# **Proceedings** of the Scientific and Citizen Forum on the Genetic Effects of Ionizing Radiation

**Organized by the Collective IndependentWHO – Health and Nuclear Power**
29 November 2014, Geneva (Switzerland)

IndependentWHO

## In memory of Chiyo Nohara (8 May 1955 – 28 October 2015)

### She died in the cause of scientific truth

ISBN: 978-2-9552736-1-6

# Scientific and Citizen Forum on the Genetic Effects of Ionizing Radiation

**Organized by the Collective IndependentWHO – Health and Nuclear Power**

29 November 2014, Geneva (Switzerland)

# Proceedings

October 2015

# Editors' note

These Proceedings are a faithful reflection of a collective effort with contributions from many different people. Before you read them, we should like to clarify the guiding "philosophy" of the drafting group set up by the Collective IndependentWHO for the purposes of this publication and for which it takes full responsibility.

We wanted to stay as close as possible to the spoken presentations of the speakers at the Forum – several of whom were not speaking their mother tongue – sometimes by reference to their written texts, in particular those of Dr. Inge Schmitz-Feuerhake and Dr Wladimir Wertelecki.

The illustrations for the talks are taken from Power-point documents submitted by the speakers.

Questions and answers that followed the presentations, as well as the exchanges that took place in the late afternoon between speakers and the audience, are based on recordings of the debates, which the drafting group has transcribed and edited whilst remaining as close as possible to the meaning of the words spoken.

Finally, the presentations and spoken or written contributions published here are the sole responsibility of their author(s).

**Group responsible for transcription, translation and publication of the Proceedings**: Line Aldebert, Emanuela Andreoli, Alain Bougnères, Christophe Elain, George Gordon-Lennox, Odile Gordon-Lennox, Alison Katz, Wladimir Tchertkoff.

**Photos**: Emanuela Andreoli

**Layout**: Alain Bougnères

IndependentWHO Website: www.independentwho.org/en

---

Published by: **IndependentWHO – Health and Nuclear Power**
Geneva
October 2015

ISBN: 978-2-9552736-1-6

# Table of contents

# Foreword

## Why this forum?

### The genome: human kind's most precious treasure

*"The genome is the most valuable treasure of human kind. It determines the life of our descendants and the harmonious development of the future generations.*

*As experts, we confirm that the health of future generations is threatened by the expansion of the nuclear industry and the growth of the quantity of radioactive sources.*

*We also consider the fact of appearance of new mutations observed in people to be fatal for them and for their descendants."*

This is how, in 1956, the expert group on genetics at the WHO, including H.J. Muller, Nobel Prize winner, assessed the threat that ionising radiation represented to the human genetic legacy.

No scientific proof has emerged since 1956 to contradict this position. On the contrary, later studies indicate that the dangers had been underestimated.

For more than half a century, the health consequences of nuclear accidents, like Chernobyl and Fukushima, and nuclear activities as a whole, have been hidden from the general public.

The World Health Organization (WHO) is complicit in this cover-up. The main reason for the cover-up is the subordination of WHO to the nuclear establishment, and in particular to its mouthpiece, the IAEA.

In the face of this complete denial of the negative biological effects of radioactive contamination, we have taken upon ourselves the task of making known to those members of the public who want to know the truth, the current state of research led by internationally renowned scientists, at this **Scientific and Citizen Forum on the Genetic Effects of Ionising Radiation.**

It follows the first **Scientific and Citizen Forum on Radioprotection – from Chernobyl to Fukushima**, that we organized, with the support of the city of Geneva in particular, on 12th-13th May 2012, the proceedings of which were published in March 2013 [downloadable from our site : http://independentwho.org/media/Documents_Autres/Proceedings_forum_IW_mai2012_English.pdf ]

This Forum is organized by the Collective **IndependentWHO – Health and Nuclear Power** that is fighting to ensure that WHO fulfils, completely independently, its mandate in the field of ionising radiation.

**IndependentWHO – Health and Nuclear Power** has maintained a silent Vigil in front of the WHO headquarters in Geneva, every working day, since 26th April 2007.

It has held a similar Vigil in Paris, every Friday, in front of the Ministry of Health, since November 2012.

## Members and supporters of IndependentWHO Collective involved in organizing the Forum:

**Line Aldebert** (France), retired librarian
**Emanuela Andreoli** (Switzerland), film editor
**Françoise Bloch** (Switzerland), retired sociologist CNRS
**Alain Bougnères** (France), retired
**Bruno Boussagol** (France), politically-engaged theatre director
**Maryvonne David-Jougneau** (France), sociologist
**Christophe Elain** (France), environmental activist
**Odile Gordon-Lennox** (Switzerland), member of “Women for Peace, Geneva”
**George Gordon-Lennox** (Canada), former international civil servant and journalist
**Marie-Élise Hanne** (France), retired pathologist
**Alison Katz** (Switzerland), member of "People's Health Movement"
**Miho Kozawa-Hoffman** (Switzerland), administrative assistant
**Claude Proust** (France), retired lawyer
**Paul Roullaud** (France), retired farmer
**Hannelore Schmid** (Germany), administrative assistant
**Annick Steiner** (Switzerland), socio-educational assistant
**Wladimir Tchertkoff** (Italy), documentary maker for Swiss television, retired

# Forum programme

## Morning session

8.30 am: Welcome

9.00 am: Introduction to the Forum

9.10 am: Immediate and delayed genetic effects of ionizing radiation through irradiation and contamination
***Dr Inge Schmitz-Feuerhake***,
*German Society of Radiation Protection, Member (retired), University of Bremen, Germany*
(Question and Answer Session)

9.55 am: Summary of past and present studies on the genetic effects of ionizing radiation, including an overview of recent technological advances in this area, and of transgenerational effects of parental exposure to mutagens
***Dr Yuri Dubrova***,
*Department of Genetics, University of Leicester, United Kingdom*
(Question and Answer Session)

10.40 am: Coffee break.

11.00 am: Abnormal levels of incorporated ionizing radiation among pregnant women and high rates of malformations in infants in Ukraine

***Dr Wladimir Wertelecki***,
*Formerly of the Department of Medical Genetics and Birth Defects, University of South Alabama, USA, President of the Board of the OMNI-Net Ukraine Child Development Programmes*

(Question and Answer Session)

11.45 am: The role and potential consequences of genomic instability induced by environmental stressors

***Dr Keith Baverstock***,
*Department of Environmental Sciences, University of Eastern Finland, Finland*

(Question and Answer Session)

12.30 am: Lunch

## Afternoon session

2.00 pm: Biological consequences of radiation in the environment for individuals, populations and ecosystems: lessons from Chernobyl and Fukushima

***Dr Timothy Mousseau***,
*Professor of Biological Sciences, University of South Carolina, USA*

(Question and Answer Session)

2.45 pm: The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly

***Chiyo Nohara***,
*University of Okinawa, Japan*

(Question and Answer Session)

3.30 pm: Coffee/tea break

4.00 pm: Question and Answer Session

5.50 pm: Conclusion

***Ruth Stégassy***,
*presenter of the programme "Terre à Terre" on Radio France Culture,*
***will moderate this forum.***

# Forum introduction

## Introduction

***Annick STEINER**, member of IndependentWHO – Health and Nuclear Power'*

Hello. Annick STEINER, private citizen, member of the collective 'IndependentWHO – Health and Nuclear Power', who organized this forum.

I should like to thank the representative of the City of Geneva, without whose help this Forum could not have taken place. More than the financial assistance they have given, we need to acknowledge their unwavering support without which we could not possibly have considered a venture on this scale.

I thank everyone here today, scientists and citizens, who have come to share information about a matter that concerns all of us and our descendants: the effects of ionizing radiation on the genome. The Forum will be looking at: the immediate and delayed genetic effects of ionizing radiation; the results of previous and current studies; the biological consequences for individuals, populations and ecosystems.

In particular, we should bear in mind what the group of experts in genetics from the WHO, including the Nobel laureate H.J. Muller, said in 1956: *"The genome determines the lives of our descendants and the harmonious development of future generations. As experts, we believe that the health of future generations is threatened by the expansion of the nuclear industry and the increase in the number of sources of radioactivity. We also believe that the appearance of new mutations observed in humans could be fatal for them and their descendants."*

For his part, in 1957 Sakharov, the father of the H-bomb, evaluated the effects of nuclear testing: *"These effects – including the development of carcinomas and genetic mutations – occur even with*

*minimal radiation and lead to statistically high levels of mortality and pathology because a large number of people and, ultimately, the whole of humanity are subjected to radiation."*

He was already talking about the fact that there is no threshold for effects and, in the long term, of 10,000 victims per megaton, calculating that at that time, 400 megatons worth of bombs had already been exploded in the atmosphere.

It must be said that in our nuclearized world, these are words that are not widely available to the public. Generally when we talk about the nuclear industry in public debates, we talk about money, the price per kilowatt, not the major problem of the effects on health.

Hence the creation of our IndependentWHO Collective in 2007, which raises the issue of health and nuclear power, and denounces WHO's abnegation of its responsibilities vis-a-vis the population in favour of the opinion of atomic experts which it supports: UNSCEAR, the ICRP and the IAEA, one of whose functions is the promotion of nuclear energy. It is this abandonment of the function of guaranteeing the health of populations that underlies our presence outside the WHO building, in the form of the Hippocratic Vigil, every working day from 8 am to 6 pm. During our interview with Dr Chan, on May 4, 2011, the Director of WHO recognized that there wasn't even any department devoted to research on ionizing radiation. We invited Dr. Chan and her key officers to attend the Forum, which aims to highlight and to fill this gap. I do not know if she signed up!

Today's meeting follows on from our first Scientific and Citizen Forum on Radioprotection, held on 12 and 13 May 2012. The Proceedings from this Forum can be downloaded from our website [http://independentwho.org/media/Documents_Autres/Proceedings_forum_IW_mai2012_English.pdf] and we still have some paper copies here in French and English.

Of course, of all the effects of ionizing radiation, those related to genetics and future generations are not the easiest to prove.

So we are extremely fortunate to have with us today some of the most highly-qualified researchers from different countries and three continents to report on progress in this area. In choosing these researchers we followed the recommendations of Professor Rosa Goncharova from Minsk, who for nearly 30 years has made a particular study of the effects of low doses of radionuclides in rodents and in fish, over 20 generations. She was not able to attend the Forum because of time constraints, but we thank her for her work and collaboration in the preparation of today's programme.

When the scientists speak, they will be using language that is not always easy to access. However we are not in an Expert Symposium and the challenge for us is to remain a Scientific AND a Citizens Forum and thus enable the latter to grasp the scientific knowledge and clarify their views. So we ask all of you not to be afraid, and that after every contribution, feel free to ask questions of our experts about anything that remains obscure or too abstract. We ask our experts to take part in this educational exercise. We remind you that we have allotted, in addition to 16 hours for presentations, nearly two hours for questions and answers between speakers and audience to develop the questions that emerge as central to the discussions. We will be helped throughout the day by Ruth Stégassy, a journalist with France-Culture, who has agreed to take on the difficult role of "chair", for which we thank her.


***Ruth STEGASSY**, journalist for France Culture*

We also thank all those who support us financially: ***Women for Peace, Greenpeace Switzerland, Laval Biocoop, Greens of Geneva, Liberal Ecology Movement, Geneva Socialist Party, "Sortir du Nucléaire" Network, Industrial Services of Geneva, Solidarity, City of Carouge, City of Geneva, City of Plan les Ouates,*** as well as private individuals, and all the volunteers who have given, and who will give their time and energy to ensure that this Forum is successful and that its voice is heard well beyond these walls and borders. Our supporters on the Internet will help us, hopefully. I thank them in advance. ◆

## Welcome speech

***Rémy Pagani**, administrative counsellor of the City of Geneva*

Distinguished members of the Collective IndependentWHO, distinguished professors and experts, distinguished representatives of the academic and scientific world, ladies and gentlemen, I have listened carefully to everything that has been said and I think that the matters that have been discussed are extremely serious; I am speaking here on behalf of the authorities.

Let me first, on behalf of the authorities of the City of Geneva, wish you all a very warm welcome to our city.

I am very pleased to welcome you, from all parts of the world, on the occasion of this Scientific and Citizen Forum on the genetic effects of ionizing radiation, which follows the first Scientific and Citizen Forum on Radioprotection, organized in May 2012 to which the City of Geneva also lent its support, and in which I had the opportunity and pleasure to participate.

You will be aware of the importance that Geneva accords to respecting and protecting human rights. And the right to health is, without doubt, one of the fundamental rights of every human being.

Nowadays, we know that nuclear energy is very expensive and that it has always been very dangerous. And it is not acceptable that, almost thirty years after the major disaster at Chernobyl and almost four years after the one at the Fukushima nuclear plant, the industry still continues to invest so much to develop this form of energy.

This is why we strongly support your goal, which is to make the public aware of the current state of scientific research into the health consequences of these disasters. I have to say that if you were not doing it, no one else would and it is in that way, in the form of a grassroots movement, that we will break down the wall of silence that surrounds these issues.

Because it is obvious that our own health, the health of our children and of future generations is threatened by the expansion of the nuclear industry and the increase in sources of radioactivity.

It is therefore our civic duty to continue to raise the question of abandoning nuclear power, both military and civilian and to commit to a real energy transition, based on saving energy and on the use of renewables.

Incidentally, the city of Geneva, as a municipality, has fully committed itself in this direction. This autumn, for the second time, our city received the European Energy Award Gold, which is the highest award given to a city for its energy policy. The title acknowledges Geneva's commitment to an active energy policy to achieving its objective of "100% renewable by 2050".

This label also focuses on projects and future development achievements, particularly in terms of improving the energy performance of buildings and putting local energy infrastructure and renewable energy supply chains in place, eventually eliminating the need for any nuclear power.

Ladies and gentlemen, I, for one, am convinced that it will soon be possible to do without either military or civilian nuclear power. Because we cannot simply wait for the next serious accident to happen, the next tragedy. And it is this state of necessity and urgency that makes your action so relevant.

I would like wholeheartedly to salute the courage and commitment of the Collective IndependentWHO, and to express our support for the citizen struggle that it pursues. I would like to express my sympathy and solidarity.

Together with you, I have had the opportunity to denounce the ambiguous position of the World Health Organization in matters of health and radiation. And I must say, I always experience heartfelt gratitude because it was 7 years ago that our comrades began their picket of WHO, and I find what they are doing quite remarkable. While for the last 7 years I have been responsible for the construction and management of the City of Geneva, they have been there in front of WHO for seven years to denounce their attitude. Can I suggest a round of applause for them, because truly, their determination is remarkable and courageous.

Ladies and gentlemen, unfortunately, it is clear that the world has not yet learned the lessons of the Chernobyl and Fukushima disasters and the situation remains extremely dangerous for the world's population if we do not take the decision to abandon the use of what is a high risk, but above all, ladies and gentlemen, an outdated technology. Today we have the means to produce more efficient energy, for example we are going to utilise the heat of Lake Geneva, we are going to put in place alternative energy sources.

This will be achieved undoubtedly through the fight against waste, through energy saving programmes, through the establishment of energy efficiency and the development of renewable energy. It will be achieved also through informing and mobilising the people and making them aware of what is at stake, which is what you are doing.

Ladies and gentlemen, I wish you all again a very warm welcome to Geneva, and above all success with your Forum.

Thank you for your attention.◆

# Immediate and delayed genetic effects of ionizing radiation through irradiation and contamination

*Dr **Inge Schmitz-Feuerhake**, German Society for Radiation Protection, Member (retired), University of Bremen, Germany*

## Introduction *by **Ruth Stégassy***

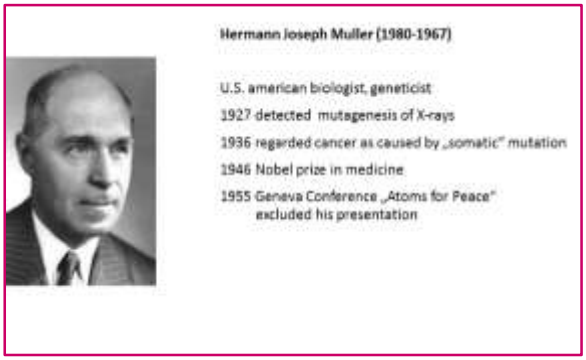
***Dr Inge Schmitz-Feuerhake** was a professor in experimental physics at the University of Bremen (Germany) from 1973 and until her retirement in 2000. Her research has assessed the biological effects of ionizing radiation at low dosage levels, as well as the diagnostic use of nuclear radiation. Her work made a major contribution to the development of biological dosimetry methods in which changes to the chromosomes in white blood cells are measured with extreme precision, by making it possible to count the concerned white blood cells under the microscope. She wrote of her scientific findings in comprehensible language, so that they can be understood by colleagues from related disciplines and interested laypeople. Dr Schmitz-Feuerhake became known in Germany since 1990 for examining the rise of the number of children suffering leukemia in the surroundings of the Krümmel Nuclear Power Plant. In 2003 she received the Nuclear-Free Future Award for her lifetime achievement. She is also chairman of the European Committee on Radiation Risk, and vice president of Gesellschaft für Strahlenschutz e.V. (German Society for Radiation Protection).*

# Presentation


Ladies and gentleman it's a very great honour for me to be the first speaker.

The Society for Radiation Protection is a non-government institution.

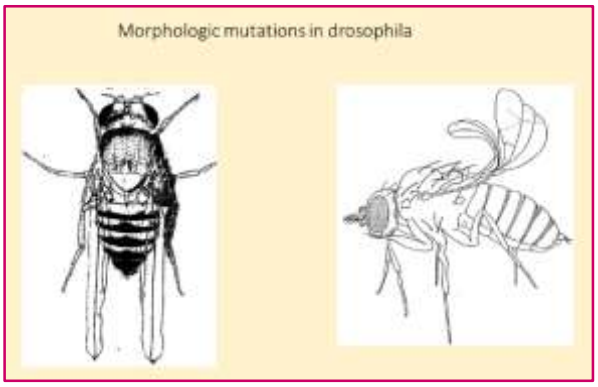
I am a physicist and I worked as a physicist, and I must confess that my knowledge in biology, medicine and genetics is very limited. The reason that I'm here to talk about that, even in presence of real experts, is my impression that there are not enough scientists and also not enough citizens who care for the problem of genetic risk, radiation risk, and who demand for higher consciousness, and higher protection against hereditary radiation effects.




I have simply made a compilation of published data, and want to show that, in contrast to the official version, hereditary diseases occurred in reality after low-dose exposures.

The most serious effects of ionizing radiation – hereditary defects in the descendants of exposed parents – had been already detected in the 1920s by Herman Joseph Muller.

He exposed flies – drosophila – to x-rays and found malformations and other disorders in the following generations. He concluded from his investigations that low dose exposure, and therefore even natural background radiation, is mutagenic.




Already in the Thirties, the idea arose that cancer is initiated by a single cell transformation, a "somatic" mutation. Likewise, Muller concluded that there is no harmless dose range for cancer induction either [Muller 1936]. His work was honoured by the Nobel Prize for Medicine in 1946.

After World War II, Muller warned that radioactivity in the environment would cause deterioration of the human genetic pool. He was subsequently excluded as a speaker at the Atomic Conference in Geneva in 1955 where the large-scale, so-called peaceful, use of nuclear energy was announced by U.S. President Eisenhower. Since then, those scientists who declared the handling of huge amounts of man-made radioactivity to be practicable and safe have been preferred and selected as experts by the authorities.

The normative body for the evaluation of radiation risks and the proposal of dose limits is the International Commission on Radiological Protection, ICRP. It replaced a committee, which had been founded in 1928 by radiological societies of several countries for the purpose of developing standards for radiation protection in the medical field. For this reason, the ICRP is traditionally beholden to the interests of the users. Since 1950, over the period of the Cold War and the development of

nuclear energy consumption, the Commission became enormously important. Although it only makes recommendations, these are applied by all Western and Eastern industrial nations.

The ICRP nonetheless developed the concept of the "stochastic" radiation effect – fully in line with Muller's understanding of the phenomenon. If a large group is exposed to a small dose, one cannot predict which individual will suffer from radiation damage, only a probability can be inferred. Adverse health effects increase with accumulated dose, and after halving the dose there is still an increased effect. It can therefore be deduced that no "threshold" exists, i.e., a dose range without risk.

The underlying idea is that a single quantum of radiation – one alpha or beta particle or one electromagnetic wave of high energy – is able to induce or promote a cell mutation. Single hit cell mutations are manifested in chromosome aberrations and can be induced by very low doses. They are also implicated in a variety of heritable diseases if induced in germ cells.

## DNA as a target of ionizing radiation

Tissue cells possessing a nucleus divide by splitting their genetic material in two equal portions. When Muller started his radiation experiments it was already known that the nucleus carries genetic information in the form of chromosomes. Human cells contain 23 pairs of chromosomes, with half of the material given by the mother, the other half by the father. The chromosomes can be made visible at a certain stage in cell division, called the metaphase.

For the purposes of presentation, they can be arranged in pairs as a karyotype (Figure 1). The characteristic shape of the chromosome as an X with a centromere and 4 arms – the chromatids – is only present at this stage when the material has been doubled in order to be divided in two parts. The chromatids carry the genes.

We learned in the meantime that the chromosomes contain (DNA) which is a very long molecule consisting of two polynucleotide strands wound around each other in the form of a double helix. The sequence of bases on the DNA strand contains the genetic code.

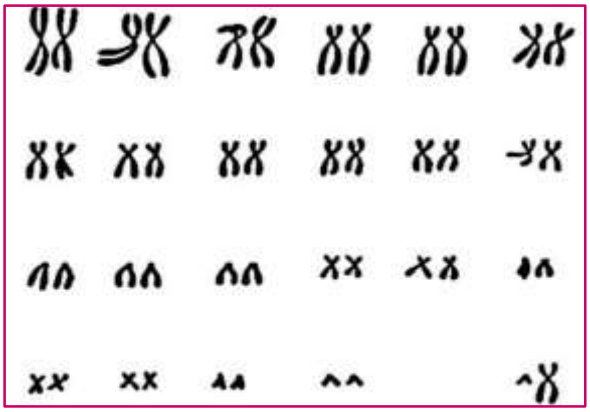


*Figure 1. Karyotype of a man, 22 pairs of autosomes, 1 pair of gonosomes: xy*

In chromosomes, the DNA molecule winds around a protein core consisting mainly of histones, which are characterized by a relatively high content of basic amino acids (Figure 2). A sequence of about 140 nucleotide pairs is wound around the histones to form a nucleosome. The nucleosomes are linked together by short stretches of DNA, giving the appearance of a string of beads.

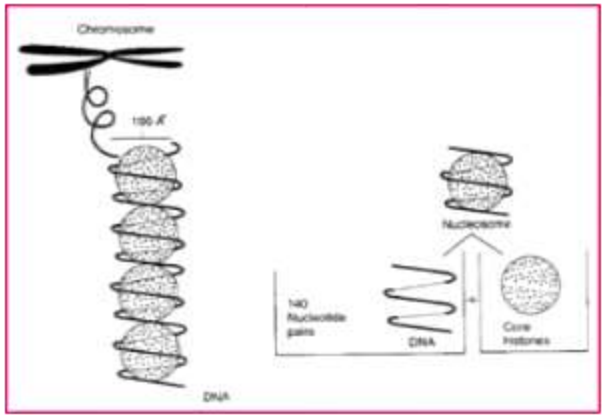


*Figure 2. Relationship between DNA molecule and chromosome [from Uma Devi 2001]*
*100 $A^0$ = 10 nm = 0.01 µm = $10^{-8}$ m*

Irradiation produces different types of lesions in the DNA molecule, which include strand breaks, base damage and crosslinks. Single strand breaks and double strand breaks are the best studied lesions. The cell has a repair system which reacts immediately to the damage. Single strand breaks are normally repaired error-free. Double strand breaks repair may be error-free or error-prone. Unrepaired or misrepaired double strand breaks can lead to cell death, mutations and cell transformations.

Base damage and strand breaks are implicated in radiation induced mitotic delay (delay of cell division) and delay in DNA synthesis.

## The evidence of low dose effects in chromosomes and genes

Radiation induces breaks in the chromosomes and chromatids. Misrepair leads to various abnormal configurations known as chromosomal aberrations. These can be numerical (change in number) as well as structural. Figure 3 shows typical radiation-induced structural chromosome aberrations which can be regarded as radiation-specific [Hoffmann 1999].

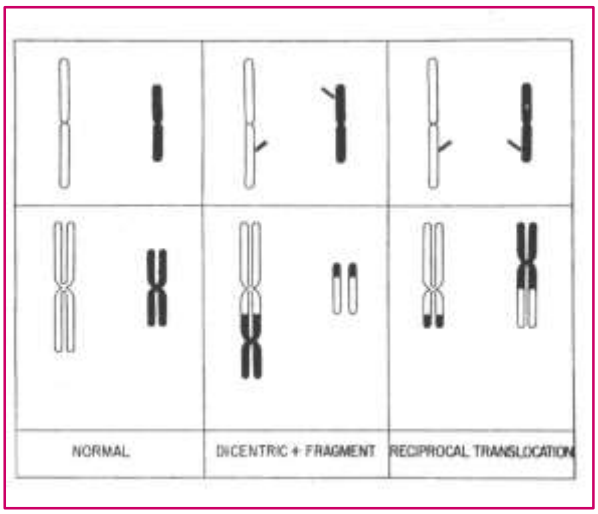



*Figure 3. Interchromosomal aberrations, radiation-induced*

The formation of a dicentric chromosome requires the simultaneous induction of two "sublesions" in the DNA, certainly double strand breaks which lead to deletions in two neighbouring chromosomes. Such aberrations result mainly from one ionizing track.

Counting the number of dicentric chromosomes in human lymphocytes is a very sensitive method of demonstrating radiation exposure in an individual person or in populations and is therefore a method of "biological dosimetry". Significant increases are found in populations living in regions with high background radiation [Barcinski 1975; Pohl-Rüling 1983; Wang 1990]. Stephan and co-workers (2007) showed that one single CT examination of the thorax or abdomen in a child or juvenile may lead to a significant increase of dicentric chromosomes.

Reciprocal translocations – made visible by a certain method of fluorescence in-situ hybridization (FISH) – are also used for purposes of retrospective dosimetry.

The pattern of chromosome aberrations in a cell after low dose exposure can deliver valuable information retrospectively about the kind of irradiation involved. In the case of x-ray or gamma radiation – so-called sparsely ionizing radiation or "low LET radiation" – we usually find only one aberration per cell, perhaps a dicentric chromosome. Figure 4 shows the metaphase of a lymphocyte after the passage of an alpha particle, which causes a higher number of aberrations, in this case 3 dicentrics, along its densely ionizing track.

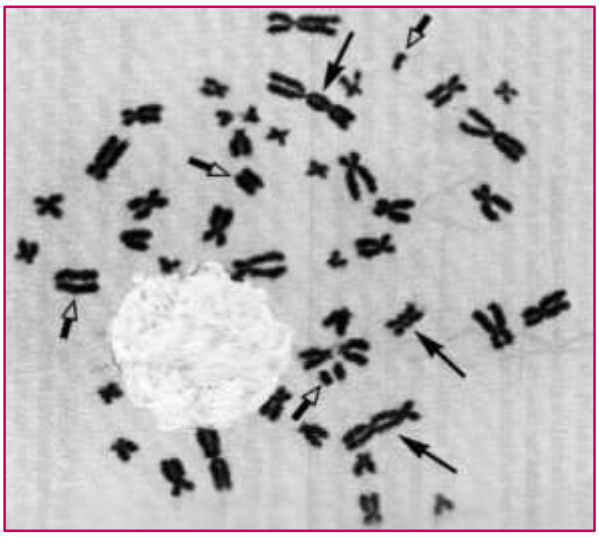


*Figure 4. Multiaberrant cell (metaphase of a human lymphocyte) after irradiation*

Radiation-induced chromosome aberrations in somatic cells are assumed to be a direct cause of cancer induction as they can also occur in the telomeres. These are the terminal ends of the arms of chromosomes. Mutations in the telomeres are thought to play a role in the development of cancer.

