennsylvania
16. Cheswick, Pennsylvania (in itinerary, "New Plant in Suburbs")
17. **New York, New York**
18. Dayton, Ohio
19. Chicago, Illinois

Overnight on train

20. **Grand Canyon, Arizona**
21. **Los Angeles, California**
22. Pasadena, California
23. **Salt Lake City, Utah**

Overnight on train

24. **Chicago, Illinois**

25. **Buffalo, New York**
26. Niagara Falls, New York
27. **Boston, Massachusetts**
28. Wellesley, Massachusetts (Wellesley College)
29. **New Haven Connecticut**
30. **New York, New York**

Marie Curie by Josef Hilpert.

On the front cover of this journal there is a stunning painting by Josef Hilpert of Marie Curie. It is painted in oil on a metal sheet, and measures 11 inches high by 9 inches wide. The painting is remarkable and has a lot of depth and character, and was painted about 1950.

Dr Joseph Hilpert (1895-1975) was born at Kollit in what was then in Yugoslavia, and was named after the Emperor. He spent a great deal of time in the USA and lived in Santa Clara CA, and by profession was a museum director, painter, and lecturer. When he was young he studied in Hungary. He exhibited at the National Exhibition held in Toronto, Canada in 1935 and presented the world's smallest perfect painting on a bloodstone, which was about 1/8 of an inch in size. It was described as being perfect in every way, and it had to be viewed under a magnifying glass to see the detail. He was a member of the Association de Bellas Arts, Havana, Cuba. Hilpert painted over 200 portraits of famous people including royalty, industrialists, presidents and film stars. In 1935 he wrote a book entitled 'My Life in Art.'