Irreversible changes in genetic material as a result of radiation, i.e., mutations, may also occur in single genes. Genes are segments of DNA, the nature of which is determined by the sequence of the bases.

They are arranged in linear order on the chromosomes. Each gene has a specific position or *locus* on the chromosome.

A mutation in any one of the genes can produce a change in morphology or physiology or both. The effects found by Muller in drosophila are gene mutations generated in the sex-linked genes. They can be dominant or recessive. Dominant genetic mutations are more easily detected as they are expressed in the F1 generation (following the exposed parents). Dominant lethal mutations result in death of the embryo. Recessive mutations will not be expressed unless they are present at both the homologous *loci*, i.e. the mutation is received from both parents. An example of a recessive mutation is the cleft palate.

Mutations which affect the irradiated individual only are called somatic. Gene mutations in the somatic cells can lead to delayed effects like cancer induction. Mutation of the p53 gene is one of the most common changes reported in human cancers.

Mutations in man are not specific to radiation and radiation-induced mutations are not distinguishable from spontaneous mutations. This poses a problem when investigating radiation effects.

Studies of the children of people who were themselves affected by Chernobyl fallout have shown that gene mutations are induced by low dose exposures. Weinberg and co-workers (2001) studied DNA sequences at certain *loci* in parents and descendants by the method of polymerase chain reaction (PCR). They investigated a group of liquidators whose families lived in regions without contamination. The children of the exposed fathers showed mutations which had newly developed. The controls were children of the same father (and mother) before exposure.

## Current official risk evaluation of radiation-induced hereditary disorders

Previously, genetic effects in descendants were thought to be the most significant injuries caused by radiation. This is why the measure used in protection against x-rays in medicine was called the "genetically significant dose".

Although many genetic defects were observed after the Chernobyl accident, which had not been recognized before, and the evidence of known effects was confirmed, the ICRP substantially decreased their risk estimate in 2007. Their risk coefficient for heritable effects in an exposed population was lowered by a factor of 6 in comparison with the former estimate (Table 1). They refer to "new concepts" for genetic risk estimations developed by the radiation committees of the United Nations [UNSCEAR 2001] and the National Academy of Sciences of the U.S.A. [BEIR 2006].

*Table 1.* ***ICRP Recommendations 2007****: Detriment adjusted nominal risk coefficients for radiation effects in an exposed population*

| | Present | ICRP 1990 |
|---|---|---|
| Heritable effects | **0.2 % per Sv** | 1.3 % per Sv |
| Cancer deaths | 5.5 % per Sv | 6.0 % per Sv |

The value of 0.2 % per Sv means that, if a population is exposed to a gonadal dose of 1 Sv, a genetic disorder will occur in 0.2 % of the newborn children. 1 Sv = 1000 mSv is quite a high dose and the genetic risk is estimated to be much lower than the cancer risk – for 1 mSv additional exposure 2 hereditary disorders in 1 million births. (Approximately 1 mSv per year is the natural background exposure, radon in houses not included.).

Their risk estimate (derived from experiments in mice) only considers heritable defects due to dominant mutations in the first generation that follows. It corresponds to a doubling dose of about 2 Sv [UNSCEAR 2001].

The ICRP claims that there is no direct evidence that children of exposed parents will suffer from heritable diseases. They refer to their preferred human reference group, the Japanese survivors of the atomic bomb explosions in Hiroshima and Nagasaki in 1945. An American-Japanese Institute in Hiroshima studied the health of survivors for decades after the war and did not find any mutations in descendants. A certain minimal risk is not excluded by ICRP referring to the evidence of such effects in animal studies.

Some scientists criticize this approach and argue that the Japanese survivors are not a suitable reference for populations exposed to chronic low dose irradiation in the workplace or by environmental contamination. And there are, indeed, many findings in exposed persons which contradict the statements of ICRP [IPPNW 2014].

## Hereditary disorders expected in humans by irradiation

What have we to expect? First I will speak about the diseases which geneticists believe are genetic, hereditary disorders. And there is a classification in four groups. (Table 2)

*Table 2.* ***Hereditary disorders*** *[Uma Devi et al. 2000]*
*(Those diseases which have been found to be inducible by ionizing radiation are highlighted in yellow by the author.)*

**(a) Mendelian**
Autosomal dominant; examples:
Huntington´s chorea, polycystic kidney, multiple polyposis, cerebellar ataxia, myotnic dystrophy.
Congenital abnormalities as syndactyly (fusion of fingers), brachydactyly (short fingers), polydactyly (more than 5 fingers or toes in each limb), taste for the chemical PTC (taste is dominant to non-taste), acondroplasia, bilateral aniridia, osteogenesis imperfect.
Autosomal recessive; examples:
Cystic fibrosis, phenylketonuria, lactose intolerance, adrenal hyperplasia.
Sex-linked; examples:
X-linked dominant/Duchenne muscular dystrophy, haemophilia A, some forms of colour blindness, fragile-X associated mental retardation, X-linked retinitis pigmentosa, X-linked recessive/birth deficit of females.
**(b) Chromosomal**
Aneuploidy (numerical chromosomal anomaly); examples:
Down syndrome (trisomy 21), Turner syndrome (X0), Klinefelter syndrome (XXY).
Structural anomalies; examples:
Cri du chat syndrome (deletion in chromosome 5), preimplantation loss, embryonal death, foetal abortions.
**(c) Polygenic**
Cluster in families; examples:
Congenital abnormalities as neural tube defects, heart defects, pyloric stenosis, cleft lip with or without cleft palate, undescended testes.
Common disorders of adult life of varying severity. Among the serious conditions are schizophrenia, multiple sclerosis, epilepsy, acute myocardial infarction, systemic lupus erythematosus. Moderately serious conditions include psychoses, Graves´disease, diabetes mellitus, gout, glaucoma, essential hypertension, asthma, peptic ulcer, rheumatoid arthritis. The least severe diseases include varicose veins of the lower extremities and allergic rhinitis. Cancer.
**(d) Non-chromosomal inheritance**
Cytoplasmic inheritance, mosaicism, imprinting etc.

**Mendelian disorders** (a) are due to defective single genes and follow Mendel´s laws of inheritance. The defective gene may belong to an autosome, which is a chromosome not influencing the sex of the individual, or it may be part of the X-chromosome.

The examples of autosomal dominant diseases listed here first appear in adult life and they are

not known to be inducible by radiation. But congenital abnormalities of the fingers or toes occur after exposure of the parents ("congenital" means that it is a feature of the newborn baby).

The other disorders named in group (a) are not known to be induced by radiation except the deficit in female births, which can be measured by the ratio of the number of male to female births.

(b) Certain disorders are accompanied by **chromosomal abnormalities**, i.e., they show alterations in the shape or number of chromosomes, both of which are detectable in the karyotype. The presence of abnormal numbers of chromosomes is called **aneuploidy**. A well-known example is Down's syndrome where chromosome number 21 is present three-fold instead of two-fold as normal. This disorder is known to be induced by radiation.

Alterations in the structure of chromosomes lead to early death of the embryo or foetus which can be studied after a miscarriage or a pregnancy termination.

(c) **Polygenic** or "**multifactorial**", "**irregularly inherited**", "**partially genetic**" refer to those traits, diseases or congenital anomalies the development of which has a genetic component, but inheritance does not follow standard Mendelian patterns, suggesting that more than one gene is involved. There may be clusters of such anomalies in families. They include severe congenital malformations ("neural tube" defects are malformations of the brain, scalp or spine with clefts as e.g. spina bifida) or severe diseases which appear in adulthood.

Cancer as a hereditary disease has been induced by irradiation in animals and must also be considered in humans (see chapter "Cancer").

(d) This group includes disorders that are obviously hereditary but are not linked to gene alterations. They are also called of "epigenetic" origin.

## Radiation-induced congenital malformations and other anomalies observed in humans

Most of the radiation-induced congenital anomalies described in the scientific literature have been observed after the Chernobyl accident, not only in the area of the exploded reactor but also in Turkey, Bulgaria, Croatia, and Germany [Busby 2009]. Because men and women were both exposed continuously to radioactive fallout, the genetic effects are not clearly distinguishable from those which can be generated by exposure of embryos and foetuses *in utero*. The incidence of malformations over time, however, shows increases for many years after the accident.

In Belarus, a central registry for congenital anomalies was established by the Ministry of Health in 1979 for continuous follow-up. The rates of anomalies before and after the Chernobyl accident can be compared [Sevchenko 1997]. Results in the 17 most contaminated regions are shown in Table 3.

*Table 3. Percentage increase in congenital malformations in 17 most contaminated regions of Belarus in the period 1987-1994 [from Lazjuk et al. 1997]*

| Kind of malformation | Elevation |
|---|---|
| Anencephaly *(lack of brain)* | 39 % |
| Spina bifida *(cleft vertebra)* | 29 % |
| Cleft lip/palate | 60 % |
| Polydaktyly *(additional fingers or toes)* | 910 %* |
| Limb reduction | 240 %* |
| Esophageal atresia *(clausura of gullet)* | 13 % |
| Rectal atresia | 80 %* |
| Multiple malformations | 128 %* |

* significant ($p<0,05$)

The authors think these effects are genetically induced because it is not plausible that doses in pregnant women rose in the period of decreasing environmental contamination and decreasing food contamination after the accident.

The genetic origin is confirmed in those anomalies which are combined with a recognized gene mutation that is not present in either of the parents. This can only have originated between the generations. This kind of congenital defect has also increased in Belarus [Lazjuk 1999).

Increased rates were recorded in the Belarussian registry at least up to the year 2004 [Yablokov 2009]. Because the data were averaged over longer periods, it is not possible to determine how long the rates were increasing, when they reached a maximum, or if they had already decreased.

Wertelecki (2010) found increased rates of congenital malformation in the years 2000-2006 –

more than 14 years after the accident – in the Ukrainian province (oblast) Rivne, about 250 km west of Chernobyl. Predominantly in the highly contaminated northern part, there are significant increases in comparison to the southern part: a 52 % increase for all malformations, 46 % for neural tube defects, 180 % for microcephaly, and 389 % for microphthalmos (abnormally small eyes).

Close to the former Soviet nuclear test site near the town of Semipalatinsk (now in Kazakhstan), the population has been exposed to large amounts of radioactivity. Above ground tests were undertaken between 1949-1963. Sviatova and coworkers (2001) studied congenital malformations in three generations of inhabitants, investigating births between 1969-1997. They found significantly increased rates of malformations as a whole, including Down´s syndrome, microcephaly and also multiple malformations in the same individual.

If a population is exposed, genetic effects will occur in the gonads of fathers as well as of mothers. In Germany, an investigation undertaken in women who were occupationally exposed to radiation, showed a 3.2-fold significant increase in congenital abnormalities, including malformations, in their offspring [Wiesel 2011]. The authors interpret this effect as generated *in utero* but do not prove such a connection because it appears improbable given the short sensitive phase in pregnancy and the ban on pregnant women working in high risk environments.

Although the study was funded by the Ministry of Environment, Protection of Nature and Nuclear Safety, these alarming results have not resulted in any action. Studies in the descendants of occupationally exposed men where the mothers were not exposed have also been undertaken and show definite hereditary effects (Table 4)

There were only a few studies before 1986, when the accident of Chernobyl occurred, in occupationally exposed cohorts and therefore also very few in their children. Exposures below the official dose limits were thought to be too low to produce statistically recognizable effects.

*Table 4. Congenital anomalies, especially malformations, in descendants (1st generation) of occupationally exposed men*

| No. | Cohort of fathers | Kind of defect | Dose | References |
|---|---|---|---|---|
| 1 | Radiologists U.S.A. 1951 | Congenital malformations: Increase 20 % | | Macht 1955 |
| 2 | Workers of the Hanford Nuclear facility, U.S.A. | Neural tube defects significantly increased by 100 % | In general < 100 mSv | Sever 1988 |
| 3 | Radiation workers at Sellafield nuclear reprocessing plant, U.K. | Stillbirths with neural-tube defects significantly increased by 69 % per 100 mSv | Mean 30 mSv | Parker 1999 |
| 4 | Radiographers in Jordan | Congenital anomalies significantly increased 10-fold | | Shakhatreh 2001 |
| 5 | Liquidators from Obninsk (Russia), 300 children | Congenital anomalies increased 1994-2002 | Mainly 10-250 mSv | Tsyb 2004 |
| 6 | Liquidators from Russia, Bryansk region | Congenital anomalies increased about 4-fold | | Matveenko 2005 |
| 7 | Liquidators from Russia 2379 newborns | Significantly increased by:<br>Anencephaly 310 %<br>Spina bifida 316 %<br>Cleft lip/palate 170 %<br>Limb reduction 155 %<br>Multiple malformations 19 %<br>All malformations 120 % | 5-250 mSv | Lyaginskaja 2009 |

The registered doses of workers in nuclear establishments (Nos. 2 and 3 in Table 4) are very low. But the alarming findings did not lead to further studies on hereditary consequences in the American or European populations concerned.

About 800,000 mainly young men from the army and other official institutions as well as reservists were "liquidators", sent after the Chernobyl catastrophe to stop radioactive emissions and for decontamination of the affected area. This is an important cohort for studying the health of descendants (Nos. 5-7 in Table 4). Typically, the anomalies seen in these groups, indicate unexpectedly high radiation sensitivity. The doubling doses are in the region of 100 mSv and below.

## Sex ratio and X-linked lethal factors

Normally, it is not possible to study how many inseminated oocytes (zygotes) will be aborted after irradiation of the gonadal cells, in humans. There is however, one way to prove such an effect. It is observed that men who were exposed before fathering will have fewer daughters than sons than is normal, i.e., the male/female sex ratio increases with dose.

Gene mutations may be responsible for the death of the zygote and will also occur in the sex chromosomes where they will predominantly affect the larger X-chromosome. The X-chromosome of the male can only be transmitted to a daughter. A dominant lethal factor will then lead to the death of the female zygote. Recessive lethal factors in the X-chromosome are much more frequent than dominant ones [Vogel 1969]. They also affect only female births.

Studies in large exposed populations can show this effect. A very impressive result was obtained in workers of the British nuclear fuel reprocessing plant at Sellafield in West Cumbria (Table 5).

*Table 5. Sex ratio for births in Cumbria [Dickinson et al. 1996]*

| All Cumbrian children | All fathers employed*) at Sellafield | Fathers employed at Sellafield > 10 mSv**) |
|---|---|---|
| **1.055** | **1.094** | **1.396** |
| *) employed before conception | | **) dose 90 days preconceptional |

A similar effect is detected in an investigation of cardiologists, who undertook interventional angiographic procedures in patients, which involve relatively high x-ray exposures at the workplace (Figure 5). The portion of female descendants declines significantly with higher exposures of the father.

German scientists Hagen Scherb, Kristina Voigt [Helmholtz Center Munich) and co-workers have shown that exposure of both parents in a population may also lead to a decline in female births. They studied different groups of inhabitants in a variety of countries after the Chernobyl accident for hereditary effects and found radiation-induced foetal deaths and early mortality, Down´s syndrome and alterations of the sex ratio in newborn children.

The sex ratio was investigated by them as a consequence of:

- Nuclear tests above ground which affected U.S. inhabitants,
- Chernobyl emissions in Europe,
- Living near European nuclear plants.

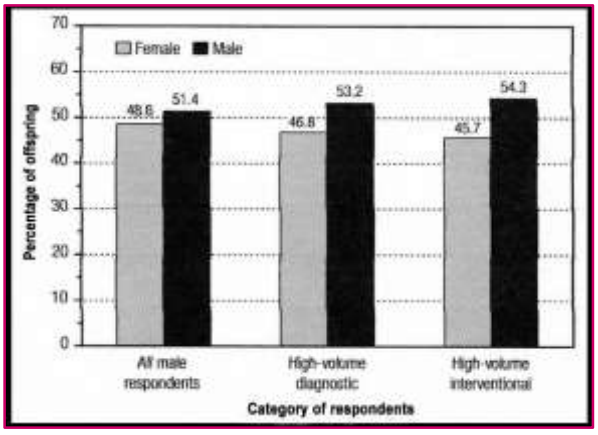



*Figure 5. Percentage of male and female offspring among cardiologists [Choi et al. 2007]*

They found significant decreases in the female birth rate in all these conditions.

Figure 6 shows the evolution of the male proportion of births after Chernobyl. The annual data show a sharp increase in the year 1987 after the accident in April 1986.

Table 6 shows their findings near nuclear plants in Germany and Switzerland. A large area (radius of 35 km), but because only a few people live in the vicinity of nuclear power plants, a significant deficit in female births is proven there.

Sex ratio is a very relevant parameter. It shows that genetic alterations are induced in the germ cells of men at very low doses, and it proves to be a sensitive indicator for exposures of the population.

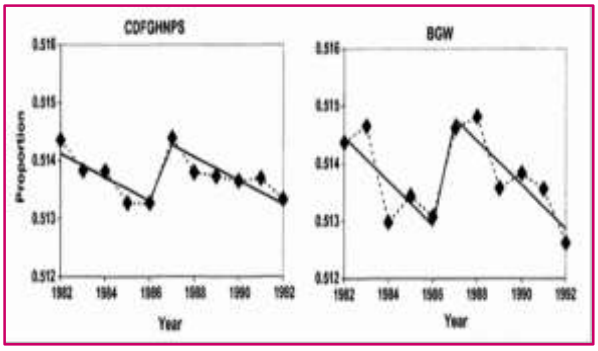



*Figure 6. Male proportion of birth rate before and after Chernobyl for the Czech Republic, Denmark, Finland, Germany, Hungary, Norway, Poland and Sweden combined (CDFGHNPS) and for Bavaria, the former GDR, and West Berlin combined (BGW) [Scherb et al. 2007]*

*Table 6. Sex ratio in newborn babies near nuclear facilities in Germany and Switzerland [Scherb et al. 2012]*

| No. (s. Fig. 2) | NF | Type | In operation since/to | Live births < 35 km during NF operation, lagged for gestation | | Sex odds ratio vs. last row of this Table | p-value ($Chi^2$) | hold one NF out p-value ($Chi^2$), compare to ** |
|---|---|---|---|---|---|---|---|---|
| | | | | male | female | | | |
| 1 | Biblis | PWR | 1975 - | 223,648 | 211,753 | 1.0017 | 0.5804 | 0.0007 |
| 2 | Obrigheim | PWR | 1969 - 2005 | 164,321 | 155,447 | 1.0026 | 0.4733 | 0.0010 |
| 3 | Neckarwestheim | PWR | 1976 - | 380,463 | 360,212 | 1.0017 | 0.4640 | 0.0005 |
| 4 | Philipsburg | BWR/PWR | 1980 - | 333,967 | 314,761 | 1.0063 | 0.0133 | 0.0019 |
| 5 | Grafenrehnfeld | PWR | 1981 - | 95,714 | 90,722 | 1.0006 | 0.8957 | 0.0007 |
| 6 | Isar I und II | BWR/PWR | 1977 - | 67,059 | 63,341 | 1.0041 | 0.4627 | 0.0011 |
| 7 | Gundremmingen | BWR | 1966 - | 142,702 | 135,276 | 1.0005 | 0.8986 | 0.0006 |
| 8 | Fessenheim | PWR | 1977 - | 99,148 | 93,694 | 1.0036 | 0.4290 | 0.0012 |
| 9 | Beznau I und II | PWR | 1969 - | 337,335 | 317,880 | 1.0065 | 0.0106 | 0.0031 |
| 10 | Goesgen | PWR | 1979 - | 220,979 | 208,604 | 1.0047 | 0.1308 | 0.0005 |
| 11 | Leibstadt | BWR | 1984 - | 143,467 | 135,293 | 1.0057 | 0.1354 | 0.0008 |
| 12 | Muehleberg | BWR | 1971 - | 218,795 | 207,560 | 0.9998 | 0.9387 | 0.0004 |
| 13 | Emsland | PWR | 1988 - | 55,502 | 52,301 | 1.0065 | 0.2915 | 0.0011 |
| 14 | Grohnde | PWR | 1984 - | 84,739 | 80,308 | 1.0008 | 0.8791 | 0.0009 |
| 15 | Wuergassen | BWR | 1972 - 1994 | 34,453 | 32,643 | 1.0010 | 0.8960 | 0.0010 |
| 16 | BR* | PWR | 1962 - 1987 | 5,332 | 5,288 | 0.9563 | - | - |
| 17 | Doel* | PWR | 1974 - | 392,512 | 375,500 | 0.9914 | - | - |
| 18 | Tihange* | PWR | 1975 - | 122,594 | 117,476 | 0.9897 | - | - |
| 19 | Dodewa* | BWR | 1968 - 1997 | 5,926 | 5,710 | 0.9843 | - | - |
| 20 | Brunsbuettel | BWR | 1977 - | 21,085 | 20,003 | 0.9997 | 0.9779 | 0.0010 |
| 21 | Brokdorf | PWR | 1986 - | 15,505 | 14,769 | 0.9957 | 0.7073 | 0.0009 |
| 22 | Kruemmel | BWR | 1984 - | 35,882 | 33,745 | 1.0085 | 0.2662 | 0.0012 |
| 23 | Stade | PWR | 1975-2003 | 43,456 | 40,771 | 1.0109 | 0.1174 | 0.0021 |
| 24 | Unterweser | PWR | 1979 - | 86,010 | 81,341 | 1.0029 | 0.5608 | 0.0010 |
| 25 | Lingen | BWR | 1968 - 1977 | 19,372 | 18,400 | 0.9985 | 0.8862 | 0.0007 |
| 26 | Karlsruhe | BWR | 1966 - 1991 | 149,269 | 140,584 | 1.0070 | 0.0624 | 0.0007 |
| 27 | Ahaus | NSS | 2000 - | 26,427 | 24,866 | 1.0080 | 0.3701 | 0.0009 |
| 28 | Juelich | NSS | 2000 - | 75,735 | 71,688 | 1.0020 | 0.7076 | 0.0008 |
| 29 | Ellweiler | UM | 1969 - | 31,361 | 29,450 | 1.0100 | 0.2225 | 0.0013 |
| 30 | Menzenschwand | UM | 1969 - | 132,037 | 124,574 | 1.0052 | 0.1892 | 0.0012 |
| 31 | Gorleben | NSS | 2000 - | 1,753 | 1,573 | 1.0570 | 0.1108 | 0.0010 |
| 32 | Hanau/Kahl | NFE | 1969 - | 54,772 | 51,343 | 1.0118 | 0.0577 | 0.0021 |
| | **German states and Switzerland < 35 km from NF** | | | **2,532,471** | **2,393,556** | **1.0035** | ** **0.0008** | |
| | **German states and Switzerland > 35 km from NF** | | | **7,948,690** | **7,538,729** | **1.0000** | **1.0000** | |

*not considered

PWR Pressurized light water nuclear power plant BWR Boiling water reactor

UM former Uranium mine NSS Nuclear storage site NFE Nuclear fuel elements

## Down´s syndrome

Even before the Chernobyl accident, scientific groups had published research showing that Down's syndrome can be induced by exposure to ionizing radiation. Increased rates of this condition have also been observed in populations living in regions with high background radiation. This is the case in the Indian state of Kerala where high concentrations of natural Thorium exist in the sands [Kochupillai 1976; Padmanabhan 1994].

The effect was also shown in high altitude regions of China that have significantly increased cosmic radiation [High Background Rad. Res. Group 1980; Wei 1990]. As already mentioned, the population near Semipalatinsk in Kazakhstan contaminated by the former Soviet nuclear test site also shows increased rates in the youngest generations [Sviatova 2001].

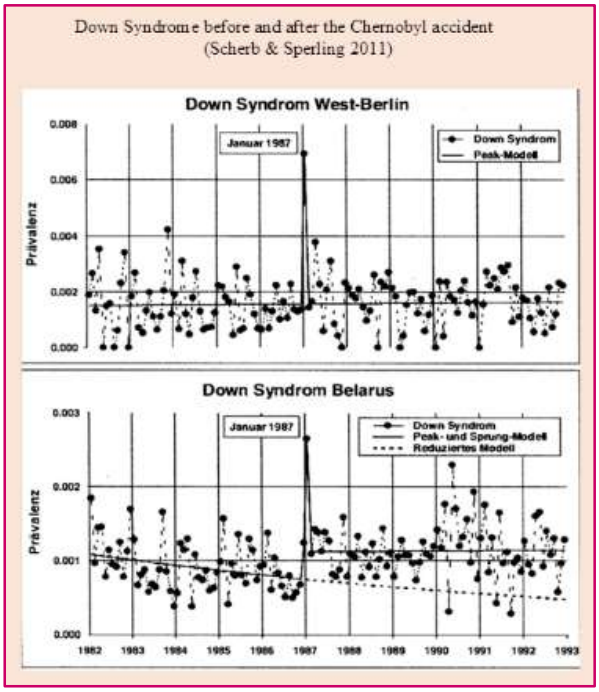



*Figure 7. Down's syndrome before and after the Chernobyl accident [from Scherb and Sperling 2011]*

After Chernobyl, the cases of Down´s syndrome increased in several contaminated European countries [Busby 2009; Sperling 2012]. Examples are shown in Figure 7. In Berlin West, which was a kind of closed island at that time, the geneticist Sperling registered a sharp and significant increase in cases exactly 9 months after the accident. A very similar situation was observed in Belarus [Zatsepin 2004]. The effect of non-disjunction for chromosome 21 is assumed to occur as a result of radiation during the first or second meiotic division of the zygote.

## Cancer

In 1984, an exceptionally high level of leukaemia cases in children and juveniles was reported in Seascale, a village near the British Nuclear Fuels reprocessing plant in Sellafield in Cumbria, UK. These were then explained by Martin Gardner and co-workers (1990) as a hereditary effect, because the fathers of the patients had worked in the plant. This result has been discussed in the literature for years and has been confirmed or denied in several subsequent studies. The effect, however, had been described in principle already in experimental studies [Nomura 1982, 2006], and has also been found after X-ray diagnostic exposures (Table 7).

*Table 7. Cancer in children after preconceptional low-dose exposure of parents*

| Exposed collective | Malign disease | Gonadal dose/mSv | Relative Risk | Doubling dose/mSv |
|---|---|---|---|---|
| Seascale fathers (Gardner 1990) | Leukaemia + lymphoma | | | |
| all stages of spermatogenesis | | 200 | 7 | 32 |
| 6 months before conception | | 10 | 7 | 1.6 |
| Sellafield workers (Dickinson 2002) | | | 1.9 | |
| Further occupational exposure of fathers | Cancer | | | |
| Military jobs (Hicks 1984) | Leukaemia + lymphoma | | 2.7 | |
| Regions of U.K. (McKinney 1991) | | | 3.2 | |
| Preconceptional X-ray diagnostics in | Leukaemia | | | |
| Fathers (Graham 1966) | | | 1.3 | |
| Fathers (Shu 1988) | | | 1.4-3.9 | |
| Fathers (Shu 1994 | | | 3.8 | |
| Mothers (Stewart 1958) | | | 1.7 | |
| Mothers (Graham 1966) | | | 1.7 | |
| Mothers (Natarajan 1973) | | | 1.4 | |
| Mothers (Shiono 1980) | | | 2.6 | |

McKinney and co-workers found a 3.2-fold increase in leukaemia and lymphomas in children of occupationally exposed men in three British regions in a case-control study (1991). The research of

Hicks and co-workers (1984) concerned exposed service men in the air force.

Statistical investigations in Belarus and the other highly contaminated neighbouring states of Chernobyl show increased cancer deaths in children who were born many years after the accident [Yablokov 2006, 2007]. Higher rates of leukaemia and other cancers have also been observed in children of liquidators [Tsyb 2004].

## Further polygenic radiation-effects

The children of liquidators did not only show malformations and cancer but also endocrine and metabolic diseases, and furthermore mental diseases [Tsyb 2004; Pflugbeil 2006; Yablokov 2009].

The national registry of Belarus was examined in 1995 by a Belarussian-Israeli group of scientists [Lomat 2007]. They found the following high rates of disease in children of Chernobyl-exposed parents:

- Hematological diseases (6-fold),
- Endocrine diseases (2-fold),
-Diseases of digestive organs (1.7-fold).

**Polygenic diseases of children with parents exposed by Chernobyl fallout** (Lomat et al. 2007):

Hematological diseases (6-fold)
Endocrine diseases (2-fold)
Digestive organs (1.7-fold)

And this is the end of the compilation of facts we observe in reality. And I wanted to discuss fact: why do the ICRP and others committees not respect all data of these findings I try to show you. That is the question we could perhaps discuss when we have the other presentations.

Thank you for your attention.◆

## References


Aghajanyan, A., Suskov, I.: Transgenerational genomic instability in children of irradiated parents as a result of the Chernobyl nuclear accident. Mutat. Res. 671 (2009) 52-57

Averbeck, D.: Non-targeted effects as a paradigm breaking evidence. Mutat. Res. 687 (2010) 7-12

Barcinski, M., Do Céu, M., Abreu, A., De Almeida, J., Naya, J., Fonseca, L., Castro, L: Cytogenetic investigation in a Brazilian population living in an area of high natural radioactivity. Am. J. Hum. Genet. 27 (1975) 802-806

Baverstock, K., Belyakov, O.V.: Some important questions connected with non-targeted effects. Mutat. Res. 687 (2010) 84-88

BEIR VII PHASE 2: Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, Health Risks from Exposure to Low Levels of Ionizing Radiation, Nat. Academies Press, Washington D.C. 2006; http://www.nap.edu

Busby, C., Lengfelder, E., Pflugbeil, S., Schmitz-Feuerhake, I.: The evidence of radiation effects in embryos and fetuses exposed to Chernobyl fallout and the question of dose response. Medicine, Conflict and Survival 25 (2009) 20-40

Choi, J.W., Mehrotra, P., MacDonald, L.A, Klein, L.W., Linsky, N.M., Smith, A., Riccardi, M.J.: Sex proportion of offspring and exposure to radiation in male invasive cardiologists. Proc. (Bayl. Univ. Med. Cent.) 20 (2007) 231-234

Dickinson, H.O., Parker, I., Binks, K., Wakeford, R., Smith, J.: The sex ratio of children in relation to paternal preconceptional radiation dose: a study in Cumbria, northern England. J. Epidemiol. Community Health 50 (1996) 645-652

Dickinson, H.O., Parker, I.: Leukaemia and non-Hodgkin´s lymphoma in children of male Sellafield radiation workers. Int. J. Cancer 99 (2002) 437-444

Domracheva, E.V., Aseeva, E.A. *et al*.: Cytogenetic features of leukaemias diagnosed in residents of areas contaminated after the Chernobyl nuclear accident. Appl. Radiat. Is. 52 (2000) 1171-1177

Feshchenko, S.P., Schröder, H.C., Müller, W.E.G., Lazjuk, G.I.: Congenital malformations among newborns and developmental abnormalities among human embryos in Belarus after Chernobyl accident. Cell. Mol. Biol. 48 (2002) 423-426

Gardner, M.J., Snee, M.P., Hall, A.J., Powell, A.J., Downes, S., Terrell, J.D.: Results of case-control study of leukaemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria. Brit. Med. J. 300 (1990) 423-429

Graham, S., Levin, M.L., Lilienfeld, A.M. *et al*.: Preconception, intrauterine, and postnatal irradiation as related to leukemia. Natl. Cancer Inst. Monogr. 19 (1966) 347-371

Hicks, N., Zack, M., Caldwell, G.G., Fernbach, D.J., Falletta, J.M.: Childhood cancer and occupational radiation exposure in parents. Cancer 53 (1984) 1637-1643

High Background Radiation Research Group: Health survey in high background radiation areas in China. Science 209 (1980) 877-880

Hoffmann, W., Schmitz-Feuerhake, I.: How radiation-specific is the dicentric assay? J. Exp. Analysis Environ. Epidemiol. 2 (1999) 113-133

ICRP, International Commission on Radiological Protection: The 2007 Recommendations of the International Commission on Radiological Protection. ICRP-Publication 103, Ann. ICRP 37 Nos. 2-4 (2007)

IPPNW International Physicians for the Prevention of Nuclear War – Physicians for Social Responsibility: Health effects of ionising radiation: Summary of expert meeting in Ulm, Germany, October 19th, 2013 http://www.ippnw.de

Kochupillai, N., Verma, I.C., Grewal, M.S., Remalingaswami, Y.: Down´s syndrome and related abnormalities in an area of high background radiation in coastal Kerala. Nature 262 (1976) 60-61

Lazjuk, G.I., Nikolaev, D.L., Novikova, I.V.: Changes in registered congenital anomalies in the Republic of Belarus after the Chernobyl accident, Stem Cells 15 (1997), Suppl. 2: 255-260

Lazjuk, G., Satow, Y., Nikolaev, D., Novikova, I.: Genetic consequences of the Chernobyl accident for Belarus Republic. In: Imanaka, T. (Ed.), Recent Research Activities on the Chernobyl NPP Accident in Belarus, Ukraine and Russia, 1999, KURRI-KR-7 (Kyoto University, Kyoto), 174-177

Lomat, L., Galburt, G., Quastel, M.R., Polyakov, S., Okeanov, A., Rozin, S.: Incidence of childhood disease in Belarus associated with the Chernobyl accident. Environ. Health Persp. 105 (Suppl. 6) 1997, 1529-1532

Lyaginskaja, A.M., Tukov, A.R., Osipov, V.A., Ermalitskiy, A.P., Prohorova, O.N.: Congenital malformations at posterity of the liquidators of the consequences from Chernobyl accident. Radiazionnaya Biologiya Radioekologiya 49 (2009) 694-702 (Russ.)

Macht, S., Lawrence, P.: National Survey of congenital malformations resulting from exposure to Roentgen radiation. Am. J. Roentgenol. 73 (1955) 442-466

Matveenko, E.G., Borovykova, M.P., Davydow, G.A.: Physical characteristics and primary morbidity in liquidator´s children. In Konferenzproceedings "Chernobyl 20 Years After", 2005, cited from Yablokov 2009, p. 148

McKinney, P.A., Alexander, F.E., Cartwright, R.A., Parker, L.: Parental occupations of children with leukemia in west Cumbria, north Humberside, and Gateshead. Br. Med. J. 302 (1991) 681-687

Muller, H.J.: Über die Wirkung der Röntgenstrahlung auf die Erbmasse. Strahlentherapie 55, 1936, 207-224

Natarajan, N., Bross, I.D.J.: Preconception radiation leukemia. J. Med. 4 (1973) 276-281

Nomura T 1982 Parental exposure to X-rays and chemicals induces heritable tumours and anomalies in mice Nature 296 575-7

Nomura, T.: Transgenerational effects of radiation and chemicals in mice and humans. J. Radiat. Res. 47, Suppl. (2006) B83-B97

Padmanabhan, V.T., Sugunan, A.P., Brahmaputhran, C.K., Nandini, K., Pavithran, K.: Heritable anomalies among the inhabitants of regions of normal and high background radiation in Kerala: results of a cohort study, 1988-1994. Int. J. Health Serv. 34 (1994) 483-515

Parker, L., Pearce, M.S., Dickinson, H.O., Aitkin, M., Craft, A.W.: Stillbirths among offspring of male radiation workers at Sellafield nuclear reprocessing plant. Lancet 354 (1999) 1407-1414

Pflugbeil, S., Paulitz, H., Claußen, A., Schmitz-Feuerhake, I.: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. In IPPNW, Ges. f. Strahlenschutz e.V. Berlin, April 2006, 76 p.

Pohl-Rüling, J., Fischer, P.: The dose-effect relationship of chromosome aberrations to $\alpha$ and $\gamma$ irradiation in a population subjected to an increased burden of natural radioactivity. Radiat. Res. 80 (1979) 61-81

Scherb, H., Weigelt, E.: Zunahme der Perinatalsterblichkeit, Totgeburten und Fehlbildungen in Deutschland, Europa und in hochbelasteten deutschen und europäischen Regionen nach dem Reaktorunfall von Tschernobyl im April 1986, Berichte des Otto Hug Strahleninstituts Nr. 24 (2003) 35-75

Scherb, H., Weigelt, E.: Cleft lip and cleft palate birth rate in Bavaria before and after the Chernobyl nuclear power plant accident. Mund Kiefer Gesichtschir. 8 (2004) 106-110

Scherb, H., Voigt, K.: Trends in the human sex odds at birth in Europe and the Chernobyl Nuclear Power Plant accident. Reprod. Toxicol. 23 (2007) 593-599

Scherb, H., Voigt, K.: The human sex odds at birth after the atmospheric atomic bomb tests, after Chernobyl, and in the vicinity of nuclear facilities. Environ. Sci. Pollut. Res. 18 (2011) 697-707

Scherb, H., Sperling, K.: Heutige Lehren aus dem Reaktorunfall von Tschernobyl. Naturwiss. Rundschau 64, Heft 5 (2011) 229-239

Scherb, H., Voigt, K., Kusmierz, R.: Modelling human radiation risks around nuclear facilities in Germany and Switzerland: a case study. In Seppelt, R. *et al*. (Eds.) 2012 Int. Congr. Environ. Modelling and Software Managing Resources of a Limited Planet. Sixth Biennial Meeting, Leipzig, Germany http://www.iemss.org/society/index.php/iemss-2012-proceedings

Schmitz-Feuerhake, I.: How reliable are the dose estimates of UNSCEAR for populations contaminated by Chernobyl fallout? A comparison of results by physical reconstruction and biological dosimetry. ECRR Int. Conference „Criticisms and Developments in the Assessment of Radiation Risks" in Molyvos, Lesbos, Greece, May 5-6, 2009. Proceedings 2011, 70-85

Sever, L.E., Gilbert, E.S., Hessol, N.A., McIntyre, J.M.: A case-control study of congenital malformations and occupational exposure to low-level ionizing radiation. Am. J. Epidemiol. 127 (1988) 226-242

Shakhatreh, F.M.: Reproductive health of male radiographers. Saudi Med. J. 22 (2001) 150-152

Shevchenko, V.A., Platonov, E.S., Snigiryova, G.P.: Genetic consequences of disaster at Chernobyl nuclear plant on April 26, 1986. In: Int. Association for Restoration of the Environment and for Safe Living of People "Senmurv" (Minsk-Moscow-Kiev): Chernobyl Accident. Reasons and Consequences. Ed. V.B. Nesterenko, Minsk 1997, P. 213-245

Shiono, P.H., Chung, C.S., Myrianthopoulos, N.C.: Preconception radiation, intrauterine diagnostic radiation, and childhood neoplasia. J. Natl. Cancer 65 (1980) 681-686

Shu, X.O., Gao, Y.T., Brinton, L.A., Linet, M.S., Tu, J.T., Zheng, W., Fraumeni, J.F.: A population-based case-control study of childhood leukemia in Shanghai. Cancer 62 (1988) 635-644

Shu, X.O., Reaman, G.H., Lampkin, B., Sather, H.N., Pendergrass, T.W., Robison, L.L.: Association of paternal diagnostic x-ray exposure with risk of infant leukemia. Cancer Epidemiol., Biomarkers & Prevention 3 (1994) 645-653

Sperling, K., Neitzel, H., Scherb, H.: Evidence for an increase in trisomy 21 (Down syndrome) in Europe after the Chernobyl reactor accident. Genet. Epidemiol. 36 (2012) 48-55

Stewart, A., Webb, J., Hewitt, D.: A survey of childhood malignancies. Brit. Med. J. (1958) 1495-1508

Sviatova, G.S., Abil´dinova, GZh., Berezina, G.M.: Frequency, dynamics, and structure of congenital malformations in populations under long-term exposure to ionizing radiation. Genetika 37 (2001) 1696-1704 (Russ.)

Tsyb, A.F., Souchkevitch, G.N., Lyasko, L.I., Artamonova, Yu.Z., Nvolokon, V.V., Raykina, L.G.: General characterization of health in first-generation offspring born to liquidators of the Chernobyl NPP accident consequences. Int. J. Radiat. Med. Special Issue 6 (1-4) 2004; http://www.mns.gov.ua

Uma Devi, P., Nagarathnam, A., Satish Rao, B.S.: Introduction to Radiation Biology. B.I. Churchill Livingstone PVT Ltd. New Delhi 2000

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation: Sources, effects and risks of ionizing radiation. 1988 Report to the General Assembly, United Nations, New York 1988

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation: Hereditary effects of radiation. 2001 Report to the General Assembly, United Nations, New York 2001; http://www.unscear.org/

Vogel, Friedrich *et al*.: Strahlengenetik der Säuger. Band 1. Fortschritte der allg. und klinischen Humangenetik. Eds. E. Becker *et al*., Georg Thieme Verlag Stuttgart 1969

Wang, Z., Boice, J.D., Wei, L., Beebe, G.W., Zha, Y., Kaplan, M.M., Tao, Z. *et al*.: Thyroid nodularity and chromosome aberrations among women in areas of high background radiation in China. J. Nat. Cancer Inst. 82 (1990) 478-485

Wei, LX., Yongru, Z., Zufan, T., Weihui, H., Deqing, C., Yongling, Y.: Epidemiological investigation of radiological effects in high background radiation areas of Yangjiang, China. J. Radiat. Res. 31 (1990) 119-136

Weinberg, H.Sh., Korol, A.B., Kirshner, V.M. *et al*.: Very high mutation rate in offspring of Chernobyl accident liquidators. Proc. R. Soc. Lond. B 268 (2001) 1001-1005

Wertelecki, W.: Malformations in a Chornobyl-impacted region. Pediatrics 125 (2010) 836-843

Wiesel, A., Spix, C., Mergenthaler, A., Queißer-Luft, A.: Maternal occupational exposure to ionizing radiation and birth defects. Radiat. Environ. Biophys. 50 (2011) 325-328

Yablokov, A.V.: The Chernobyl catastrophe – 20 years later. In C.C. Busby, A.V. Yablokov (Eds.), European Committeee on Radiation Risk ECRR, Chernobyl: 20 Years on. Green Audit 2006; http://www.euradcom.org

Yablokov, A.V., Nesterenko, V.B., Nesterenko, A.V.: Chernobyl– Consequences of the catastrophe for people and the environment. Ann. New York Academy of Sciences Vol.1181, Boston 2009 http://independentwho.org/media/Documents_Autres/Chernobyl_Consequences_of_the_catastrophe_for_people_and_the_environment_Reduit.pdf

Zatsepin, I.O., Verger, P., Robert-Gnansia, E., Gagniere, B., Khmel, R.D., Lazjuk, G.I. (2004): Cluster of Down´s syndrome cases registered in january 1987 in Republic of Belarus as a possible effect of the Chernobyl accident, Int. J. Radiat. Med. Special Issue 6 (1-4), Kiev: 57-71; http://www.mns.gov.ua

# Question and answer session

***Ruth Stégassy***

Thank you very much. If there are points that seem unclear on which you would like to have clarification, now is the time.

## Question

My question relates to the natural background radiation measurements that were included in the presentation. Has this background increased since 1945, or is it impossible to say whether it has increased or not, in the last 60, 70 years?

***Ruth Stégassy***

You talk about natural radioactivity?

Absolutely. Called natural, that's to say, what we can currently measure. It is called natural, but is it not already caused by an amount of artificial radionuclides which have spread already on the planet? To be sure that it is natural, should it not be measured before the first bombings, in practice, before 1945? Or even before 1943?

## Answer

***Inge Feuerhacke***

As I know, the most influx of background radiation is generated by radon in houses. The natural concentration of radon is elevated in houses which are isolated against… in order to stir the insulated. And that is, they say about 2 mSv per year. And as I know the former nuclear tests in background until 1963 they have no discernible increase to the background. If the French reprocessing plant in La Hague emits krypton, as an adoptive product of the nuclear fission, we can measure it in Germany, but it is not really proportion which elevated significantly the background, from formerly background.

Is it what you wanted to know?

***Ruth Stégassy***

It's ok.

## Comment

I just want to complete what Madame said. I completely agree, but it must be remembered that regarding the natural background radiation here, we have a value that indicates 1 millisievert per year. It's very, very variable. In the German area and here, in Gex, it could be variations of 0.2 millisievert. This means that if you moved from Saint Genis to Sergy, your external exposure from soil will increase by 0.2 millisievert. Just through the effect of moving.

On contamination after the nuclear tests in the 60s, there has been contamination by $^{90}$strontium, $^{14}$carbon, tritium. Apart from $^{90}$strontium which is always found in the bones of new-borns, concentrations of $^{14}$carbon and tritium are almost down to a negligible level. Not due to radioactive decay, but because of the exchange with the huge masses of Ocean. But today, the natural background radiation values of tritium and $^{14}$carbon are completely normal. ◆

# Summary of past and present studies on the genetic effects of ionizing radiation,

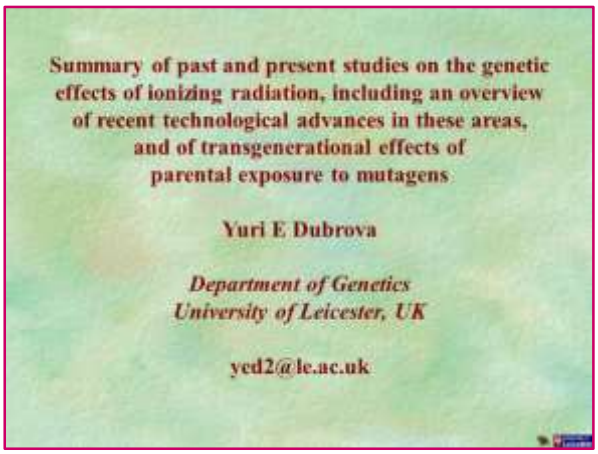
## including an overview of recent technological advances in this area, and of transgenerational effects of parental exposure to mutagens

*Dr **Yuri E. Dubrova**, Department of Genetics, University of Leicester, United Kingdom*

## Introduction *by **Ruth Stégassy***

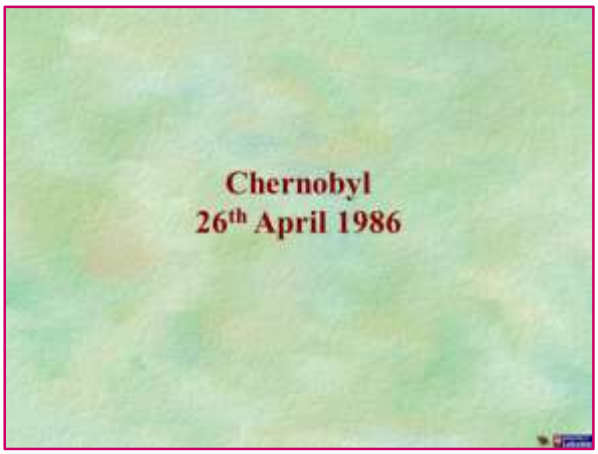
***Dr Yuri E. Dubrova** professor of genetics at the University of Leicester (UK), was born in Kiev (Ukraine). He obtained a BSc degree in Biology at Kiev State University and a PhD in Genetics Vavilov Institute of General Genetics in Moscow, where he undertook a number of research projects in population genetics. In 1994 he moved to the Department of Genetics, University of Leicester, to study the genetic effects of exposure to ionising radiation and chemical mutagens in mammals. Professor Yuri Dubrova's research interests focus on the analysis of germline mutation induction in humans and mice following exposure to ionising radiation, chemical mutagens and some anticancer drugs. His recent research has also involved transgenerational genomic instability manifesting in the offspring of exposed parents. He is the author of more than 110 peer-reviewed publications in his field.*

# Presentation

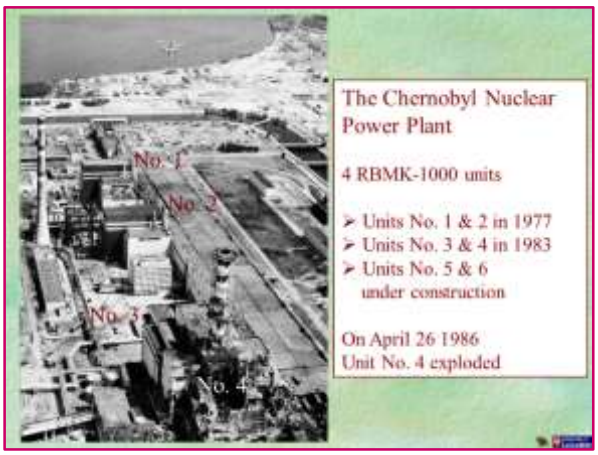



First at all, thank you very much indeed for a very kindly invitation to present our data here, I'm absolutely delighted and honoured.

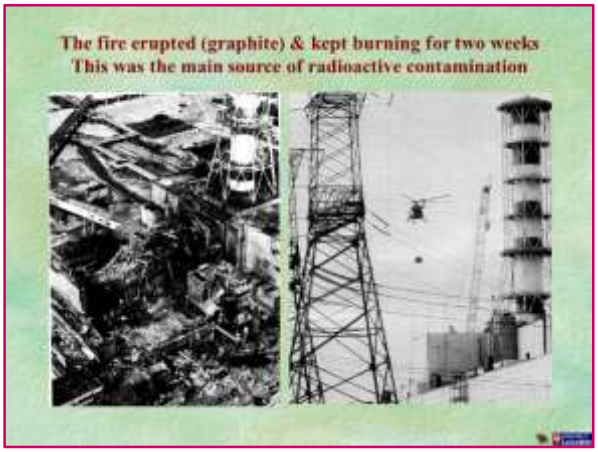
So, what I'm going to do today. I'm going to skip a lot of science. It's boring. I'm going to tell you about a story of one man-made experiment, called Chernobyl, and what happened after. Not only to the people who were affected by the disaster, but also what happened to us scientists, working trying to analyse the genetic effects of this disaster, perfectly illustrates where we are now with regards to the analysis of these effects. And most importantly where we should be analysing these effects.




So what happened? It was the 26th of April 1986.



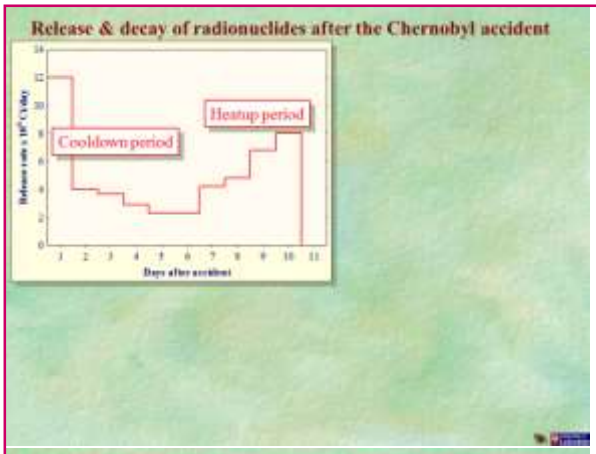

This unit, unit number 4, exploded. For many reasons, sending huge amounts of radioactivity in the atmosphere. So it was man-made disaster which happened 20 and something years ago. What happened? It's not only that the reactor exploded, the key problem was: the whole thing was filled with graphite and it starting burning.

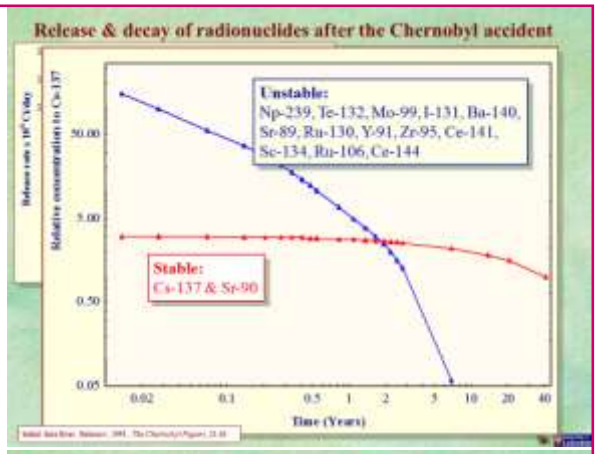


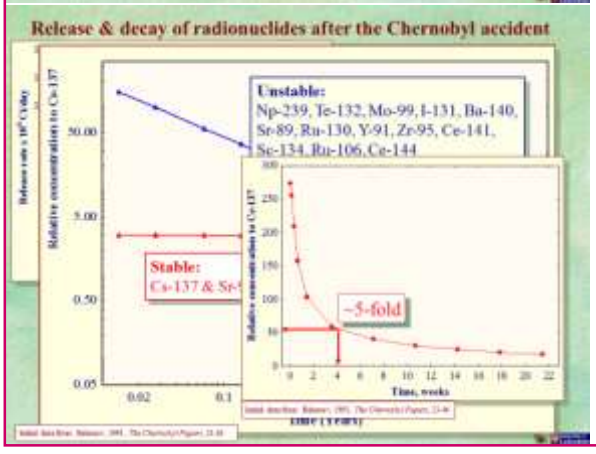

And for 10 days, despite all the heroic efforts, they couldn't do anything about it. And burning graphite was sending huge amounts of radioactivity in the atmosphere. So, the main source of contamination was not the explosion per se, but was a fire, which occurred after. As a result what is this wonderful multicolour map.

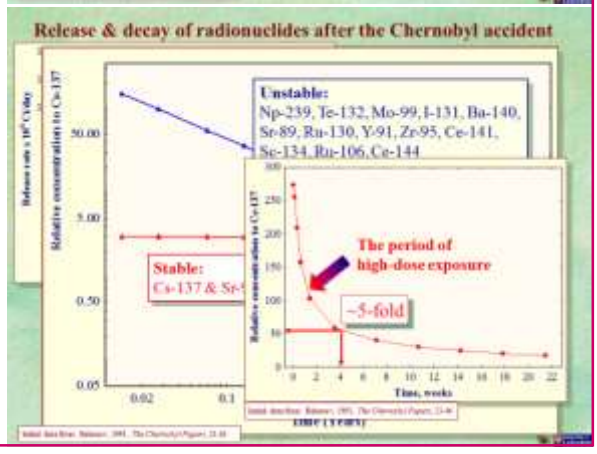

This is Chernobyl, these are the most heavily contaminated areas nearby of Belarus, Ukraine and Russia. And if you think that the rest of Europe got away, think again by the way: Switzerland, United Kingdom, Scandinavian and so on, also got their share. So, to put it in plain English, Europe was sheeted by radioactivity.

The way the whole thing was burning was quite interesting. It was initial period immediately after the eruption, after the fire broke there, then it went down and only on day eleven, after heroic efforts of hundreds of people, they managed to seal the hole over the reactor. And that was it. That was the end of polluting the atmosphere. So, what was released?



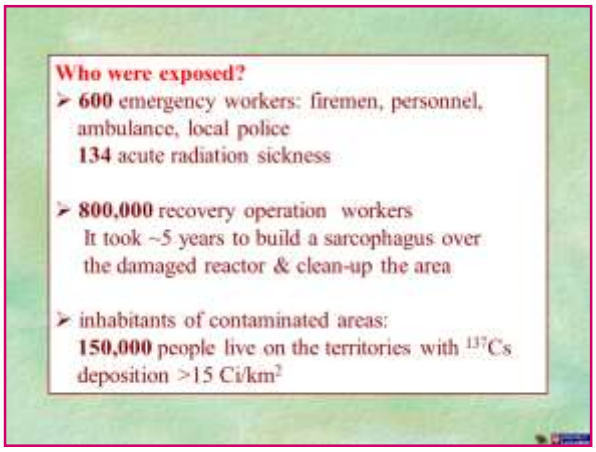



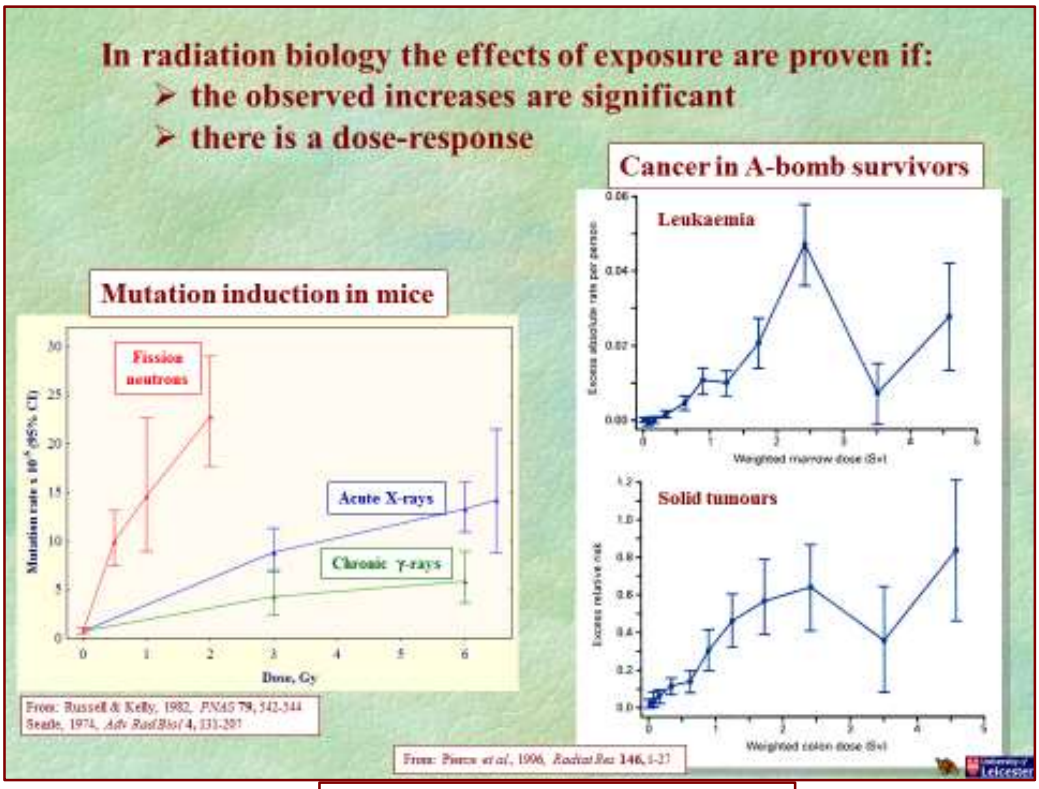
Stable isotopes, caesium most, caesium and strontium with a half-life of roughly 30 years.

So, even 40 years after, the whole thing is still screaming, but what was most interesting: huge amounts of unstable stuff was released. With a half-life ranging from minutes to weeks. And in a matter of weeks, few weeks, the amount of radioactivity dropped down to five fold, because it was attributed mostly to highly unstable nuclides. So we're having here a period of high dose exposure to those who happened to be nearby. And then the period of a long protracted chronic exposure.

Who were exposed? 600 of what we call emergency workers: firemen and ambulance personnel, local police, basically those heroic people who went straight into hell. They were doing their best, to close the reactor and to make sure that it did not fume anymore radioactivity. Then the next group, at our estimation 800 thousand recovery workers, or liquidators, and it's those who appear after the reactor was sealed, and they started decontaminating the area, and they started building the sarcophagus over the place. But there are also another group of people, innocent bystanders, people who are still living in the territories, highly contaminated by nuclides, such as caesium and strontium. They mostly inhabit territories in Belarus, Ukraine and some parts of Russia.




Why, I'd like to make clear? In radiation biology the effects of exposure are proven if: the observed increases are significant and there is a data/dose response. Examples.

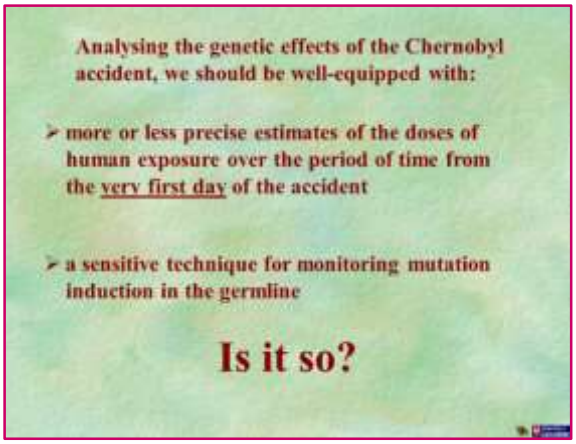



**Is this the case for post-Chernobyl studies?**

Well normal data, the dose of radiation, the early mutation in the sperm of irradiated mice. The effect is here, the dose response is also here. Already mention data obtained in the Hiroshima-Nagasaki. The incidence of cancer. The effects for leukaemia and solid tumours are here. The dose response is also here.

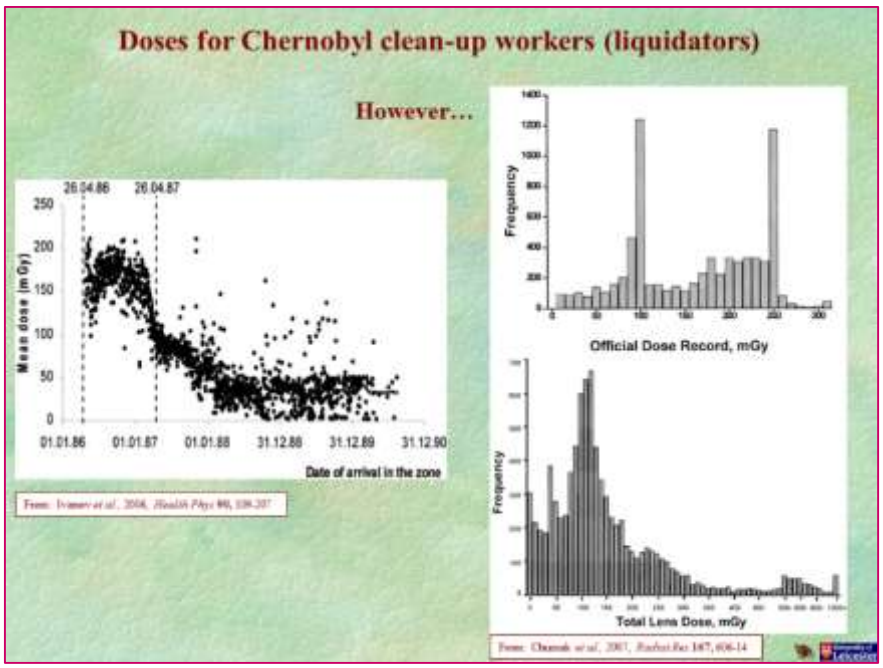
And the question is: is that the case of the post-Chernobyl studies? So, do we see enough evidence for observed increases, which are significant? And do we have enough even evidence for dose response?

Analysing the genetic effects of the Chernobyl accident we should be well-equipped with more or less precise estimates of the doses of human exposure over the period of time from the very first day of the accident, when the doses were high. And a sensitive technique for monitoring mutation induction in the germline.



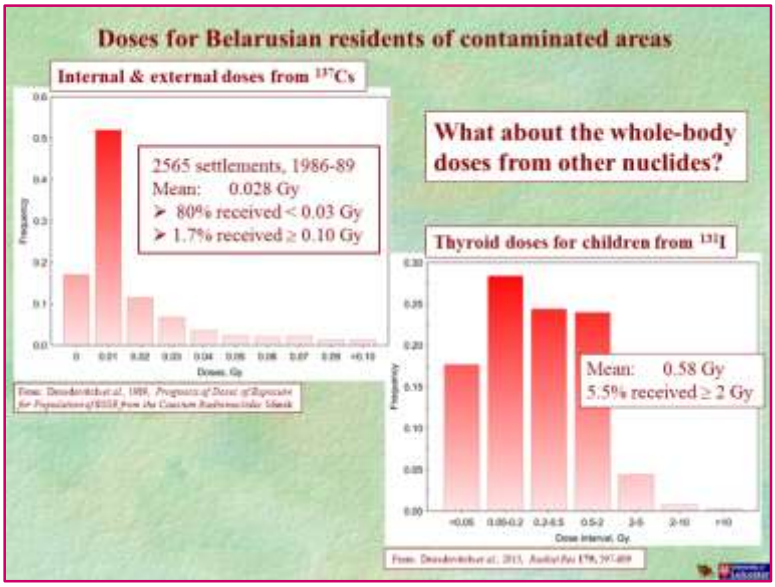

So we should pick up mutants, the majority of them, in the children of irradiated parents, and control parents, we should compare the numbers, frequency and so on. And only then will maybe we are in the position to tell you what's going on. Is it so? The answer is, no, of both questions.

## Doses of exposure




That was we got for group of people who took part in decontamination. This is estimate based on physical dosimetry.

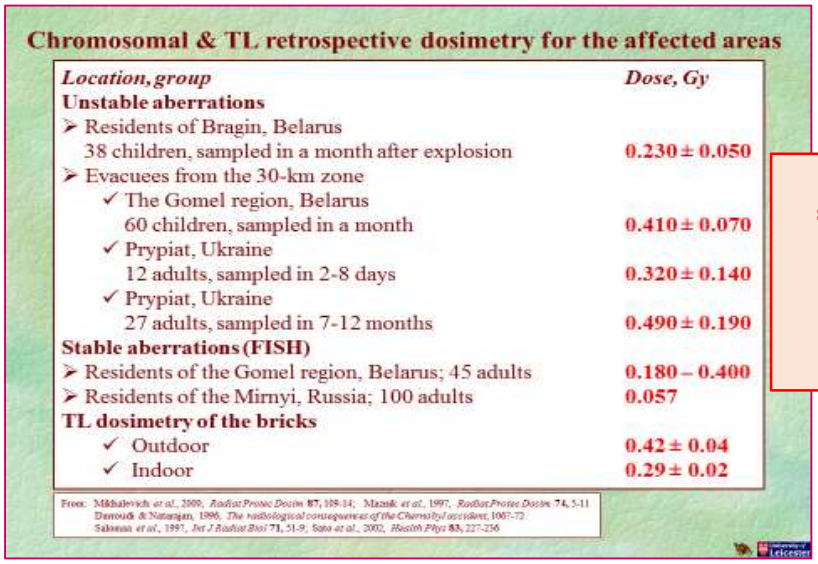
Now, look here. The same study: they use official data for the liquidators, and then they did another analysis of the doses. No need to go into details to see that the two distributions are clearly different. So, even here we got plenty of uncertainties. The situation is getting more complicated when we go to people who live in the contaminated areas.




This is official estimates, obtained by meter physical dosimetry, for people living in the most heavily contaminated areas of Belarus.

But these estimates take into account only one thing: exposure from the long life isotopes such as caesium and strontium. But we don't know anything, according to my knowledge, about the doses of exposure from short life stuff. But what the beauty of human body is: we accumulate mutations as we speak. So, as we speak now you're getting more mutations in your body. So the number of accumulated mutations in my body, in your body depends on your age and the history of your exposure to any sort of mutagen. Including ionizing radiation. This is what we called biological dosimetry.

Have a look, a handful of data for residents of Belarus and Ukraine.




**Clearly, the results of these studies substantially differ from the estimates shown on the previous slide**

**0.2 – 0.5 Gy *v* 0.00 – 0.10 Gy!**

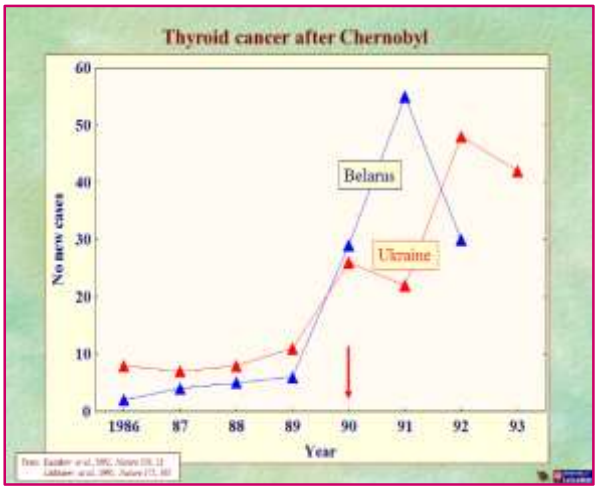
**Q. Who is right and who is wrong?**

The doses here reconstructed on the base of the number of mutations, chromosomal aberrations that people accumulated, are far higher. So they claim by biological dosimetry, doses up to half a Gy. The best estimates using physical dosimetry of the same area is no more than 0.10 Gy.

Who is right and who is wrong? I don't know.

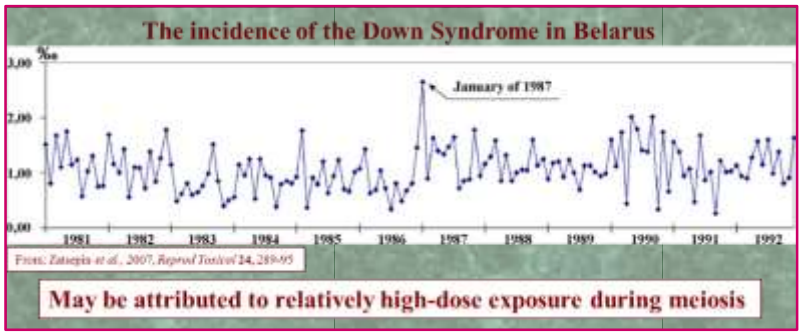
## What happened after?

Well-known drastic increase in the incidence of thyroid cancer among the children on heavily contaminated areas of Belarus and Ukraine and also the same through of some area of Russia.




Other endpoints. So, what happened after? Leukaemia, solid cancers, non-cancer diseases, somatic mutations… also those things, the most compelling evidence we have of that amount of accumulated somatic mutations in those who were exposed either in the work in decontamination around the reactor, or those living in the contaminated territories, are up. The rest is, evidence is vague, not entirely precise and so on.

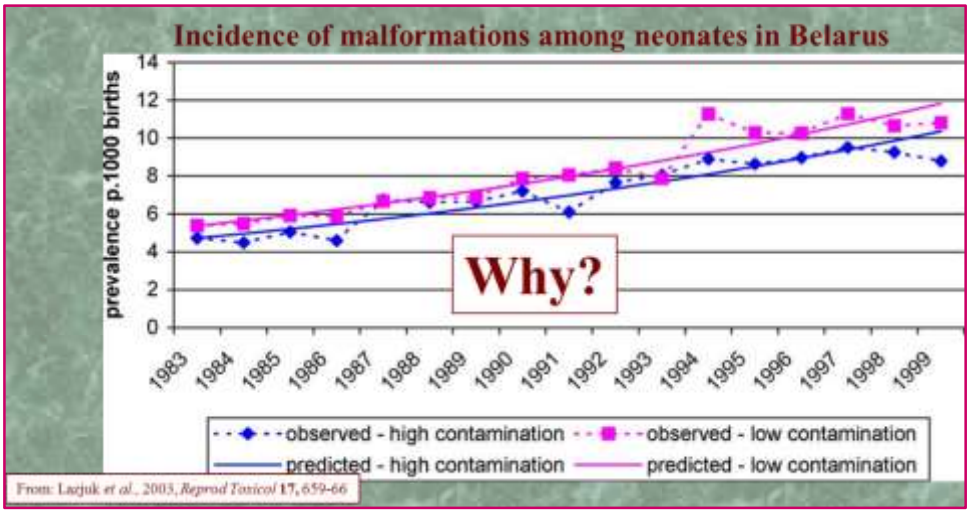

The genetic effects even more complicated. I did it to put two columns here: the positive data, the negative data. So, it's all over the place. So, for the frequencies of miscarriages in the Finland we see something, in Sweden and Hungary and Austria we don't see. Perinatal death in Germany up, in Belarus, Hungary and Norway no. Malformation in embryos and in birth in Belarus up, in Hungary, Norway, Austria and Sweden no. And so on.



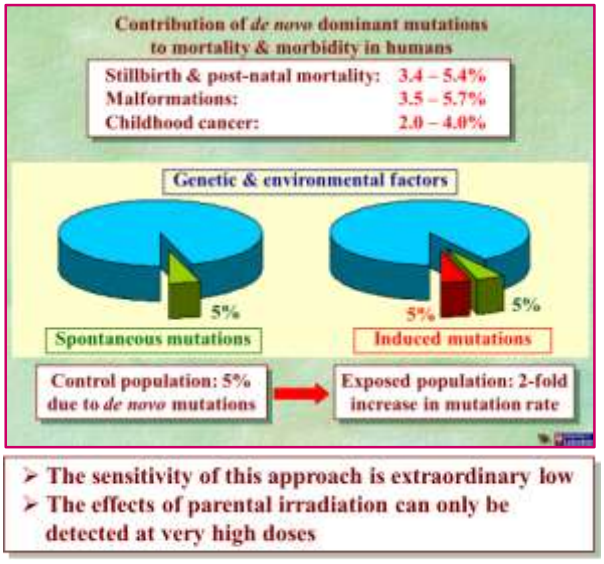

In this example are demonstrated the Down syndrome.

It's very interesting because what you see here – the data replicated in Germany, Belarus and Scotland – a sudden jump here, basically 9 months after the disaster. Why?

If people are exposed at the moment when they are conceiving a child, their gene cells are at the end of the life cycle. So, they're going to the final stage of their maturity. And they are extremely sensitive to any sort of environmental factors. So here, both parents were exposed to Chernobyl at the moment of conception practically. They got doses. Their gene cells being very sensitive to ionizing radiation got extra chromosome, and as result we have spike of Down syndrome here.

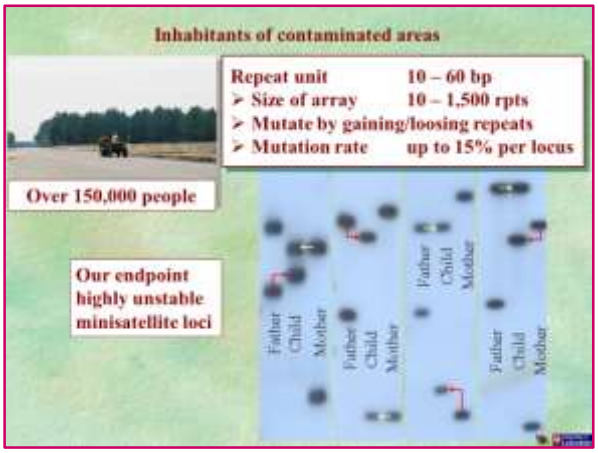



If you look on the dimension data of the number of congenital malformations in Belarus, then you will see first of all both in clean areas and contaminated areas, it goes up. We don't know why, but the fact is: in Belarus the percentage of congenital malformations of children goes up. There are plenty of speculations on the way, but this is the case. But the thing is, there is no difference between contaminated areas and non-contaminated. Why? It's easy to explain because a percentage of mutations which are in charge of making children malformed is extremely low.

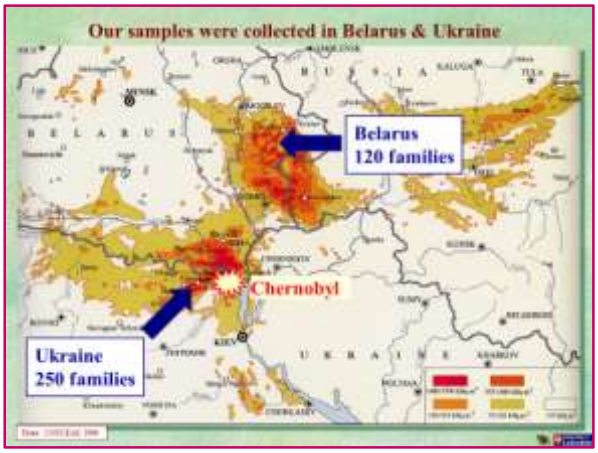


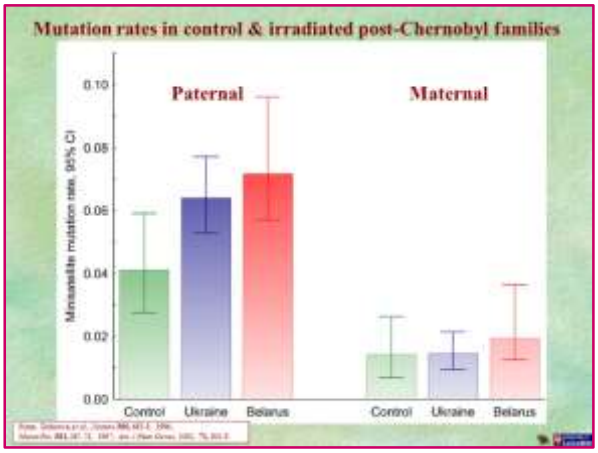

And there is no way you can detect these small changes, analysing the incidence of malformations in children.

To this end we decided, ages ago, we should try something else. And to do this, our collaborators went to the most heavily contaminated areas of Belarus and Ukraine, collected blood samples for our study, and we started looking for mutations affecting very bizarre sequences in our genome, called minisatellites.



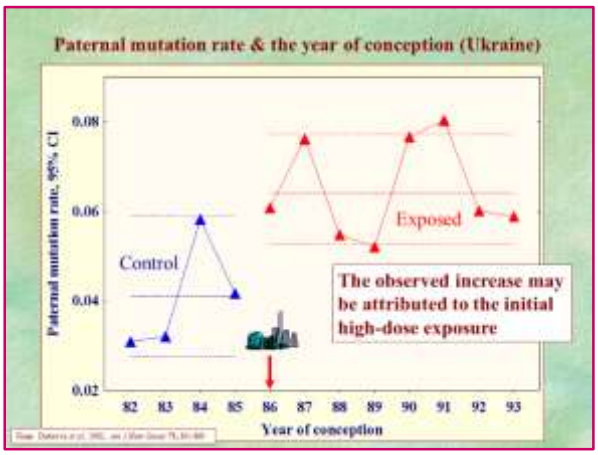

These sequences they mutate by gaining or losing a certain number of repeats, and it's quite easy to find these mutations. So, imagine you have a train consisting of many carriages. At the station someone either adds a couple of carriages or removes them. This is what is happening with these repeats in sequences and this is what we are analysing. We collected samples here in Belarus and also in Ukraine, in quite heavily contaminated areas, all people living there from the very beginning of the disaster, and look what's going on here.




Mutation rate in fathers, i.e. we are here measuring main mutants which occurred in the sperm of fathers, and eggs of those mothers. And what we found here: highly significant increase in a number of mutations occurring in sperm. So, fathers are sensitive to ionizing radiation according to our data. This is not the case for mothers.

What's also interesting here is this one.



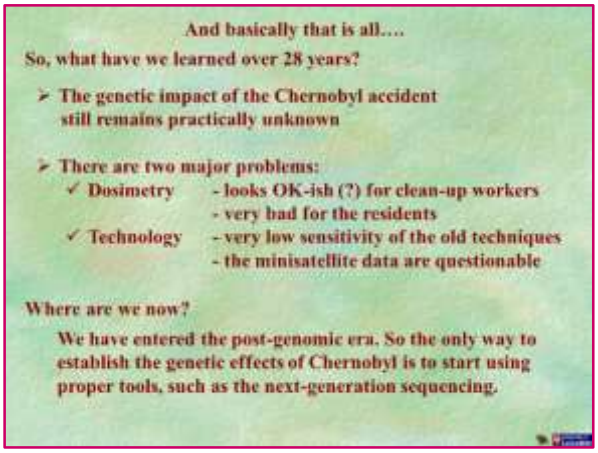

We looked on the number of mutations in fathers, depending on the age of year of conception. So, this is how many mutants in sperm of fathers, who are doing their job in 1982, 1983 and so on, before the Chernobyl disaster.

This is Chernobyl, and this is what went on in sperm of fathers doing business in 87, 88 and so on. So, just I'm showing this graph you will see immediately one thing. The whole thing is up but flat. So, what does it tell us? One thing. That they got all mutants here, immediately after the disaster. So, high dose exposure in a matter of few weeks after Chernobyl gave them this.

The rest exposure to caesium and strontium, weeks and months after the disaster, was practically irrelevant.

## And basically that is all…

So, let me sum up. What have we learned over 28 years after the disaster?

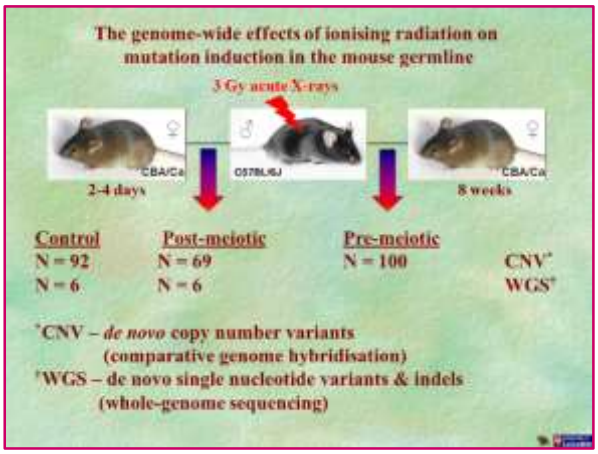



The genetic impact of the Chernobyl accident still remains practically unknown. I'm telling you this with sacrifice of ten years of my life analysing the effects, and still the effects are largely unknown. There are two major problems. Dosimetry, it looks OK-ish for clean-up workers, and extremely bad for the residents. And technology, very low sensitivity of the old techniques, our minisatellites data are questionable.

So, where are we now?

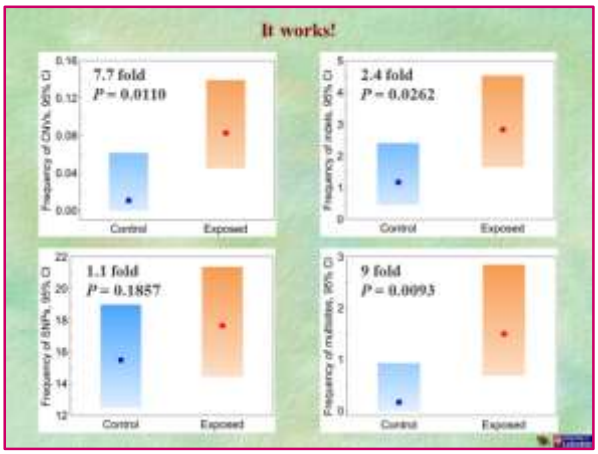
Fortunately we're living at the post-genomic era. Now we got plenty of very powerful tools, and

we can start measuring what's going on, not on the level of handful of genes but at the level of the whole genome. We can sequence the genome of all animals and see what's going on there. And this is exactly what we did.




We irradiated male mice, we mated them with non-irradiated females. Then we were looking for the presence of quite large changes on their genome, called "copy number variance", and then we were also sequencing the genomes of the whole animals looking for small changes.

Look what's going on. This is the first even data of what's going on, on the level of the all genome.




**If it works in mice, then we should start using the genome-wide approach in humans. This is our future**

Eight fold increase in the number of large changes, some of them are detrimental, significant increase in number of small changes, and quite substantial increase in a number of changes which are affecting two nearby nucleotides.

So, on the basis of these data, now we can make a prediction. The exposure to radiation can affect developing of offspring, because these mutants are clearly detrimental to some of them also.

It works in mice. And when we can start getting the same sort of data in humans, then and only then we will be in a position to figure out the genetic effects of human exposure to ionizing radiation are the mutagens.

And finally I would like to acknowledge people who took part in this study.


Human studies: our team in Leicester plus our collaborators from Belarus and Ukraine who collected samples

Mouse studies: again my team, Wellcome Trust Sanger Centre, and our collaborator from Moscow.

Thank you for tolerating me.◆

# Question and answer session

***Ruth Stégassy***

Thank you very much, I imagine there'll be several questions. We're listening (You have the floor).

## Question

I apologize for always asking questions, I will proceed in English, it's better for Mr. Dubrova. So, first I was surprised by the Down syndrome peak. It's very close, it has something to do with the Chernobyl accident. But is it statistically significant?

***Yuri Dubrova***

A good question. So, what happened, according to my knowledge. The first publication regarding this, first of all, we know this from the mouse genetics. So, if you irradiated mice, and mate them immediately, both parents, you will see an increase in a Down-like thing in the offspring. So, we know that this is particularly late stages of spermatogenesis, late meiotic stage of spermatogenesis, and all genomes are particularly sensitive to ionizing radiation. So if you irradiated during this very narrow window of opportunity, you may get gametes with extra chromosomes. And as far as the human data are concerned, the first publication was ages ago in Berlin. Then the same publication was, with the same window, in Scotland. And then people from Belarus who got the biggest database, they re-analyse their data and got the same spike. It is significant.

## Question

OK, and plausible and scientifically experimented?

***Yuri Dubrova***

I'm not in the position to comment whether it's real; it's not my data, I wash my hands. But it's there, and there are three independent studies showing that this is the case. It looks as though it is real, but if you look at number of Down syndrome children, born annually, and if you assume that the window of opportunity was say a few weeks, then the increase in number of Down syndrome children in Chernobyl this is small. So, there, I believe, it's there in some areas which were heavily contaminated, when the parents doing this business were exposed, and some of their children have got Down syndrome. That's it is.

## Question

It's clear. The second one is this continuous increase in Down syndrome over the years. Could it be because of increase of exposure to other mutagens? Because we know that ionizing radiation is not the only mutagen people are exposed to. As the society gets more and more develop, we have more and more of them. Could it be an explanation?

***Yuri Dubrova***

You are perfectly right.

***Ruth Stégassy***

Thank you.

## Comment

Just a detail. In Three Mile Island there was also a very strong peak of Trisomy 21, nine months after the accident, and it was recognized by the US courts. The company had to pay large sums to families.

***Yuri Dubrova***

No comment. I'm not physician.

## Question

I would like to know if there are any correlations between different diseases. Unfortunately children's thyroid cancer is the only officially spoken diseases but, we still measure the food primarily for $^{137}Cs$, and human data is getting more and more difficult to obtain in Fukushima. And the cover-up is coming. We would like to see more a circumstantial evidence that would as support the future hypothesis-building.

***Yuri Dubrova***

You are perfectly right. Yes, we need more human data.

## Question

I am a doctor anatomopathologist. Before, I posed the question of natural background. And my second question is along the same lines: should we wait for the results of epidemiological studies which are extremely difficult, if not impossible, precisely because of this dilution and also the heterogeneity of radioactive fallout on populations? So I want to thank you for referring to the experimental studies that have much faster results and are more meaningful for the authorities, than epidemiological studies whose results can only be extremely contradictory and very long term. Should we wait for generations to admit that ionizing radiation is just not good for health? We know that since more than a century.

***Yuri Dubrova***

I'm a geneticist, my lab mostly works with mice. We started with humans but… I hundred percent agree with you that the carefully organized lab-based studies should give us much more than any epidemiological studies. Besides any epidemiological study is a black box: you measure something on the out, but you got no clue what is going in.

## Question

My question goes somewhat in the same sense. I would recall that IRSN organized a scientific seminar on March 25, 2014, and a representative of the IRSN said that, from 1965 to 2013, only 79 publications address the ingestion of $^{137}$caesium in body issues, while on cadmium one can easily reach 100,000 publications.

This person adds that: the Chernobyl disaster did not significantly increase the number of studies. We start to look at the issue with Fukushima, and thanks to the programme EnvirHomme on rats. So my question is the following: when do we take your studies into account when dealing with global health?

***Yuri Dubrova***

I don't take into account my studies, someone does.

***Ruth Stégassy***

There was a question in here.

## Question

I apologize for asking this question now, but I must go.

I invite children from the contaminated areas in Belarus, the children are between 7 and 10 years of age, for a health stay here in Geneva, in Switzerland. I have often ask myself to what extend such short stay, health stay of three to four weeks, can be of any good to these children who are growing up.

***Yuri Dubrova***

I don't know. No comment.

***Ruth Stégassy***

So there is an answer out there, yes?

## Comment

I will try to give you a small answer. I am Daniel Reininger of the association "Les Enfants de Tchernobyl" (Children of Chernobyl) and every year we invite more than 200 children to come to stay in France for 3 or 8 weeks, depending on the case. We have done this for the past 20 years and we have always been very strict: we measure the internal contamination of the children before they come to France and we measure them again when they return home. From experience, we can say that the stay, either in Switzerland or France, in uncontaminated areas, reduces internal contamination by caesium by about 30%. Three weeks.

We had internal contamination decreases up to 80% in 8 weeks. Obviously this is only temporary, but it allows them to go back with lower internal contamination. We continue to help the children when they are back home, to get clean food. I want to point out one thing. The children we receive today are just as contaminated as those we received 10 or 15 years ago, they continue to become contaminated through food in an area that is almost as large as Switzerland. So these children come with significant contamination, sharply higher than the 20 Bq per kg of weight Professor Bandazhevsky had set as a limit for the impact on children's health.

But I remain convinced that the fact they come to France is good for them. We see this with the hindsight we have on children who are now grown up. It is also possible to undertake health education, as a way to help them. So if you are in any doubt about the beneficial effects of receiving children I would like to reassure you. I think we can say that the effect is beneficial.

***Ruth Stégassy***

Thank you very much for these clarifications. There is a lady who wants to speak but there will be time this afternoon to a longer debate. ◆

# Pregnant women with high levels of $^{137}$caesium and high rates of congenital anomalies near Chornobyl

***Dr Wladimir Wertelecki**, formerly of the Department of Medical Genetics and Birth Defects, University of South Alabama, USA*
*President of the Board of the OMNI-Net Ukraine Child Development Programme*

## Introduction *by* ***Ruth Stégassy***

***Dr Wladimir Wertelecki*** *is President of the Board of the OMNI-Net Ukraine Child Development Programmes, a group that has done extensive studies into congenital malformations in the Polissia region in Rivne, Ukraine. Polissia is one of the most affected regions by the Chornobyl disaster. He is adjunct Professor at the Dysmorphology Division of the University of California in San Diego and at the Graduate Programme in Biomedical Anthropology of the New York State University in Binghamton. Dr Wertelecki was born in Poland and is fluent in languages of regions impacted by the 1986 Chornobyl disaster. Largely educated in Switzerland and Argentina, where he obtained his medical degree from the University of Buenos Aires, he trained in Pediatrics at the Saint Louis Children's Hospital of the Washington University and in Clinical Genetics at the Boston Children's Hospital of the Harvard School of Medicine. Dr Wertelecki was Chair of the Department of Medical Genetics and Birth Defects, University of South Alabama, from 1974 to 2010. His major areas of interest include medical genetics, human handicaps, and pediatrics. He has organized many conferences dealing with genetics and birth defects, as well as public health and other issues. He is the recipient of numerous awards and the author of more than 250 articles and abstracts.*

# Presentation


Pregnant Women with High Levels of $^{137}$Caesium and High Rates of Congenital Anomalies near Chornobyl

Wladimir Wertelecki[1], Lyubov Yevtushok[1,2], Natalia Zymak-Zakutnia[1,3], Serhiy Lapchenko[1], Illya Kuznetsov[4], Oleksandr Komov[5], Zoriana Sosyniuk[1,2], Diana Akhmedzhanova[1,3], and Bogdana Ievtushok[1,2]

[1]OMNI-Net Ukraine Birth Defects Programs, [2]Rivne Regional Medical Diagnostic Center, Rivne, Ukraine, [3]Khmelnytsky Perinatal Center, Khmelnytsky,Ukraine, [4]Human and Animal Physiology Department, Eastern-European University, Lutsk, Volyn, Ukraine, [5]Rivne Province State Sanitary-and-Epidemiologic Service, Rivne, Ukraine

## Definitions and abbreviations

**$^{137}$Caesium** or **$^{137}$Cs** – among the most abundant and convenient to measure radioactive matter (radionuclides) released by atomic chain reactions – this nuclide is similar to potassium and so are its incorporation and tissue bindings characteristics;

**$^{90}$Strontium** or **$^{90}$Sr** – a frequent radionuclide released by atomic chain reactions – its similarity to calcium is conducive to long lasting binding to bones and concentration of IR damage on bone marrow cells resulting in leukemia;

**ABCC** – Atomic Bomb Casualty Commission, established by the U.S.A. government to conduct studies of the impacts of the Hiroshima and Nagasaki atomic bombs explosions;

**anencephaly** – an early congenital anomaly of the rostral (cephalic) pole of the neural tube from which derives, among other structures, the cerebrum and the retina;

**anophthalmia** – lack of ocular globes;

**biota** – living matter;

**blastopathies** are anomalies of the fertilized egg prior to its implantation in the uterus and the onset of embryonic development;

**blastula** – the earliest stage of a fertilized egg –

**Bq** – or Becquerel, a unit of radiation reflecting energy released by disintegrating atoms;

**CA** – congenital anomalies, in this study comprising, for the most part, visually evident structural anomalies noted by fetal prenatal ultrasonography or clinical examinations detected after birth up to the age of one year;

**carcinogen** – see text;

**epigenetics** – see text; process that results in the modification of gene expression rather than alteration of the genetic code per-se;

**FASD** – fetal alcohol spectrum disorders;

**IAEA** – International Atomic Energy Agency;

**ionizing radiation** or **IR** – radiation with sufficient energy which upon impacts with matter can liberate electrons or molecules resulting in positive or negative electric charges denoted by the term "ionizing";

**microcephaly** – reduced head size, in this study of at least two standard deviations below the average for sex and age;

**microphthalmia** – small ocular globes;

**IRPA** or International Radiation Protection Association;

**millisievert or mSv** – a calculated unit or indirect estimate of biologic impact of ionizing radiation;

**mSv** – see millisievert;

**M/M** – microcephaly and/or microphthalmia;

**mutagen** – see text;

**neural tube defects** – anomalies resulting from developmental alterations of the neural tube from which derive the brain and spinal cord;

**non-P** or non-Polissia – represents Rivne regions excluding seven counties categorized **as Polissia;**

**NTD** – see neural tube defects;

**NPP** – nuclear power plant or complex, which in Ukraine usually includes an "atom-city";

**P** or Polissia **or** Prypiat Marshes – name of the flood plains of the eponymous river and two of its tributaries – the soils of the seven counties in Polissia are sandy, a factor that augments the transfer of nuclides from the soil to the food-chain;

**radionuclides** – chemical molecules that contain unstable atoms (nuclides) that decay and emit energy, mainly ionizing radiation;

**spina bifida** – a failure of closure of the distal or caudal pole of the neural tube – a serious anomaly conducive to paralysis of the lower limbs often compatible with survival;

**teratogen** – see text;

**UNSCEAR** – United Nations Scientific Committee on the Effects of Atomic Radiation;

**WBC** – whole body counts of incorporated IR, in this report this measure solely detects incorporated $^{137}$Cs;

**WHO** – World Health Organization.

## Background

### *Chornobyl (in Russian, Chernobyl)*

The 1986 disaster at Chornobyl was soon followed by the implosion of the Soviet Union and Ukrainian independence. An index of the profound social impacts of these events on the population in Rivne province is evident in a precipitous drop of birth rates in Rivne, which to the present remain below those prior to the disaster at the Vladimir Lenin nuclear power plant (NPP) discretely renamed as Chornobyl.

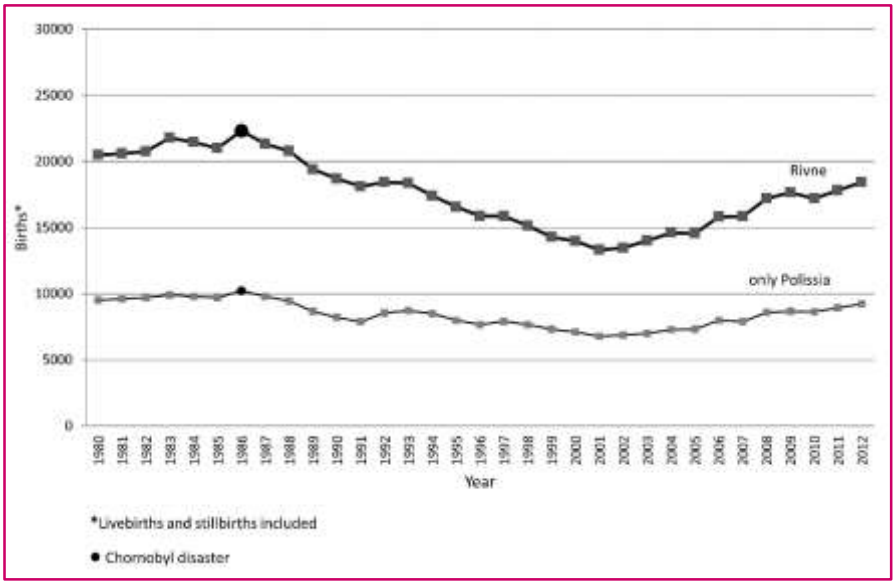



*Figure 1. Birth rates in Rivne and in the Polissia region*

Soviet Union and IAEA (International Atomic Energy Agency) experts defined regions most impacted by the Chornobyl ionizing radiation (IR) fallout. For unknown reasons, the Polissia (P) region of the Rivne province in Ukraine was ignored. Five years later, in 1991, during events that culminated in Ukrainian independence, the error was corrected [Decree 106, 1991]. It is now recognized that the population in P is among the largest and most severely exposed to Chornobyl IR in Ukraine [Likhtarev *et al.* 1996, 2000; Zamostian *et al.* 2002]. It also became evident, as alluded to later, that these experts were unlikely to focus attention on the impacts of IR on developing human embryos. To address IR on pregnancy outcomes, a group of like-minded physicians and scientists formed a partnership that evolved into an organization named OMNI-Net, now registered in Kyiv, Ukraine as an international not-for-profit entity [Wertelecki 2006]. Among the goals of OMNI-Net is to sustain nearly identical projects, in Rivne and two adjoining provinces: registers of every newborn and every instance of visually detectable congenital anomalies (CA). Prenatal exposures to alcohol and evidence of Fetal Alcohol Spectrum Disorders (FASD) were investigated concurrently [Wertelecki 2006; Mattson *et al.* 2010, Wertelecki *et al.* 2014].

### *Polissia and Polishchuks in Rivne*


*Figure 2. Polissia lowlands are conducive to an isolated life style and mineral-poor soils.*

Nearly one-half of the population of Rivne inhabits wetlands known as P or Prypiat Marshes which are flood plains of the river Prypiat and its tributaries flowing across the lowlands of P (Figures 2, 3, and 4).

Among Polishchuks, high rates of isonomy of family names are indicative of high rates of endogamy which translates into higher rates of consanguinity of prospective spouses [Colantonio *et al.* 2003]. External exposures to IR in P are minimal. Internal exposures are mostly through inhalation and ingestion. It is unlikely that frequently published estimated exposures to IR in P, usually relying on dietary data collected in other regions, may not be relevant in view of the social circumstances in P as well as its soil characteristics. The wet and boggy soils in P are associated with the highest transfer index of $^{137}$caesium ($^{137}$Cs) from soil to biota in Ukraine. Preliminary investigations in P demonstrated that the daily ingestion of $^{137}$Cs by pregnant women is above the daily safety limits set by Ukrainian authorities of 3,700 and 14,800 Bq (Becquerels) for individuals under the age of 14 years or above, respectively. [Dancause *et al.* 2010]. Since 1986, the isolated native population in P continues to be exposed to IR polluted air, smoke and water. Furthermore, Polishchuks and their children virtually have no alternatives but to consume water drawn from shallow wells and locally grown food polluted by IR. Smoke from burning bio-mass, forest fires, and wood burning for cooking and heating is readily evident in P. Smoke is one factor that mobilizes IR and its deposition alters IR soil patterns. In P, approximately 67 percent of households burn local wood for cooking or for heating. The radioactive smoke is inhaled by both adults and their children. Families also use wood ash to fertilize their home garden plots which concentrates $^{137}$Cs in these soils, and the homegrown or locally cultivated food consumed by the family and domestic animals. During harvests, women, among whom many are pregnant, undertake the task of burning plant remnants which results in the mobilization of radionuclides that are then inhaled in smoke. The stems of potato plants grown in P and subject to burning contain $^{137}$Cs as well as strontium ($^{90}$Sr). Virtually all infants born in P are exposed to $^{137}$Cs since their conception. A growing proportion of their parents also are exposed to $^{137}$Cs since their conception.


*Figure 3. Schematic map of Ukraine and of the Chornobyl impacted regions and Rivne province.*

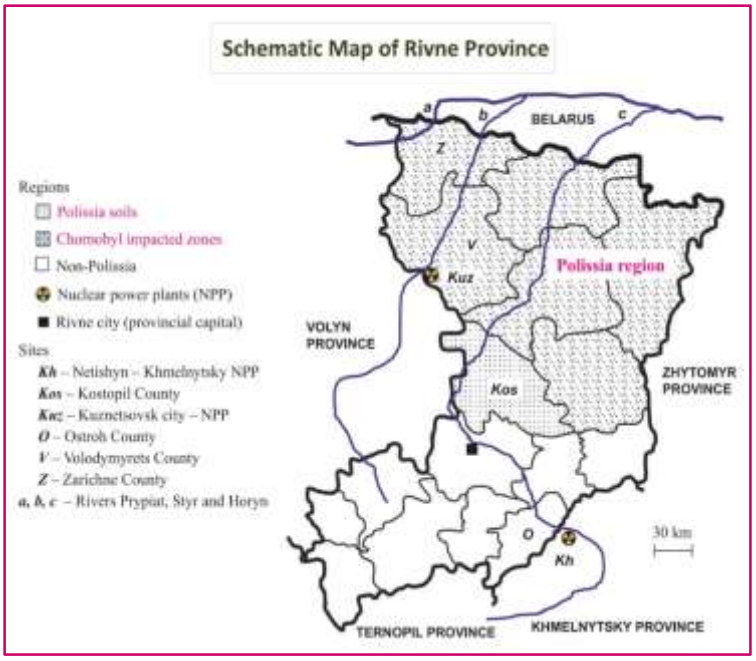



*Figure 4. Schematic map of Rivne province, Polissia soils, Chornobyl impacted counties and location of two nuclear power plants.*

## Previous studies

Most investigations of Chornobyl IR impacts on health in Ukraine as well as elsewhere are focused on adults and on their increased cancer risks. Substantive population-based investigations of CA are

rare. EUROCAT, a consortium of CA monitoring systems across regions of Europe, conducted investigations among populations living in European regions distant from the Chornobyl site. The results did not show an impact of Chornobyl IR on rates of CA in these distant regions from the disaster [Dolk & Nichols 1999]. Numerous other studies of relatively small series of patients did show increased rates of CA, in particular neural tube defects (NTD), but were dismissed or largely ignored for a variety of reasons. We are unaware of other substantive long term large population-based studies of CA rates in populations living in relative proximity to the Chornobyl site.

### *Notions inherent in the terms teratogen, mutagen and carcinogen*

The notion "teratogen", as emphasized in this report, was consolidated after the Hiroshima and Nagasaki events which were followed a few years later by an extensive global rubella epidemic and aggressive marketing of Thalidomide. It became evident that both rubella and Thalidomide were associated with clusters of characteristic CA referred to as "Rubella Fetopathy" and "Thalidomide Fetopathy". It also became evident that the prenatal rubella or Thalidomide impacts were neither "genetic" nor "carcinogenic" in nature. In view that IR is also a cause of characteristic CA such as, among others, microcephaly and cataracts as well as genomic mutations and cancer, it could be concluded that IR is teratogenic, mutagenic and carcinogenic. After these seminal events, it became clear that many medications and agents such as alcohol are teratogenic but are not a cause of "genetic" alterations such as gene mutations or carcinogenesis.

Mutagens, defined briefly, are agents that alter the genetic code of cells conducive to cell death, teratogenic alterations, sterility, heritable disorders, and in some instances to carcinogenesis.

An additional perspective is rapidly arising under the eponym "Epi-Genetics". In essence, in the context of IR impacts, this notion concerns heritable alterations not due to mutations of the genomic code but reflecting impacts on regulatory mechanisms of gene expression.

Arguably, it cannot be taken for granted that the teratogenic, mutagenic, and epi-genetic impacts by acute, intense, and brief external IR exposures in Hiroshima-Nagasaki are equivalent or even similar to those in Rivne as implied in assertions by the IAEA with concurrence by the WHO (World Health Organization). As elaborated upon later, these agencies assert that IR exposures in Rivne are too low to cause detectable impacts on CA rates. Irrespective of such Hiroshima-Nagasaki to Chornobyl and more recently to Fukushima Daiichi extrapolations, in Rivne, the rates of CA are among the highest in Europe. Regarding nuclides released by the Chornobyl explosion, their variety and diverse chemical nature translate into a variety of modes of their incorporation by pregnant women and their embryos. The exposures in Hiroshima-Nagasaki were external, often intense and brief. In Rivne the IR are chronic, of low overall intensity or high intensity in particular embryonic sites. Furthermore, the sensitivity of embryonal tissues to IR teratogenic is variable, a reflection their developmental stage. Virtually all pregnant women born in P after the 1986 Chornobyl disaster and all their embryos are exposed to nuclides since their own conceptions.

## Introduction

The 1986 Chornobyl disaster is among the largest man-made disasters and the released ionizing radiation (IR) continues to have negative impacts on the ecologic integrity, social welfare, and human health in vast regions of Europe. The scope and impacts of the Fukushima Daiichi disaster in Japan are equally enormous. The observations reported here are likely to be relevant, at least in part, to studies of IR radiation impacts in Japan.

Most investigations of Chornobyl IR impacts, including this report, are limited to measurements of $^{137}Cs$. IR impacts from other nuclides remain largely unaccounted for. This deficit is illustrated by our observation of significant levels of $^{90}Sr$ in stems of potato from P. The potential of releases of nuclides by two NPP in proximity of populations in Rivne is also a factor to be taken into consideration (Figures 1 and 2).

Another prevalent teratogen in Rivne in addition to IR is alcohol. We conduct an ongoing investigation of maternal consumption of alcohol and its impact on embryonic development [Wertelecki *et al.* 2014].

The CA monitoring programme in Rivne is a full partner of EUROCAT, a network of programmes sharing goals and methodologies [EUROCAT Guide 1.4 and reference documents 2013]. This network facilitates comparisons of patterns and rates of CA in Rivne with those noted elsewhere in Europe.

## Methods and population

To assess IR exposures, we computed whole-body counts (WBC) as Becquerel (Bq) emanating from incorporated $^{137}$Cs. We analyzed 44,438 WBC obtained between 2001 and 2013 from outpatients who volunteered to undergo the procedure. This group includes individuals of at least 20 years of age and pregnant women of any age. There were 6,425 pregnant women of any age and of known body weight. The officially set upper norms for WBC in Ukraine are 3,700 Bq and 14,800 Bq for individuals under the age of 15 years and for adults, respectively. Additional information on the subject is summarized in Table 1.

A population-based CA monitoring was initiated in 2000. Every infant born in Rivne and those with evident CA at birth or during the first year of life are registered in a neonatal registry and if appropriate in the CA registry.

Whole body counts of incorporated $^{137}$Cs were obtained by a single device, a spectrometer incorporated into a chair and calibrated yearly by the Kyiv Metrology Center (Kyiv Metrology Center reference); recording methods were defined by the Kyiv Ecology Institute [SVITCH-M3 "SKRINNER" User Manual 1992]; counts were recorded as total Bq; recordings below the detection limit of 100 Bq were excluded from analyses; repeated measurements of some individuals were included.

Analyses of WBC radiation measurements and CA rates were focused on determining contrasts between those in P and the rest of Rivne or non-Polissia (non-P).

*Figure 5. Early anomalies or blastopathies (arising prior to the implantation of the fertilized egg or early embryogenesis). Illustrated are conjoined twins (left); sacral teratoma (upper center); anencephaly (lower center); and an association anencephaly-iniencephaly-omphalocele (lower right). These blastopathies are prevalent among females (see text).*

Additional analyses were focused on two counties proximal to nuclear power plants (NPP). The first is Volodymyrets County in P which includes Kuznetsovsk City as an integral component of the Rivne NPP. The second is Ostroh County in non-P, which is adjacent to the Khmelnytsky NPP. Further descriptions of WBC analyses are given elsewhere [in press].

Population-based congenital anomalies surveillance, classification and coding adhered to methods developed by EUROCAT [EUROCAT Guide 2013]. Every infant born in Rivne is registered in a neonatal registry and CA among stillborn or live born detected up to one year of age are recorded in a separate registry. The microcephaly category includes instances of at-birth occipito-frontal circumferences at least three standard deviations below normal for age and sex and excludes instances of holoprosencephaly. microphthalmia and anophthalmia are reported jointly. Instances of Down syndrome include individuals solely diagnosed clinically. Population-based rates are calculated per 10,000 live births of CA detected prenatally or before one year of age. Finally, statistical software R [http://www.r-project.org/] was used for analyses and graphing.

## Results

### *Whole body counts*

The number and residence of individuals who underwent WBC recordings are shown in Table 1. The WBC's of males are higher than those of females in general. The body weights of women of similar ages are similar in Polissia and non-Polissia. Although the averages of WBC in Polissia and non-Polissia differ significantly, within P and within non-P the ranges are quite similar. The WBC's of pregnant women are higher than those of females in general and often approach or exceed those of males. The WBC from Volodymyrets County are among the highest in Polissia and those from Ostroh in non-Polissia are the lowest in Rivne. In Kuznetsovsk City in Volodymyrets County, the average WBC of men, women and pregnant women is much lower than in the rest of this county. A Poisson regression of all WBC data from Volodymyrets County, with dummy coding for Kuznetsovsk City, yields a highly significant 60% lower mean WBC in Kuznetsovsk than in the rest of Volodymyrets County ($P<0.0001$) (Table 1).

*Table 1. $^{137}$Cs Whole Body Counts in Rivne regions.*

| Category | Polissia | Non-Polissia | Kuznetsovsk City | Volodymyrets County[4] | Ostroh County |
|---|---|---|---|---|---|
| WBC (≥100 Bq $^{137}$Cs) | | | | | |
| Number of Males[1] (2001-2013) | 6520 | 3266 | 825 | 432 | 268 |
| Median Bq | 1516 | 379 | 1250 | 2918 | 307 |
| Mean Bq | 2663 | 519 | 1391 | 3414 | 413 |
| Number of Females[2] (2001-2013) | 23628 | 11024 | 2013 | 2163 | 1207 |
| Median Bq | 1486 | 404 | 1117 | 2425 | 341 |
| Mean Bq | 2352 | 523 | 1164 | 2918[5] | 493 |
| Pregnant[3] Females (2011-2013) | 3865 | 2560 | 90 | 507 | 377 |
| Median Bq | 1942 | 594 | 1428 | 2197 | 507 |
| Mean Bq | 2655 | 744 | 1460 | 2533 | 703 |

*(1) At least 20 years of age; (2) includes women of at least 20 years of age and those pregnant of any age; (3) pregnant women of known weight; (4) excludes Kuznetsovsk City; (5) the mean WBC of the whole county is 2,072.*

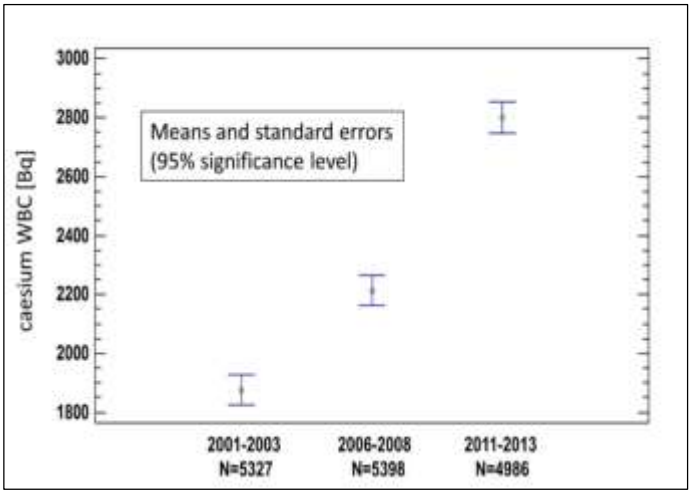



*Figure 6. $^{137}$Cs temporal trends of whole body counts of women residing in Polissia*

Women's WBC in P and in non-P, from 2001 through 2013, exhibit large differences. In women from P and non-P, the mean WBC are respectively 2,352 and 523 Bq. There is also a statistically significant temporal rise in Polissia ($P<0.0001$) shown in Figure 6 above and a statistically non-significant rise in non-Polissia ($P=0.09$, is not illustrated).

The $^{137}$Cs burden of pregnant women during 2011-2013 was determined from WBC and body weight (kg) measurements in Polissia (N=3,865) and in non-Polissia (N=2,560). In P, the specific activity ranged from 1.4 to 629 Bq/kg with a mean value of 40.4 Bq/kg. To determine the temporal trend, a Poisson regression was used. The average caesium burden increased by 6.3 ± 1.8% per year ($P=0.0006$). In non-P, the specific activity ranged from 0.9 to 207 Bq/kg with a mean value of 11.3 Bq/kg and the average decreased by 15 ± 2% per year ($P<0.0001$). Further analyses of WBC are available upon request.

### *Rates of congenital anomalies*

The number of live births and number of individuals with CA and corresponding rates are presented in Table 2. The NTD and microcephaly/microphthalmia (M/M) rates in P were

24.1 and 17.5 and 8.6 and 5.2 respectively, a statistically significant contrast (P=0.0014 and P=0.005 respectively). This difference has persisted over the years.

*Table 2. Number and Rates of Congenital Anomalies in Polissia*

| Category | Polissia | | Non-Polissia | | Volodymyrets County[1] | | Ostroh County | |
|---|---|---|---|---|---|---|---|---|
| Live Births (2000-2012) | 98069 | | 99429 | | 21671 | | 5636 | |
| Congenital anomalies | N | Rate | N | Rate | N | Rate | N | Rate |
| NTD[2] | 236 | 24.1 | 174 | 17.5 | 57 | 26.3 | 18 | 31.9 |
| M/M[3] | 84 | 8.6 | 52 | 5.2 | 23 | 10.6 | 6 | 10.6 |
| Cleft lip w/o palate[4] | 97 | 9.9 | 108 | 10.9 | 21 | 9.7 | 10 | 17.7 |
| Down Syndrome[4] | 156 | 15.9 | 142 | 14.3 | 33 | 15.2 | 6 | 10.6 |

*Abbreviations: NTD, neural tube defects; M/M, microcephaly and/or microphthalmia; w/o, with or without.*

*(1) Includes Kuznetsovsk City; (2) includes one individual with M/M from Volodymyrets County in Polissia; (3) excludes 8 individuals with holoprosencephaly and includes 6 individuals with cleft lip w/o palate from Polissia and 3 from non-Polissia, one of which is from Ostroh County; (4) includes individuals with NTD or M/M mentioned above.*

For further statistical analysis, NTD and M/M cases were pooled. A logistic regression on a county level (7 counties in Polissia, 9 in non-Polissia) was conducted to test the dependency of malformation rates on WBC. Dummy coding was used to test for any systematic difference in rates between Polissia and non-Polissia. Possible excess rates in the two counties proximal to NPP, Volodymyrets in Polissia and Ostroh in non-Polissia, relative to the rates in their respective Polissia and non-Polissia regions, were also tested. A highly significant 58% excess is found in Polissia vs non-Polissia (P=0.0004). We also note that in Ostroh County, the NTD-M/M rate is 82% higher than in the rest of non-Polissia (P=0.007); in fact it is the highest rate in Rivne province. No deviation from the expected rate in Polissia is found in Volodymyrets County. Other results of WBC patterns are available upon requests to the authors.

*Table 3. Temporal Trends of Neural Tube Defects and Microcephaly/Microphthalmia in Rivne Regions*

| Category | Polissia | | Non-Polissia | |
|---|---|---|---|---|
| | NTD | M/M | NTD | M/M |
| 2000-4 | 29.1 | 7.1 | 18.4 | 3.9 |
| 2000-6 | 27.2 | 6.7 | 18.7 | 3.0 |
| 2000-9 | 26.1 | 8.6 | 16.4 | 4.1 |
| 2000-11 | 24.6 | 8.5 | 17.1 | 5.1 |

*Rate per 10,000 live births.*

*Abbreviations: M/M, microcephaly and/or microphthalmia; NTD, neural tube defects.*

*Table 4. Female Prevalence among Blastopathies in Rivne (2000-2009)*

| Categories | N | Sex | | |
|---|---|---|---|---|
| | | M | F | M/F |
| Live Births | 145437 | 75292 | 70117 | 1.07 |
| Neural Tube Defects (NTD) | 309 | 114 | 129 | 0.88 |
| Microcephaly | 68 | 32 | 36 | 0.89 |
| Isolated | 22 | 6 | 16 | 0.38 |
| Microphthalmos | 24 | 11 | 13 | 0.85 |
| Conjoined Twins | 7 | 1 | 4 | 0.25 |
| Teratomas | 10 | 1 | 6 | 0.17 |
| Sacro-coccygeal | 9 | 1 | 5 | 0.20 |

Table 4 shows male-female proportions in individuals with blastopathies. As further observations of these relatively rare CA accumulate, statistical analyses will become possible.

A survey of at-birth head circumference showed statistically significant reductions in males and females, born in Zarichne County in Polissia in comparison to neonates born in Rivne City in non-Polissia. A follow-up investigation found a similar contrast among male and female infants born in Volodymyrets County in Polissia compared to those born in the remaining counties in non-Polissia (Figure 7) [Wang & Wertelecki 2013; Wertelecki *et al.* 2014].

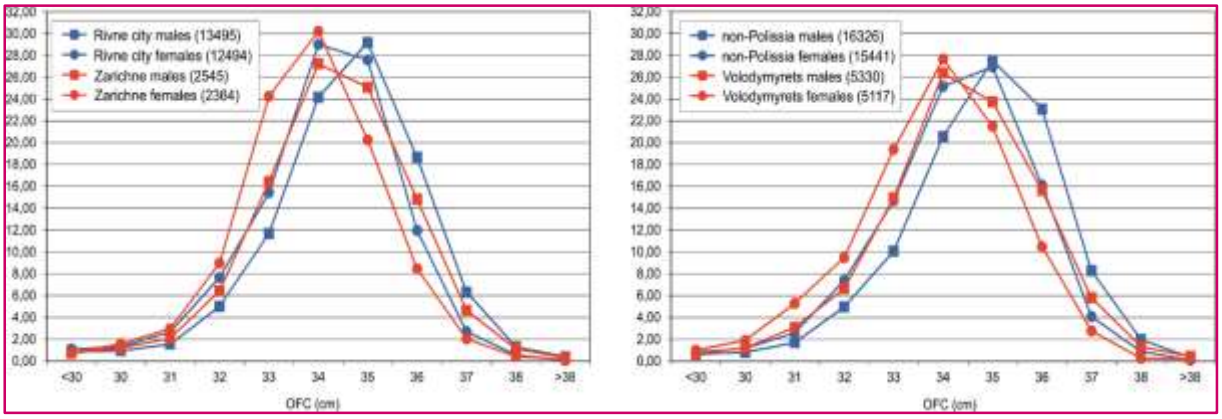



*Figure 7. Comparison of 2000-2009 at-birth occipito-frontal head circumferences of infants in Zarichne County in Polissia with those in Rivne City in non-Polissia and of infants from Volodymyrets County in Polissia with infants gestated in nine non-Polissia counties (Polissia vs. non-Polissia P<0.01, unpublished data)*

## Discussion

### *Hiroshima-Nagasaki and Chornobyl*

Before Chornobyl, the largest human populations impacted by IR were those living in the cities of Hiroshima and Nagasaki in Japan. As mentioned earlier, the exposures in Hiroshima-Nagasaki were external, intense, and brief, and the residual radioactivity was considered to be negligible. In contrast, those in Rivne are internal, chronic, and characterized by official agencies as of low intensity. However, uptake of incorporated nuclides by particular embryonic tissues may become concentrated in particular embryonic tissues, as is the case with high concentration of radioactive iodine or $^{90}$Sr in thyroid or skeletal embryonal tissues respectively. The severe consequences expressed as childhood thyroid carcinoma and leukemias are well known examples. As elaborated upon later, experts and officials of the IAEA-WHO are dismissive of the notion that

Chornobyl IR could possibly be a cause of elevated CA because exposures compared to those in Hiroshima-Nagasaki are too low.

Following the Hiroshima-Nagasaki atomic blasts, the United States established the Atomic Bomb Casualty Commission (ABCC) to sponsor and coordinate investigations of IR health impacts on exposed survivors and their children. We are aware of a single investigation of *in utero* exposed children – the results were inconclusive largely due to the limited number of subjects and the difficult circumstances that followed the atomic bomb detonations [Plummer 1952]. A larger investigation was focused on unexposed *in utero* children aptly summarized in a detailed report "The Children of Atomic Bomb Survivors – a Genetic Study". Among 14,768 and 12,324 infants in Hiroshima and Nagasaki, 165 and 154 had CA, compared to 49,645 births observed in the Tokyo Red Cross Maternity Hospital between 1922 and 1940 among whom 456 had CA (tables 8.2 and 8.3 on pages 101 and 103 respectively). [Neel & Schull, 1991]. Due to the diverse nature of the two cohorts of children, no conclusions can be drawn regarding CA rates nor patterns. The main conclusion was that "... the frequency of malformed ... reveals no significant, consistent effect of parental exposure" (page 117). This conclusion is often extrapolated to sustain IAEA-WHO assertions that implicitly equate external with internal IR radiation and distinctions of teratogenic from mutagenic impacts.

The ABCC sponsored investigations did show a clear association of IR external exposures with microcephaly and reduced mental capacity. [Neel 1958, 1994; Otake & Schull 1984; Schull & Otake 1999; Wood *et al.* 1967a, 1967b, 1967c; Miller & Blot 1972]

In Rivne, IR impacts on human health emanate from incorporated radionuclides by individuals and mother-embryo pairs. Earlier studies concerned with Chornobyl IR, including our own, rely solely on measurements of $^{137}$Cs. Measurements of other nuclides are technically and financially more burdensome. As indicated earlier, the chemical nature of nuclides determines their impact on embryonic sites where the sensitivity and regeneration-repair of IR damage differ as the embryo develops. Compared with adults, the human foetus and children remain highly sensitive to IR impacts, in particular during periods of rapidly developing tissues. Perhaps early impacts on blastogenesis could disrupt body-axis formation expressed as conjoined twins, an anomaly quite frequent in P, a subject elaborated upon later.

### *After Hiroshima and Nagasaki*

An official study of congenital malformations in Bavaria, the German region most affected by the Chernobyl fallout, reported no increase of malformation rates after Chernobyl [Schoetzau *et al.* 1994]. But an analysis of the prevalence of malformations at birth (1984-1991) as a function of $^{137}$Cs burden, which was approximated by the district average caesium soil contamination times the trend of the (calculated) caesium concentration in pregnant women, found a significant association when a linear-quadratic trend model was used, with a negative slope at low caesium values and a steep increase at higher values. The investigators also indicated that the results should be interpreted with caution since the analysis was conducted as an explorative observational study [Kuchenhoff *et al.* 2004].

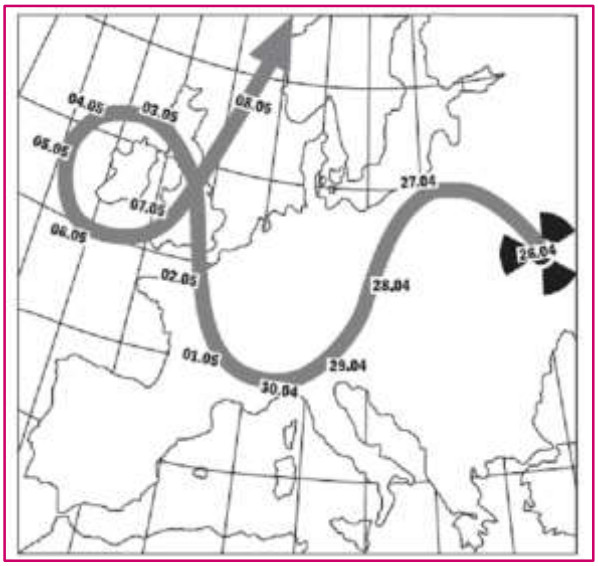



*Figure 8. The path of a Chornobyl radioactive cloud across Europe from April 27 to early May 1986 [Yablokov & Nesterenko 2009]*

In a European context, the NTD and M/M rates in P are persistently among the highest reported to EUROCAT [Wertelecki *et al.* 2014]. After P, the next highest rates of NTD and of M/M in

Europe are noted in northern regions of Great Britain known to have been more severely impacted by Chornobyl IR that the rest of the country (Figure 8). This region also includes the Sellafield nuclear complex where one investigation demonstrated elevated rates of NTD [Parker *et al.* 1999]. Such observations may be fortuitous but it is imprudent to disregard them. Perhaps follow-up investigations by EUROCAT may clarify the relevance of these patterns of CA.

*Table 5. Rates (a) of Neural and Other Malformations in Polissia and Remaining Counties of Rivne Province in Ukraine and Other Regions of Europe*

| Categories[b] | Births | NTD | MIC | mOPH | CL/P | DS |
|---|---|---|---|---|---|---|
| *Polissia (2000-2011)* | *89680* | ***24.42 (49)***[d] | ***6.24*** | ***3.35*** | *10.04* | *15.05* |
| *Non-Polissia (2000-2011)* | *90879* | *16.95 (68)* | *4.40* | *1.10* | *10.89* | *14.19* |
| EUROCAT Registries (2005-2011)[c] | | | | | | |
| UNITED KINGDOM (UK) | | | | | | |
| Northern England | 233134 | **14.41 (79)** | 1.46 | 0.73 | 10.90 | 22.86 |
| Wales | 243992 | 14.02 (82) | **4.75** | **1.52** | 10.94 | 22.91 |
| East Midlands & South Yorkshire | 510172 | 11.92 (76) | 0.92 | 0.33 | 8.96 | 19.25 |
| Thames Valley | 209508 | 11.41 (83) | 1.00 | 0.76 | 9.07 | 27.45 |
| Wessex | 206120 | 11.30 (90) | 1.31 | 0.63 | 10.96 | 27.70 |
| South West England | 343636 | 11.09 (83) | 4.51 | 1.08 | 8.79 | 27.97 |
| CONTINENTAL EUROPE | | | | | | |
| Paris (France) | 187658 | 12.26 (87) | 2.61 | 1.07 | 7.99 | **43.06** |
| Basque Country (Spain) | 145543 | 10.72 (87) | 3.78 | 1.37 | 5.57 | 34.08 |
| Norway | 425676 | 9.44 (74) | 0.52 | 0.70 | 12.4 | 19.52 |
| Nine others – highest rates[a] | | 9.16 (56) | 4.11 | 1.28 | **13.18** | 24.04 |

*(a) In **bold**, highest rates per 10,000 births [for further information see Wertelecki et al. 2014];*
*(b) Abbreviations: CL/P, cleft lip with/without cleft palate; DS, Down syndrome; EUROCAT, European Surveillance of Congenital Anomalies; MIC, microcephaly; mOPH, microphthalmia; NTD, neural tube defects;*
*(c) EUROCAT occasionally introduces data updates, the data analyzed was last accessed on December 25, 2013;*
*(d) Percent of pregnancy terminations.*

Two investigations in proximities to the cluster of NPPs in Hanford, Washington State, U.S.A. were sponsored by the CDC (Centers for Disease Control) to determine CA rates and patterns. The results of both investigations found increased rates of NTD. However, although the investigators judged both studies as scientifically sound they dismissed their significance because the results contradicted those reported to the ABCC and disseminated by the IAEA/WHO [Sever *et al* 1988a, 1988b]. Interestingly, recent reports of clusters of NTD in proximities to the Hanford site have triggered another investigation by the CDC [Centers for Disease Control and Prevention 2013].

Two independent investigations in central regions of Norway and Sweden of children found that those exposed *in utero* to Chornobyl fallout had reduced mental capacities as teenagers. These observations are concordant with ABCC sponsored investigations that demonstrated an association of IR exposures with intellectual deficits. ABCC sponsored studies also showed an association of IR with

microcephaly which is consonant with our observations in P [Almond *et al.* 2009; Heiervang *et al.* 2010; Schull & Otake 1999].

In addition to microcephaly, we also noted modest reduction of at-birth occipito-frontal head circumferences among infants gestated in two counties in P. These observations must be confirmed by further investigations.

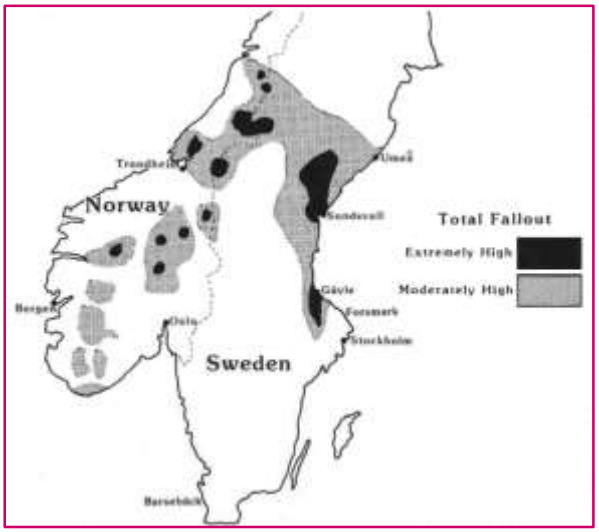



*Figure 9. Patterns of Chornobyl's fallout in Sweden and Norway [Almond et al. 2009]*

Regarding Europe, high concurrent rates of similar blastopathies to those noted in P in areas of the British Isles, call attention. It remains to be investigated if such patterns are associated with higher exposures to IR or other teratogens.

### Polissia and radionuclides

Geographic isolation and contrasts in ecology, traditions, language, and contamination by Chornobyl IR render the native population in P distinct from other populations in Ukraine [Dancause *et al.* 2010].

Analyses of WBC show that levels of $^{137}$Cs incorporated by males, females and pregnant women living in P are consistent with the official categorization of P as significantly impacted by Chornobyl IR. The analyses also demonstrate higher WBC in men than women but those of pregnant women approach or may surpass those of males. Presumably, this is a reflection of increased weight during pregnancy. We also note that since 2001, the average WBC of women has steadily and significantly risen. This rise is unlikely to reflect human bio-concentration of $^{137}$Cs since an association with age and corresponding weight gain are lacking. Instead, perhaps the temporal rise of WBC reflects a growing bio-concentration of radionuclides in locally produced food which continue to be consumed by the mostly rural populations in Polissia.

Of particular interest is the city of Kuznetsovsk in Volodymyrets County in P. The city arose as a component of the local NPP. The average WBC of men, women and pregnant women from this city are significantly lower than those from individuals living in the rest of Volodymyrets County. Presumably, this difference is indicative of the largely imported food low or free from $^{137}$Cs consumed in Kuznetsovsk City. This proposition is consistent with observations in Japan which demonstrated a rapid reduction of $^{137}$Cs WBC when dietary intakes excluded contaminated edibles [Tsubokura *et al.* 2014]. Furthermore, ongoing analyses of samples of milk from markets in Kuznetsovsk confirm that the $^{137}$Cs levels are nearly four times lower than in samples of home produced milk from rural households.

Ostroh County is also adjacent to the Khmelnytsky NPP. However, in contrast to Volodymyrets County, in Ostroh County, the $^{137}$Cs WBC recordings are among the lowest in Rivne while the rates of NTD, M/M are the highest in Rivne, even higher than those in P counties. On the other hand, the rates of both sentinel CA in Volodymyrets and Ostroh counties are similar to those in P, non-P and in Europe in general (Tables 2, 5).

The populations in Volodymyrets and Ostroh counties are not obviously distinct from those in other counties in their respective P and non-P regions with the exception that they live in proximity to NPP. The possibility of IR leaking from these NPP is suggested by studies of tritium in Prypiat river waters upstream from the Chornobyl site. Studies by Gudkov and Kuzmenko [Gudkov & Kuzmenko 1996, 1997] noted high levels of tritium and concluded that the likely source were discharges from the Kuznetsovsk and Khmelnytsky NPP into tributary Prypiat rivers flowing across P (Figure 4).

Within the overall context of our studies, investigations of tritium pollution of waters consumed by the populations in P and Ostroh County gain urgency.

### *Radionuclides, blastopathies and female prevalence*

It is generally accepted that CA reflect outcomes of "multi-factorial" interactions of teratogenic and regeneration-repair processes. It is known that IR is a cause of anencephaly, microcephaly, microphthalmia and other anomalies of the neural and other developing systems. It has also been demonstrated that IR destruction of neurons during early embryogenesis is followed by full or nearly complete recovery [D'Amato 1982]. It is also known that alcohol may interfere with folate metabolism and that folate supplements reduce but do not entirely eliminate the occurrence of NTD. These examples suffice to conclude that it is of considerable interest to establish to what extent folate supplements will reduce NTD rates in P compared to non-P which may aid in defining similarities or contrast attributable to their pathogenesis or etiology.

A review of effects after prenatal irradiation on embryonic development by the ICRP (International Commission on Radiological Protection) asserts that "no human data are available for these parameters ... and that female mice have a higher radio-sensitivity" [Valentin 2003, page 7]. In a companion report, we also find a significant prevalence of females among the blastopathies noted in P and non-P. The same is noted by earlier investigators although such is not stressed in some reports. Recent molecular studies led multiple investigators to propose that any factors that delay embryonal growth and maturation may result in blastopathies, including monozygotic twinning, conjoined twins, and NTD, among others. It is also noted that blastogenesis and early embryogenesis in females is slower than in males, a difference attributed to the process resulting in the inactivation of one of the two X-chromosomes [Juriloff & Harris 2012].

### *IAEA/WHO attitudes*

It is difficult to reconcile our observations in Rivne with untested notions disseminated by the IAEA/WHO and recently by USCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). For nearly a decade, these agencies have asserted that the levels of IR exposures after Chornobyl are too low to cause increases of CA that can be attributed to the Chornobyl event [Chernobyl Joint News Release 2005, IAEA 2006]. A relevant precedent is the regrettable dismissive attitude of these agencies of early indications of an emerging epidemic of childhood thyroid carcinomas that soon followed the Chornobyl explosion [Baverstock 2007]. A recent UNSCEAR report concerning the Fukushima Daiichi disaster conveys a similarly dismissive attitude [Sources, effects and risks of ionizing radiation 2013]. This report, produced by scientists engaged by a relatively small number of governments cites the same results of ABCC studies extrapolated earlier to dismiss potential Chornobyl impacts. In both instances, similar arguments are presented. The UNSCEAR report asserts that accumulated IR doses are "… unlikely to cause observable effects" and that "… effects at the population levels are unlikely to be observable". Concerning children, the report asserts that "... no heritable effects in humans due to radiation exposure have been explicitly identified ..." and that "There is essentially no evidence of an increase in chromosomal instability, mini-satellite mutations, trans-generational genomic instability, change in sex ratio of offspring, congenital anomalies or increased cancer risk in the offspring of parents exposed to radiation". Readers may conclude that further investigations are unwarranted. Another concurrent impact of such declarations is a chilling effect on agencies willing to fund research to independently verify such critical assertions. The UNSCEAR report troubles some independent researchers. The vice president of IRPA (International Radiation Protection Association), for example, during a panel session at the World Nuclear Association's 2014 Symposium stated that the nuclear industry and governments "have not been honest in presenting the risks of radiation at low levels" [World Nuclear Association's 2014 Symposium site]. Other investigators view the UNSCEAR report as misleading because it ignores studies that are contrary to its conclusions [Mousseau & Moller 2014]. Perhaps this may be the reason why our report published in the journal of

the American Academy of Pediatrics is not included in what UNSCEAR presents as an unbiased comprehensive review of the scientific literature [Wertelecki 2010]. The above circumstances are indicative of the need for IAEA, WHO, UNSCEAR, and other agencies to include genuinely independent scientists and to avoid relying solely on experts and staff beholden to governments that employ them. The potential impacts of IR on the unborn are too critical to be solely judged by those whose mission is to serve governments or to promote the nuclear industry.

## Summary and conclusions

The observations reported here stem from descriptive epidemiological studies of a population chronically impacted by IR emanating from incorporated $^{137}$Cs and to identify associations that may guide prospective investigations of cause-effects manifested as particular CA. Among the most salient observations are that pregnant women living in P incorporate nearly four times more $^{137}$Cs (40.4 Bq/kg) than those living in non-Polissia (11.3 Bq/kg). Furthermore, the levels of incorporated $^{137}$Cs have significantly risen in P but not in non-P. The concurrent elevated levels of incorporated $^{137}$Cs by pregnant women and higher rates of female prevalent blastopathies in P do not constitute proof of cause and effect. However, our view is that disregarding these facts is imprudent. Prospective collaborative cause-effect investigations are essential and likely to expand the knowledge concerning the CA observed.

Finally, the reported observations and prospective cause-effect studies are, in our view, relevant to the circumstances arising in Japan after the Fukushima Daiichi disaster. Dual, concurrent and coordinated investigations are likely to accelerate and enhance the significance of virtually any sort of prospective studies.

## Acknowledgments

We thank Drs. C. Chambers, A. Korblein, and Y. Korzhynsky for their contributions toward the categorization of congenital anomalies, statistical analyses, and coordination of clinical studies respectively. ◆

## References


Almond D, Edlund L, Palme M. 2009. Chernobyl's subclinical legacy: prenatal exposure to radioactive fallout and school outcomes in Sweden. Quart J Econ 124:1729–1772.

Baverstock K. 2007. The recognition of childhood thyroid cancer as a consequence of the Chernobyl accident: an allegorical tale of our time? J R Soc Med. 100(9):407-9. Review.

Centers for Disease Control and Prevention. 2013. Notes from the Field: Investigation of a Cluster of Neural Tube Defects — Central Washington, 2010–2013. MMWR 62: 728.

Chernobyl: the true scale of the accident. 2005. Joint News Release WHO/IAEA/UNDP http://www.who.int/mediacentre/news/releases/2005/pr38/en/ . Accessed September 15, 2014.

Colantonio SE, Lasker GW, Kaplan BA, Fuster V. 2003. Use of surname models in humans population biology: a review of recent developments. Hum Biol 75:785–807.

D'Amato CJ. 1982. Regeneration and Recovery in the Fetal Nervous system after Radiation Injury. Exp Neur 76: 547-467.

Dancause K, Yevtushok L, Lapchenko S, Shevchenko G, Wertelecki W, Garruto R. 2010. Chronic radiation exposure in the Rivne-Polissia Region of Ukraine: implications for births defects. Am J Hum Biol 22:657–674.

Decree 106. 1991. Regarding Realization of Decrees of Supreme Soviet of Ukrainian Soviet Socialist Republic about Realization of Laws of Ukrainian Soviet Socialist Republic concerning the Legal Status of Territories Polluted by the Chornobyl Catastrophe Radiation and regarding the Status and Social Protection of People Suffered from the Chornobyl Catastrophe. Decree Number 106 of Cabinet of Ministers of Ukrainian Soviet Socialist Republic of July 23, 1991 [online]. Available at: http://zakon.rada.gov.ua:80/cgi-bin/laws/main.cgi?nreg=106%E0-91-%EF&p=1236860994819643 [September 17, 2013] (in Ukrainian).

Dolk H, Nichols R, EUROCAT Working Group. 1999. Evaluation of the impact of Chernobyl on the prevalence of congenital anomalies in 16 regions of Europe. Int J Epidemiol 28:941–948.

EUROCAT Guide 1.4 and reference documents 2013. Available at: http://www.eurocat-network.eu/aboutus/datacollection/guidelinesforregistration/guide1_4. Accessed 13 October 2014.

Gudkov DI, Kuz'menko MI. 1996. Tritium in Water Objects of Chernobyl 30-km Zone. In: Problems of Chernobyl Exclusion Zone: Scientific-Technical Collection. Kyiv: Naukova Dumka. Volume 3: 130-133. [In Russian]. ISBN 512004288 0.

Gudkov DI. Kuzmenko MI. 1997. Restoration of tritium inflow dynamics in regulated river systems. Trace Hydrology 97, Kranic 9th ed. Rotterdam: Balkema. ISBN 9054108754.

Heiervang K, Mednick S, Sundet K, Rund B. 2010. Effect of low dose ionizing radiation exposure *in utero* on cognitive function in adolescence. Scand J Psychol 51:210–215.

IAEA. 2006. Report Chornobyl's legacy: health, environmental ani socio-economic impacts and recommendations to the governments of Belarus, the Russian Federation and Ukraine [online]. Technical Report, International Atomic Energy Agency. Available at: http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf . Accessed 17 September 2013.

Juriloff D, Harris J. 2012. Hypothesis: the female excess in cranial neural tube defects reflects and epigenetic drag of the inactivating X chromsome on the molecular mechanisms of neural fold elevation. Birth Defects Res A Clin Mol Teratol 94:849–855.

Küchenhoff H, Engelhardt A, Körblein A. 2006. Combined spatial-temporal analysis of malformation rates in Bavaria after the Chernobyl accident. In: Busby C, Yablokov AV (ed.) Chernobyl 20 years on: Health effects of the Chernobyl accident. Green Audit Books, 179-183.

ISBN: 1-897761-25-2. Available at: http://www.alfred-koerblein.de/chernobyl/downloads/chernobylebook_p.187-191.pdf. Accessed 13 October 2014

Kyiv Metrology Center (DP) "Kyivoblstandartmetrologia", Bila Tserkva, Ukraine. Available: http://www.bcdst.kiev.ua/index.php/metr/dmkzvtib. Accessed 11 June 2014. [In Ukrainian].

Likhtarev IA, Kovgan LN, Vavilov SE *et al.* 1996. Internal exposure from the ingestion of foods contaminated by $^{137}Cs$ after the Chernobyl accident. Report 1. General model: ingestion doses and countermeasure effectiveness for the adults of Rovno Oblast of Ukraine. Health Phys 70:297–317.

Likhtarev I, Kovgan L, Vavilov S *et al.* 2000. Internal exposure from the ingestion of foods contaminated by $^{137}Cs$ after the Chernobyl accident. Report 2. Ingestion doses of the rural population of Ukraine up to 12 y after the accident (1986–1997). Health Phys 79:341–357.

Mattson SN, Foroud T, Sowell ER *et al*. 2010. Collaborative initiative on fetal alcohol spectrum disorders: methodology of clinical projects. Alcohol 44:635–641.

Miller RW, Blot WJ. 1972. Small head size after *in utero* exposure to atomic radiation. Lancet. Oct 14;2(7781):784-7

Mousseau TA, Moller AP. 2014. Genetic and ecological studies of animals in Chernobyl and Fukushima. J Hered. 2014 Sep-Oct;105(5):704-9.

Neel J. 1958. A study of major congenital defects in Japanese infants. Am J Hum Genet 10:398–445.

Neel JV. 1994. Physician to the gene pool: genetic lessons and other stories. New York: John Wiley and Sons Inc. 457 p.

Neel JV, Schull WJ. 1991. The children of atomic bomb survivors – a genetic study. Washington, DC: National Academy Press. 511 p.

Otake M, Schull W. 1984. *In utero* exposure to A-bomb radiation and mental retardation; a reassessment. Br J Radiol 57:409–414.

Parker L, Pearce M, Dickinson H, Aitkin M, Craft A. 1999. Stillbirths among offspring of male radiation workers at Sellafield nuclear reprocessing plant. Lancet 354:1407–1414.

Plummer G. 1952. Anomalies occurring in children exposed *in utero* to the atomic bomb in Hiroshima. Pediatrics 10:687–693. Available at: http://pediatrics.aappublications.org/content/10/6/687 [September 17, 2013].

Schoetzau A, van Santen F, Irl C, Grosche B. 1994. Säuglingssterblichkeit und angeborene Fehlbildungen in Bayern nach dem Reaktorunfall in Tschernobyl. Bericht im Rahmen des Strahlenbiologischen Umweltmonitorings Bayern. Institut für Strahlenhygiene, Bundesamt für Strahlenschutz.

Schull W, Otake M. 1999. Cognitive function and prenatal exposure to ionizing radiation. Teratology 59:222–226.

Sever L, Hessol N, Gilbert E, McIntyre J. 1988a. The prevalence at birth of congenital malformations in communities near the Hanford site. Am J Epidemiol 127:243–254.

Sever L, Gilbert E, Hessol N, McIntyre J. 1988b. A case-control study of congenital malformations and occupational exposure to low-level ionizing radiation. Am J Epidmiol 127:226–242.

SVITCH-M3 "SKRINNER" Spectrometry Specialized Hardware-Software Complex for Human Incorporated Radiation: User Manual. 1992. Kyiv, Ukraine: Ecology Institute. 17 p. [In Russian].

Tsubokura M, Kato S, Nomura S, Gilmour S, Nihei M, *et al*. 2014. Reduction of High Levels of Internal Radio-Contamination by Dietary Intervention in Residents of Areas Affected by the Fukushima Daiichi Nuclear Plant Disaster: A Case Series. PLoS ONE 9(6): e100302. doi:10.1371/journal.pone.0100302.

Sources, effects and risks of ionizing radiation. UNSCEAR 2013 report vol. 1. Available at: http://www.unscear.org/unscear/en/publications/2013_1.html. Last accessed September 24, 2014.

Valentin J, Editor. 2003. ICRP Publication 90: Biologic Effects After Prenatal Irradiation (Embryo and Fetus). New York, New York:Elsevier Inc: p. 7.

Wang B, Wertelecki W. 2013. Density estimation for data with rounding errors [online]. Comput Stat Data Anal 65:4–12. Available at: http://www.sciencedirect.com/science/article/pii/S0167947312000989. Accessed September 17, 2013.

Wertelecki W. 2006. Birth defects surveillance in Ukraine: a process. J Appl Genet 47:143–149.

Wertelecki W. 2010. Malformations in a Chornobyl-impacted region. Pediatrics 125:836–843.

Wertelecki W, Yevtushok L, Zymak-Zakutnia N, Wang B, Sosyniuk Z, Lapchenko S, Hobart HH. 2014. Blastopathies and microcephaly in a Chornobyl impacted region of Ukraine. Congenit Anom (Kyoto). 54(3):125-49.

Wood J, Johnson K, Omori Y. 1967a. *In utero* exposure to the Hiroshima Atomic bomb: an evaluation of head size and mental retardation: twenty years later. Pediatrics 39:385–392.

Wood J, Johnson K, Omori Y, Kawamoto S, Keehn R. 1967b. Mental retardation in children exposed *in utero* to the atomic bombs in Hiroshima and Nagasaki. Am J Public Health Nations Health 57:1381–1390.

Wood J, Keehn R, Kwamoto S, Johnson K. 1967c. The growth and development of children exposed *in utero* to the atomic bombs in Hiroshima and Nagasaki. Am J Public Health Nations Health 57:1374–1380.

World Nuclear Association's 2014 Symposium. Available at: http://www.wna-symposium.org/ehome/81896/170693/. Accessed September 21, 2014.

Yablokov AV, Nesterenko VB. 2009. 1. Chernobyl contamination through time and space. Ann N Y Acad Sci. Nov;1181:5-30.

Zamostian P, Moysich KB, Mahoney MC *et al*. 2002. Influence of various factors on individual radiation exposure from the Chernobyl disaster. Environ Health 1:4. Available at: http://www.ehjournal.net/content/1/1/4. Accessed September 17, 2013.

# Question and answer session

***Ruth Stégassy***

Thank you for this presentation. There is a question.

## Question

Thank you very much for your presentation. About EUROCAT. What could be European surveillance of congenital abnormalities without Ukraine? Ukraine is member of European council. Could be, they can be associated member? I attended of FDI meeting in the US and European meeting FDI in Europe, I attended European congresses medical associations, and speaker and writer they are from US from South Asia. So Ukraine could be associated member. Anyway…

***Wladimir Wertelecki***

Would you synthesize for me, please. If coordinator can help me, I would appreciate it.

***Ruth Stégassy***

I also did not really understand.

## Question

I say that Ukraine could be an associate member of EUROCAT. He asked you to report it, that's very important.

***Ruth Stégassy***

He is just saying that Ukraine could be an associate member of EUROCAT.

***Wladimir Wertelecki***

Ukraine is a full member of EUROCAT. Not associated but a full partner of EUROCAT with the exception that it is unfunded, other members are funded by the European Union.

## Question

You didn't mention maternal health. I don't know how or what is your point, or what is your analysis on maternal health and how do you see morbidity and mortality… we see statistics in Ukraine maybe only on morbidity which means from 0 to 1 year.

***Wladimir Wertelecki***

First of all, what is health? If you would like to define health, I will be here for two months listening to you. OK, so usually maternal health in public health statistics is defined by infant mortality and morbidity.

We can tell you that the children, in terms of indices of let's say birth rates have much … very satisfactory birth rates, both in Polissia and non Polissia. Maternal mortality, you can go to the website, the official website of the Ministry of Health and you are going find the data year after year.

The biggest morbidity in Ukraine is the big child. Not the little one, not the premature, very large children over four kilograms, and then they have difficulty delivering because they don't do enough Caesarian sections. And by not doing Caesarian sections for a variety of reasons the child asphyxiates and it's either dead or born with brain damage. So, there is a Swiss programme in fact dealing with maternal health and child morbidity. And it is the most effective programme I know in Ukraine. Certainly I know every programme that the United States Agency for International Development did put in Ukraine.

***Ruth Stégassy***

We are going to be short because we have one other question and 10 minutes.

***Wladimir Wertelecki***

So, in any event for Switzerland, I want to underscore that their programme is top. It is really an outstanding programme, you should know that.

***Ruth Stégassy***

Thank you so much, there is another question and then we will stop here because we are already quite late. We'll resume questions at 16 h.

## Question

You were talking of your research funding problems. Who financed them? And another question, is: is there a succession? You are over 18 years, are there young researchers who take over on your research?

***Ruth Stégassy***

The question is double. Who finances your research and are there younger researchers who are continuing your work.

***Wladimir Wertelecki***

The work is ongoing, is not that we have young or old. The alcohol study is financed by the National Institute of Alcohol and Drug Abuse. It is an international consortium that includes Ukraine. The rest is financed by multiple sources. And yet I underscore the pro bono. 90% of the cost, if you have to pay for, is financed by Ukraine.

***Ruth Stégassy***

Thank you very much. We will stop the questions for now but I'm sure there will be many more this afternoon. ◆

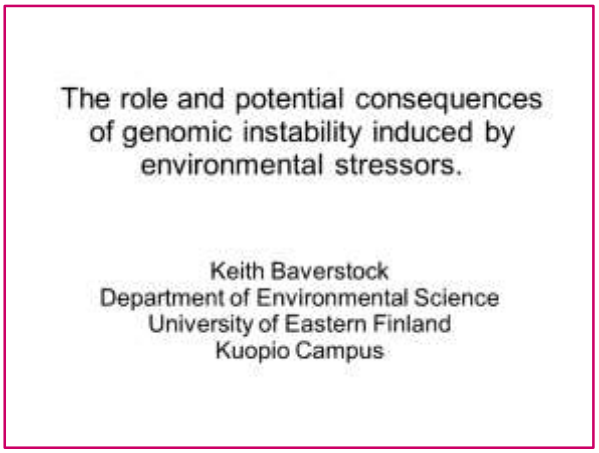
# The role and potential consequences of genomic instability induced by environmental stressors

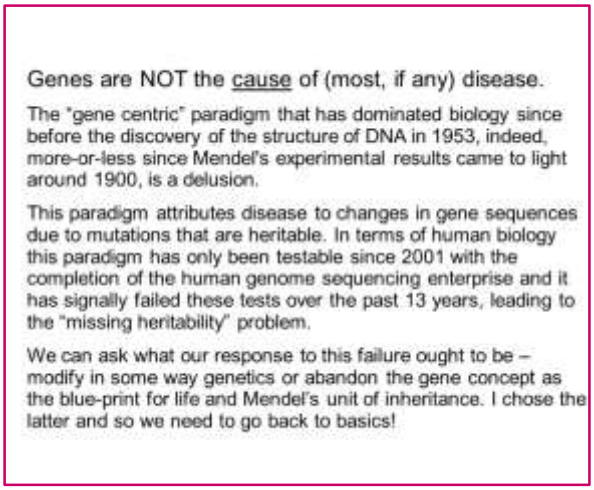
***Dr Keith Baverstock**, Department of Environmental Sciences, University of Eastern Finland, Finland*

## Introduction *by* ***Ruth Stégassy***

***Dr Keith Baverstock** is currently a docent in the Faculty of Natural and Environmental Sciences of the University of Kuopio, Finland, where he lectures and researches on the effects of ionising radiation. Dr Baverstock, a graduate of London University, led the Radiation Protection Programme at the World Health Organization's Regional Office for Europe from 1991 to 2003. From 1998 to 2002 he set-up a dedicated project office in Helsinki for nuclear emergencies and public health and in 2002 he transferred to the WHO's European Centre for Environment and Health located in Bonn where he was the Regional Advisor for Radiation and Public Health. The WHO's radiation programme was instrumental in bringing to world attention the increase in thyroid cancer in Belarus, now attributed to the Chernobyl accident. In 2001 he was a member of a UN mission charged with making a situation analysis on the Chernobyl affected regions of Belarus, Russia and Ukraine. The mission report "The human consequences of the Chernobyl accident: a strategy for recovery" was published by the UN in 2002. From November 2003 to April 2005 he served on the UK Committee for Radioactive Waste Management (CoRWM). Currently he is a partner in the European commission funded ARCH project the objective of which is to develop a strategic research agenda for the health effects of the Chernobyl accident. His current research interests are in the dynamical aspects of the process by which ionising radiation and other environmental agents cause genomic instability and cancer, the effects on human health of low doses of ionising radiation and the psychosocial aspects of exposure to ionising radiation.*

# Presentation




First thank you for that kind introduction and thank you to the organizers to invite me to come and speak to you at this meeting. Genomic instability is something which was uncovered – I call it uncovered rather than discovered – in 1991 by some of my colleagues at the Medical Research Council's Radiobiology Unit in Oxford. It was uncovered because it actually had been discovered much earlier in 1976, by a Swedish scientist, Luning, in a study with mice, looking at the effects of plutonium. Now, it was very interesting, – I did not learn about Luning's work – when I learned about what my colleagues had found with cells in culture, I was on the point of leaving to join WHO, and so I thought, well this is an interesting thing to think about, but of course I won't be able to do any experimental work on that because I'm leaving research behind. I started to think about what were the implications of it and how is it happening, how does the cell respond in this particular way which produces this progressive damage from one cell generation to the next, which we now characterize as genomic instability.

I want to introduce you to a completely different kind of concept from the genetic concept that biology has become accustomed to since at least the time the DNA structure was determined by Crick and Watson, but in fact even before that.

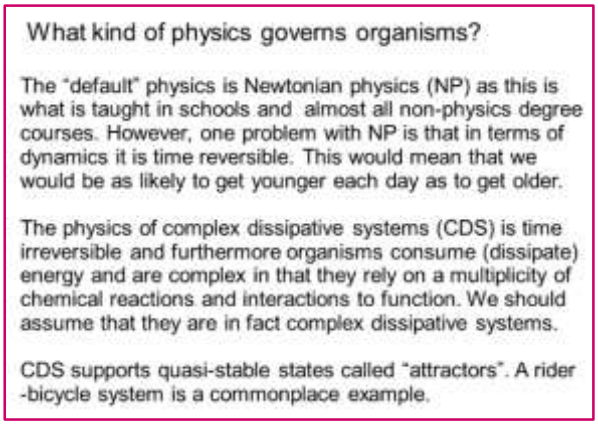
And the point is that in fact genes, as we have been thinking for the last 60-odd years, are really not the cause of most or probably any disease.

I'm not saying they are not associated, but they are not the cause. And we need to understand the cause of what we are looking at in terms of health effects. So, this paradigm as I say, has dominated biology for over 60 years – 1953 – and in fact before that, from the time that Mendel's discoveries came to light.

And this paradigm attributes disease to changes in the genomic sequence. So, we can sequence the DNA now, we only knew the sequence of the human genome in 2001, after a project which started in 1991. And that is the first time we have been able to look at a hypothesis about the change in the sequence leading to a disease. And this process of testing this hypothesis which is been taking place over the last 13 years, has signally failed. And we have what is known as the "missing heritability" problem.

Now, we can ask what to do about this. I mean we could continue trying to modify genetics in some way to get over this problem, or we could abandon genetics, we could abandon the idea that these genes are the blue-print for life or Mendel's unit of inheritance. And that is what I thought, it was at least worth trying to do. So, we need to go back to basics, and the basics, as far as we are concerned, is really physics. So, what kind of physics do we need to understand how organisms are responding to environmental stresses?

Now, the default physics, what we were taught in school, what all undergraduates except specialist physicist undergraduates are taught, is what we call Newtonian physics.




It has one small problem because it is time reversible. If you look at a pendulum swing, if you look for just a short time, it doesn't tell you anything about which direction time is running. It could be running forwards, it could be running backwards, as though we were talking about a film. So, it means, in biological terms, that if we are governed by Newtonian physics then there is an equal chance each day that we have either become younger or older. And I think most of us know that it's the latter that is working almost exclusively. Some might feel younger one day but actually you get older every day. So, that physics is clearly not suitable for biology.

Now, there is another physics, physics of Complex Dissipative Systems, and that is the kind of physics which I think it is the most appropriate, because cells, human cells, or animal cells or bacteria, they are dissipative systems. We dissipate energy, we consume and live on the basis of taking in energy. And this is a physics of these kind of systems.

One of the most important features of this, what I call CDS, is it supports these quasi-stable states, called "attractors". Now remember that if something isn't stable we would never observe it. So, we have several kinds of stability, there is a kind of stability like this glass, resting on the table. That's Newton's kind of stability. But there is another kind, and we encounter it in many contexts in everyday life…

There is the picture of a cyclist. A young lady riding a bicycle.

An interesting thing about that is this combination: this system of the rider on the bicycle enables the bicycle to adopt a vertical upright position. And you will never see a bicycle on its own, unsupported in that position, it only falls over, it is not stable. But the stability arises from having this system, the combination of the rider and the bicycle together. And the rider operates the bicycle in such of way, by shifting their weight to the left or to the right, by turning the handlebars to the left or the right, and these are four actions which we call "dimensions of the system". They can keep the bicycle in the upright position, and the bicycle-rider is an "attractor". This is a kind of quasi-stability which is maintained as long as all four of those dimensions are available to the rider. If one of them is lost, the wheel gets up against the curb, the bicycle falls over, the rider falls off, and the attractor is lost.

We encounter attractors in numerous examples of everyday life, but we don't recognise the phenomena.

A candle for example is an attractor. That's why its difficult to blow a candle flame out, much more difficult to blow out the candle flame than a match flame. That is also why when you have got a clean windscreen in your car and it's heavily raining, and you see water running down the windscreen, those waves' ridges of water running across this screen and they're attractors, they are very stable. So attractors are a common phenomenon and we are arguing that the phenotype of the cell is an attractor and it acts like a switch.

An attractor state behaves like a switch

Either the system is in an attractor or it is not. In the case of the "rider-bicycle" system being out of the attractor is to be lying on the road, but more complex systems may have several alternative attractors (*variant attractors*) and transitions between attractors are possible.

I and my colleagues have proposed that cellular phenotype is an attractor state within a complex system of protein and other macromolecular interactions. In addition to supporting the phenotypic properties of the cell (encoding information) it regulates the cell and is what Mendel termed the "unit of inheritance". In other words we have each inherited attractor states from our parents.

In this latter sense the attractor replaces the gene.


JOURNAL OF THE ROYAL SOCIETY Interface

rsif.royalsocietypublishing.org

Research

Genes without prominence: a reappraisal of the foundations of biology

The phenotype of the cell is in the attractor or it has been kicked out by some form of environmental stress. Now, the cell is much more complex than the bicycle rider system. There are approximately in a normal cell type of the human some 3,000 dimensions, instead of just four. And there are perhaps an infinite number of attractors. And so, what we get is the transition from one attractor to another attractor. A change of phenotype. And this is the way genomic instability works. This attractor is composed of proteins interacting. And we may have known that, but it's not something that is emphasized when we look at the genetic perspective of biology. So the attractor is something which is passed down from one generation to the other, and this is what we would say with Mendel's "unit of inheritance". And we inherited from each parent an attractor, and those two attractors synchronize in a zygote, and we get the new individual. So in this sense the attractor is replacing the gene.

Now these ideas have been published a year ago in a very prominent journal of The Royal Society, and although it challenges it, this paper challenges genetics, not one single geneticist in the past year has written to us, or spoken to us and said, "you know, this is wrong".

And yet it replaces to a large extent what many geneticists are doing.

So, I have some confidence in presenting to you these ideas, because I think by now we should have been told that's wrong, if it is.

So what we have done, is we have tried to replace the genetic paradigm with actually true theory based on physics. And this is based on physical laws which are well established: the 2nd *law of thermodynamics*, and the principle called *the principle of least action.*

Annila and I have shown in this paper how it is possible to reformulate biology as a truly scientific theory (rather one than relying on statistical associations) of living systems based on the 2nd *law of thermodynamics* and the principle of *least action*, underpinned with the physics of CDS and the attractor state representing phenotype. In this reformulation genes (and therefore genetics) play a minimal, if any, role.

It is worth noting here that there is strong evidence that, for example, cancer is NOT a genetic disease. A Nordic study of identical twin pairs showed that for most cancers the concordance (both twins contracting the disease) was less than 10%, mostly less than 5%. As identical twins have nearly identical genotypes, if cancer was a genetic disease i.e., determined by the sequence of the DNA, concordance would be much closer to 100%.

The question is then if disease is not "in the genes" where does it lie.

And an action is a process. And what the principle of *least action* says is that, if a process is going to occur, – for example the transfer of energy, if you like, the energy in your warm house on a cold day, you are concerned about loss of energy, the loss of heat from your house –, the principle *of least action* says that this equilibrium between the house and the outside will be resolved as quickly as is possible. And so if you leave the door open it will be resolved more quickly than if you don't. So, it's very, very simple, and in this context it means that if there is an excess

of energy, for example at lunch time there would be an excess of energy around the table, it would a table be surrounded by hungry people, and that energy would be consumed as quickly as possible, or at least as quickly as good manners allows. And so, it becomes the process by which selection occurs. If an organism can extract energy to grow from its environment more effectively, more efficiently than another organism, it will be selected. So we have a Darwinian selection, not based on genes, but based on the ability to extract energy.

Now, it's worth noting here that cancer for example is not a genetic disease, although everybody seems to continue to treat to it as if it is. A Nordic study published in 2000 studied identical twins. Identical twins have identical genomic sequences, DNA sequences. And therefore you expect that if one twin contracts a genetic disease, the other twin has a very high probability of contracting the same disease, if the disease is encoded in the DNA sequence.

Well, actually, as it turns out from most common cancers, what we call the *concordance* – the extent to which the two twins, identical twins get the same disease – is really lower than 10 percent and usually around 5 percent or even less. So, this is clearly not a genetic disease. There is no basis in genetics to call this a genetic disease.

Where does this disease lie, where does the origin of this disease lie? That's the question we need to answer. The answer lies, as I say, in this attractor. And this attractor is a complex thing.

The answer is that the attractor is fulfilling the functions that have been attributed to the gene. This not as revolutionary as you might think because it has long been accepted that cellular function is provided by proteins and not DNA. It is also well known that proteins "interact" one with another and this is usually expressed in terms of networks.

Diagrams like this are a snapshot in time of the proteins being expressed in a cell – some are related only to one other protein, but others are part of hubs consisting of several 10s of proteins and they act collectively. Some traits arise from the loners but others require several proteins acting together. Each protein is derived from a peptide that is coded for by a gene, but the attractor regulates how the peptide is folded (to become a protein) and when it interacts.

This is what is known as a protein interaction network. And you can see that each of those dots is a protein, this is a typical snapshot in time. So just an instant in time of how the proteins are interacting together. Those interactions give rise to this attractor state, and that becomes the phenotype. But not only that, it also regulates the cell, it is really the centre of the cell.

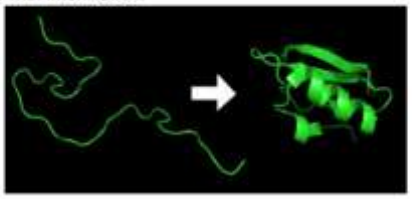
So we have moving the focus of the attention of the centre of the action from the genomic sequence to actually the phenotype itself, and the proteins that are interacting to give rise to the phenotype.

Another interesting thing is how do these proteins do this? Because actually we need some form of information to process what is going on in the cell. Because actually it's a very highly ordered thing, I mean, the cell does what it has to do and we are healthy. So, how does that, just take place with just proteins?

Well, proteins are derived from peptides, and peptides represent the sequence of the DNA.

So, the sequence of the DNA calls for a stream of amino acids called the peptide. And a peptide is not active, it doesn't do anything, except fold up into the protein. And you see the coiled three dimensional structure there of the protein.

Folding the peptide to a protein and activating it endows the protein with information.



This is well established in the fact that enzymes recognise their specific substrates only in the folded form. For many proteins folding is carried out by other proteins called chaperones. By expressing well in excess of 100,000 proteins the human cell can generate all the phenotypic functions required for the human organism, but this has to be done in a highly coordinated way and in the appropriate time sequence. This is the task of the attractor – essentially it both regulates the cell and expresses the phenotypic traits. It is also the attractor that is inherited from one cell generation to the next.

In the same time during that process, information is encoded in some way onto that protein.

We know this because we are very familiar with the chemistry of enzymes. And enzymes recognize just one molecule, their substrate, and they react exclusively with that. So they have information which says: I know that, that is the molecule that I can interact with, in a sense.

So, this information is being generated in this folding process which involves the dissipation of energy. So we're speaking actually of conversion of energy to information. And that information is an area, this is an area of protein chemistry that we haven't even explored. We didn't even think of this aspect, of the way proteins would be working. But they do this: roughly the human cell has well in excess of 100,000 proteins, it gets this from some 20 thousand DNA coding sequences, it gets the peptides, but it increases that number to a hundred thousand by folding the same peptides in different ways. And so you get different proteins from the same peptide. And this task of folding these proteins in the correct way is the task of the attractor.

It essentially both regulates the cell and expresses the phenotypic traits. And the phenotypic traits are a form of information which is existing on the cell, and enables the cell to communicate with other cells and exchange the information.

And that we see, commonly we regard it as cell signalling. And there's a huge area of biology that concerns cell signalling. And as I say it is also the attractor that is inherited from one generation to the next.

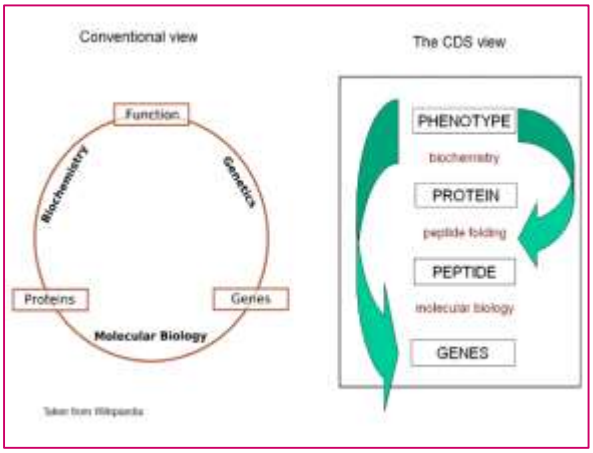
So let's look at the two different concepts now.

We have this conventional view of genetics which is kind of circular in structure, that genes, through molecular biology, devised the proteins, no mention of peptides. Because most molecular biologists believe that there is only one way to go from a gene coding sequence to a protein. Not more than one. The peptide, they know its there but it's irrelevant. And then the proteins, as in my model will, through bio-chemistry, produce the function. But there is very little interest in that aspect. And then, the function of the phenotype, in its relationship to the genes, so the genes are giving rise, are causing, the phenotype that is the subject of genetics.

Now, we look at it in a slightly different way. Genes go through the molecular biology, but they produced peptides. And the peptide folds to the protein, and then the biochemistry takes place to produce the phenotype. But the causality, the phenotype, acts down, on the peptide folding and can strain the genome sequence. And I think that the changes that people report as a result of radiation are often due to this process, and not the primary effect of the radiation.

Now this is what's known as downward causation. It's very controversial, but it exists. Because if somebody was to make a huge bang in this room, it will be detected essentially through the ears by the brain. It would cause physiological changes. You would feel fear, you would feel a tingling in your spine as the result of that. That's downward causation. That's something you detected with the brain and you get a physiological response.

We're saying that the phenotype acts downwards, on its own components.



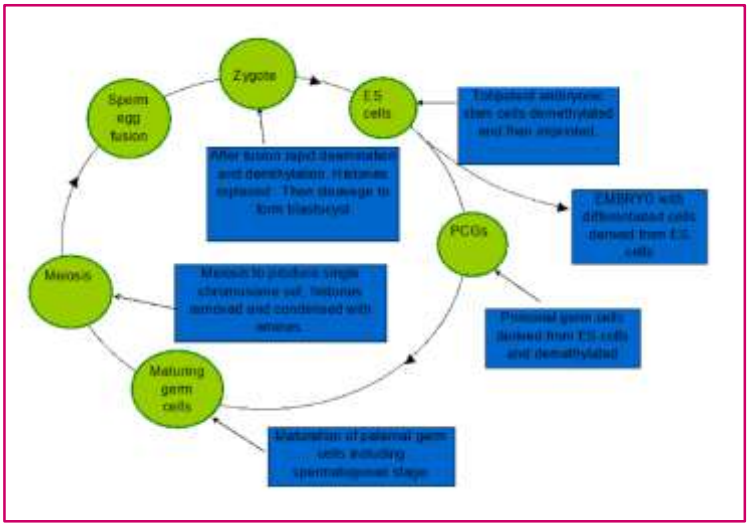

One further point about the attractor representing phenotype: for any germ cell from a stably replicating species, the stable state is termed the *home attractor*. It has, over many generations in a given ecosystem, achieved the optimum integrity in replication and a high degree of resistance to being made unstable. This we call *evolutionary conditioning*. If this home attractor is lost that is irreversible and any subsequent *variant attractor* adopted is a) less accurately replicated and b) more likely to be lost. This leads to a progressive degradation of species integrity – that is, higher levels of disease. That is genomic instability and it is the initial step in the transition to a new species.

I want to leave the theory here with just one further point: you have probably understood we are talking about circular causality and that is a very non-Newtonian thing. However, if life was initiated without an external agent (creator) as most biologists believe, then there is no alternative to life having created itself. A phenotype begot a phenotype.

So now there's one further point that I want to emphasise, and that is this particular kind of attractor. So if the species, if an individual of the species is being replicated true to form, every generation is in a home attractor.

And that attractor has specific properties. It has got the property of accurate replication and it has a stability. It has an extra level of stability that other attractors, what we call variant attractors in the cell, don't have. But if that home attractor is destructed such that it collapses, then what we see is genomic instability. The genomic instability is the progression of the cell through many different attractors, variant attractors, they are unstable, more easily perturbed, and that is a process which is inherited and ongoing for ever, ever more. I just make a note here that this is circular causality, and really means that the phenotype which arose by some kind of random process at the initiation of life, formed all the phenotypes to follow.

I will skip that since the time is short because I want to go on to this.




So, this is the cycle of germ cells.

Because what we're really concerned about genomic instability, is when it occurs in germ cells. You can see that this cycle, this ring of green dots, green circles, this goes on and on, but every time it goes around, it produces an embryo which grows into a human being. And damage to those cells never gets eliminated from the system. So once we have genomic instability induced in a human, individual, if its a male that instability will be transferred to the next generation, and then to the next generation, down the male line. These embryos which have somatic cells, they will experience ill effects, as a result of the instability, as the result at not having the correct phenotype.

All cells in the body have this home attractor, but if it's lost in the germ cells, then we will see this effect transmitted from one generation to the next.

Yuri Dubrova, who you heard earlier, has done the most important work on this, but it is supported by other work, for example on rats and it's increasingly, I think, becoming investigated.

So, what are the implications for humans?

**What are the implications for humans?**

Humans have a generation time of about 30 years and many diseases that afflict the population are not registrable as is cancer. These two factors mean that detecting the consequences of induced GI in human populations is impracticable unless we can see potential causes of GI say 50 to 100 years ago and follow-up an exposed population. One potential source of exposure is nuclear weapons testing in the 1950s where the second generation of the exposed are now being born. Dubrova ran a small study of survivors of the weapons testing in Semipalatinsk and observed the markers of GI in two generations.

The problem with using markers is that they are very system dependent in ways we do not understand. In work with round worms I was involved in we did not observe any markers, but found that the phenotype was modified more than 10 generations after exposure.

That it is an irreversible process which will lead to the degradation of the several generations of the human species. So it will lead to malformations, to mental damage, it will lead to increased disease. But it's going be difficult to see because it takes 30 years for a generation… to pass onto the next generation. So we're not going to be able to detect it very easily, because it's imperceptibly slow in the time frame that we can look at it.

We cannot study it using markers, but that's not necessarily very reliable, and the markers differ from one system to another. So, we really do need to focus our minds on how we are going to study this.

OK, how can you be sure I am not spinning you a fairy-tale? Well, I think there are four reasons.

How can I be sure I am not spinning a fairytale?

The first thing is that the genetic paradigm that has dominated biology for 60 years is failing and we see that more clearly every day. So what is being replaced is definitely wrong.

Secondly, the theoretical argument for what is being claimed is based firmly on sound and very basic physics dating back to 100 years before Darwin's "*The Origin*" (~1760).

Thirdly, there is sound empirical evidence in animals both with disease endpoints and markers.

The main source of funding for work of this type in Europe, the MELODI platform, which has taken over the European Commission programme, after having failed to uncover the mechanism for radiation induced genomic instability, now denies the phenomenon even exists!

One is that there is something wrong with the genetic paradigm. Secondly there are theoretical arguments for this position, based on fundamental physics. Thirdly there is empirical evidence, which we can call upon in some of Yuri's work if it falls in that category. And then there is a final thing, it's that the European commission, Melodi platform, investigated this with very huge sums of money over period of about 10 years, and they just dropped it and said, "actually we don't think that the phenomenon exists". So they don't work on it, really at all now. And I think that's because they understand the implications.

To sum-up, genomic instability is a profound and irreversible phenotypic change, and it's much more easily induced than, for example, specific mutations in DNA. Because all damage induced on DNA has to be repaired, and the origin of this is in stress on those repair processes, and the general functioning of the cell.

To sum-up:

Genomic instability is a profound and irreversible phenotypic change, which is much more easily induced than, for example, specific mutations in DNA.

If the arguments presented here are correct, over the next several generations there will be a degradation of the integrity of the human species entailing increased and earlier onset of disease and malformations.

Given the generation time of the human it will be very difficult to observe through epidemiology, but one possibility might be those exposed to radioactive fallout from weapons testing in the 1950s, where the second generation is now being born.

If the arguments here presented are correct, we know for several generations there will be a pronounced degradation of the species. And this is really part of the process of the evolution. It is the other side of the coin to the stability of the species, that if an organism cannot adapt well to its environment, then it would move on to try and find a better form of itself, that will adapt better. It will be very, very difficult to observe directly, especially through epidemiology, but we might look at some populations that were exposed in the 1950s. So we have a long period to follow up.

Finally I would like to acknowledge my coworkers, Dr Andrei Karotki, Professor Arto Annila and Dr Mauno Rönkkö. Thank you. ◆

Finally, I would like to acknowledge here my collaborators in this work:


Dr Andrei Karotki


Professor Arto Annila


Dr Mauno Rönkkö

Thank you for your attention!

# Question and answer session

***Ruth Stégassy***

Thank you very much, we take some questions.

## Question

You have been saying that genetics doesn't explain cancer. Obviously it's not primary mutation which is responsible for most cancers but it's something which happens during life later on during environmental factors which is something which I don't think there're any contradiction between genes and cancer. In your conference you're trying to speak about attractors in genomic instability but you don't show any scientific experiments to support your hypothesis, which I find a bit annoying from scientific point of view.

***Keith Baverstock***

Well, I've been asked to talk to a lay audience here, and also within a specific time limit. And we are talking about a profound change in a way we look at biology. I think if you read the literature you would find that there is empirical evidence and you'll find in the paper that I showed you that some of that is quoted.

To go back to your first point, the point that I'm making is that if you sequence the DNA to look for changes in the sequence, and you try to relate those to common diseases, it doesn't work. The reason given for that is because common diseases don't just involve one particular gene sequence, but the interaction between several; and it is very difficult to resolve that interaction. But I don't think that argument is correct because I think there is a fundamental reason why the information in the sequence of the DNA is not the information that arises on the protein: it's because of the different ways in which the proteins can be folded. And you're probably then aware of the existence of chaperone proteins which do a lot of protein folding, and you might then wonder what is the reason why cells develop chaperone proteins. If for example the idea that the sequence of amino-acids in the peptide determines the structure of the protein… which is what is generally assumed.

## Question

Thank you. I was told or I read somewhere that actually genes… – I'm a lay person, just to give you the level of my question –, the genes as you said, they are not necessarily what they make out to be the cause of the disease, but actually the genes are the record, the records. That means that the disease is there and it could be recorded in your genes. But so will the healing if it happens. The genes would

change, it's like history record in a way. Do you confirm this? Did I understand this well or not well?

***Keith Baverstock***

No, I don't think necessarily you'll see the disease in the genes. Because if it's correct that the attractor state is responsible for the inheritance, then the attractor state is not directly connected to the genome sequence. And the reason is in a sense that, when ionizing radiation causes damage to the DNA, the cell tries to repair as much as it possible it can, before cell division. It expends an enormous amount, something like 30%, of the energy passing through the cell in its metabolic processes is used for damage detection and repair.

So, it is extremely important, but when that damage occurs, it has to be repaired wherever it occurs, and 98% of DNA is not gene coding DNA. So you could have, let's say, genomic instability which led to cancer, induced by damage to DNA, not in any genes, not in any genes at all in the remainder of the DNA. And that's one of the reasons why genomic instability is so much more sensitive than mutation. Because you require not only in some cases the mutation to be in a specific sequence, but you also expect it to be in a specific place in that sequence.

So you are talking about a very rare event occurring – an ionizing radiation causing the mutation – whereas in the genomic instability alternative explanation for the mechanism is what it is, that damage could be anywhere in the DNA, and still lead to that cancers. So, I don't think it holds that kind of a record, but it does hold the record of how we've evolved… to a degree.

## Question

I think slightly a disadvantage of some mutation can be fixed in a population in some generations, and that can be calculated at certain ratio. So, if that happens to some regulatory regions of multiple locations, and then each mutation can be just only almost invisible at the interiors, but in future generation that might arise, as a combinatorial damage, as a new disease. And would you expect of something like that happen?

***Keith Baverstock***

Well, no, I mean I think we don't go down that route. Actually most mutations that occur in the DNA, but from any sources, it might be from ionizing radiation, it might be from traffic pollution or whatever. Many, many things causing mutations, cigarette smoking and that sort of things. But actually most of those mutations don't actually do anything, they don't appear.

So, the system is quite resilient to that, but what it is not resilient to, or as resilient as it perhaps could be, is because at this quasi-instability you can if you like switch off the right phenotype and adopts a variant phenotype. That variant phenotype will never find its way back to the original home attractor. And so you will never get the true phenotype back. So actually what you're looking for in a population that has been subject to these stresses, is the abnormal phenotype. And that's quite complex, because a phenotype has hundreds of aspects to it. Biologists usually concentrate on one or two, at a time like it's a pink flower it changes to a blue flower. But what else changes as well? They take this view that well everything else remains the same, but actually that doesn't work in economics, and it doesn't work in biology either.

## Question

I would like to thank the last speaker for emphasizing the idea which seems to me extremely important: ionizing radiation that passes through a living organism damages not only the DNA molecules it encounters, including possible carcinogenic mutations, but all other molecules, particularly proteins, and therefore the ionizing radiation endangers the entire machine of the cells.

The second idea I learned is that it gets worse over generations.

The third idea is that it takes 300 years to prove it.

So my question is: how to present this kind of result to the pro-nuclear governments, including the government of France, where I live, and which maintains a total of 19 operating nuclear power plants, with 58 reactors on Switzerland's doorstep? And that our government is openly pro-nuclear and

has no understanding of the arguments presented this morning.

So, the question I ask is, how to translate your research in a convincing way for our politicians, that is, those who ultimately will decide to maintain this nuclear industry that affects the survival of humanity.

***Keith Baverstock***

I think there's a step before that, and that step is to engage, at the scientific level, to debate how this is relevant and whether it does indeed replace the genetic paradigm. That debate, I'm sad to say, since it has been published and several papers published several years before, going back 2008, have not stimulated any discussion at all with the genetics community. So, until they decide that they are going to engage in this debate, this will just be ignored. That's the fact.

***Ruth Stégassy***

Thank you very much, it was a very dense morning, so we stop to eat together, as the organizers are kind enough to invite us, and we resume our work at 14 h. ◆

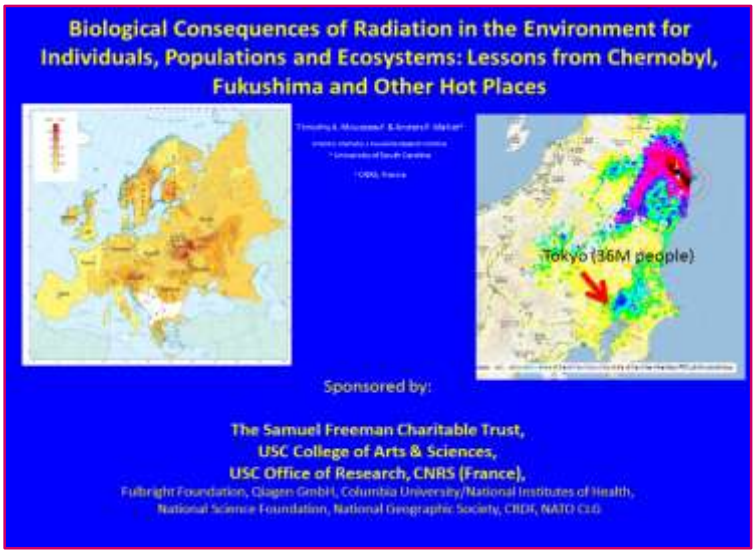
# Biological consequences of radiation in the environment for individuals, populations and ecosystems: lessons from Chernobyl and Fukushima

***Dr Timothy Mousseau**, Professor of Biological Sciences, University of South Carolina, USA*

## Introduction *by* ***Ruth Stégassy***

***Dr Timothy Mousseau*** *has been a member of the faculty of the Department of Biological Sciences at the University of South Carolina since 1991. He received his doctoral degree in 1988 from McGill University and completed a NSERC (Canada) postdoctoral fellowship in Population Biology at the University of California, Davis. At USC, Dr Mousseau and his students have worked on a wide diversity of organisms, from bacteria to beetles to birds, and his primary areas of research interest include the genetic basis of adaptation in natural populations. Since 1999, Professor Mousseau and his collaborators have explored the ecological, genetic and evolutionary consequences of low-dose radiation in populations of plants, animals and people inhabiting the Chernobyl region of Ukraine and Belarus. He recently initiated a second research programme in Fukushima, Japan. His research suggests that many species of plants and animals experience increased mutational loads as a result of exposure to radionuclides stemming from the Chernobyl disaster. In some species (e.g. the barn swallow, Hirundo rustica), this mutational load has had dramatic consequences for reproduction and survival. Dr Mousseau's current research is aimed at accurately assessing doses received by animals living in the wild and elucidating the causes of variation among different species in their apparent sensitivity to radionuclide exposure.*

# Presentation



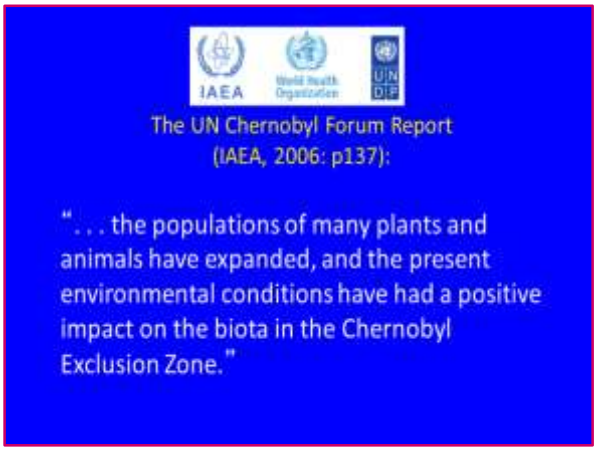

It really is a great privilege to be here today, thank you so much for coming out. I am going to spend my time briefly covering, touching upon a few key results that we have generated over the past 15 years really in Chernobyl, in the last three and half years in Fukushima.

As everyone in this room knows, Chernobyl happened in 1986, twenty-eight and half years ago, Fukushima March 11th 2011. In many ways they're very similar events but in many ways they're also different and so we've attempted to capture and to use the similarities and differences to test some of our models concerning the effects of radionuclides on natural populations.

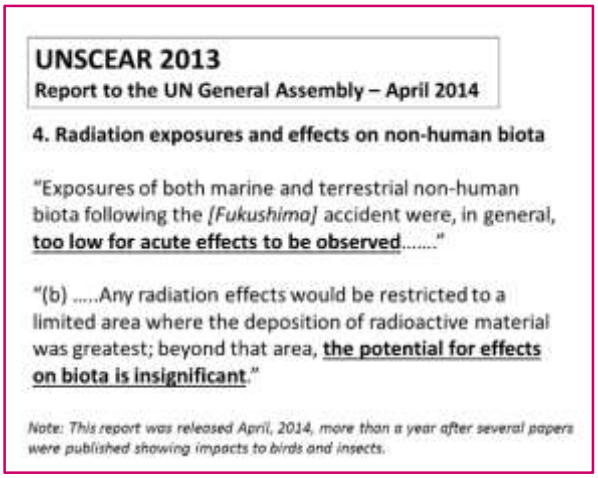
I'm going to start with a couple of these kinds of slides which really provided a lot of the motivation and some of the context for the work that we have been doing for the last few years.

I think you've all heard about the Chernobyl Forum Report, parts of it were released in 2005, officially in 2006, and it suggested, among other things, that the animals and plants in the Chernobyl zone were thriving, were doing great because there were no people – there's a nice big fence around it.

And so this came as a big surprise to us because we had been there for several years already and we really hadn't noticed that there were many, many animals everywhere, in fact we had had a hard time finding many of the animals and so we were a little shocked and surprised.




The next report came just last early this year, the UNSCEAR 2013 report released in April 2014, related the same thing. This time they suggested that exposures related to Fukushima were generally "too low for acute effects to be observed".

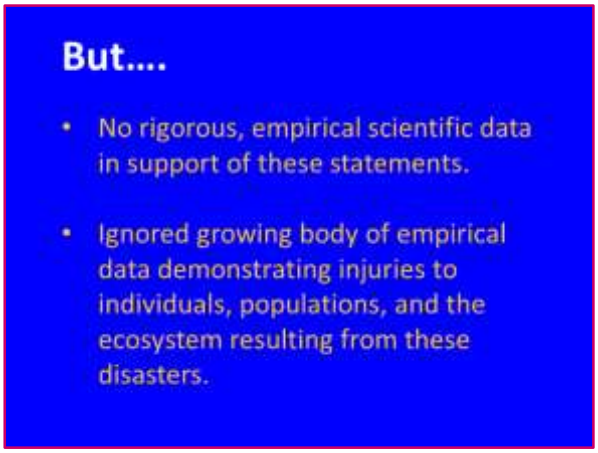



They also suggested that "the potential for effects on biota is insignificant", even if maybe there was some radiation (laughs)…

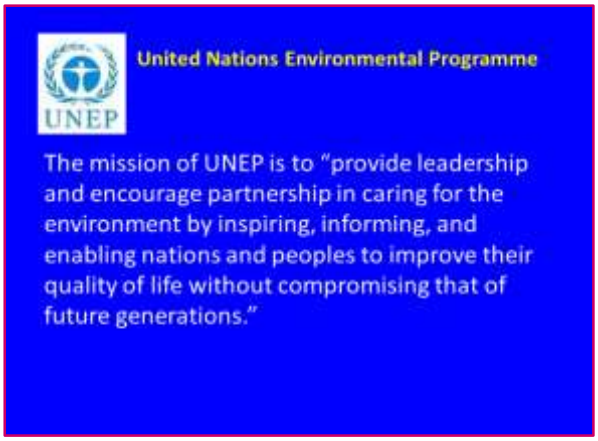
They released this report without considering all of the literature that's been generated for Chernobyl in the past ten years, of which we published some, and also the much more limited bunch of publications that have been generated in association with Fukushima in the last three years.

So to us it was very surprising, we have a hard time understanding why they would be generating these kinds of statements with a complete absence of any raw data, ignoring most of the data that existed.

So no rigorous empirical scientific data exists in support of either of these two reports that have had a humungous influence on how we've viewed the risks and hazards of nuclear disasters and radiation in general.



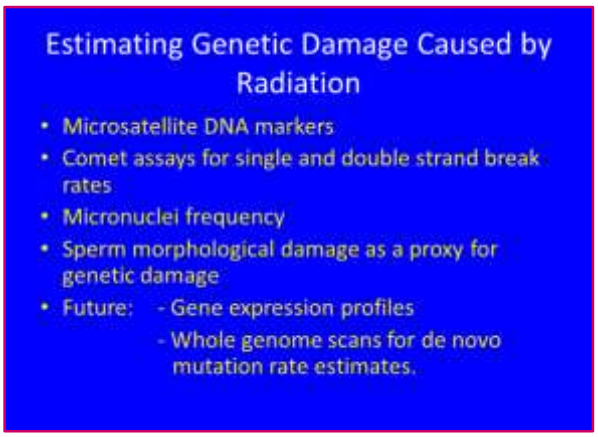

And this kind of goes against the general UN mandate of also protecting the environment; it's not just about protecting humans, it's also about protecting the environment for the good of man, in the end.




Since I don't have a whole lot of time today, I'm going to really touch upon a few key areas very quickly and just to make a couple of points. The first general areas concerns the notion of whether or not the level of radiation, the level of radioactive contamination that we see in places like Chernobyl and Fukushima, actually does generate damage to the DNA.

I'm going to make the assumption that damage to the DNA is important in terms of some of these consequences. And so we have been working with different kinds of markers for DNA damage: microsatellite DNA markers. These are the fingerprints that police use to identify bodies, they also mutate very quickly, they're often a good marker for immunogenesis; we have a technique that we can look specifically at breakage to the chromosomes such as comet assays.

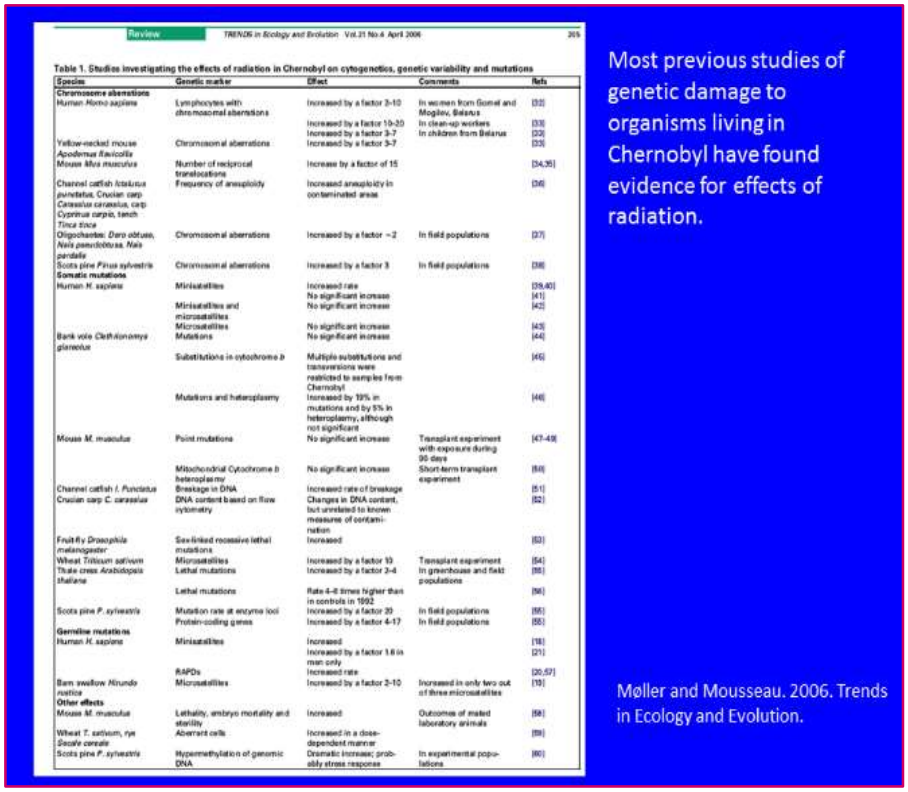
But there are other standard methods of assessing genetic damage due to radiation: micronuclei frequency.




We also use a few other proxies like sperm damage as a measure of some kind of gene effect. In the future we hope, if we get funding, there will be more use of other more complex genomic techniques for assessing genetic damage.

So, ten years ago, when this topic started to heat up a little bit, we decided that we needed to review the literature: what is known about the effects of radiation in the environment on genetic damage? We went to the Western literature, we went to the Eastern reputed literature, focussing on studies done in Chernobyl and we made review of those published in a journal called *Trends in Ecology and Evolution*.

This is a table showing the results of about forty-four studies that had been done at this time and thus should have been included in the Chernobyl Forum Report, but that in large part were not.




When you look at all of these forty-plus studies, almost about 85 per cent of them show some evidence of genetic damage related to the radiation exposure in Chernobyl; so fairly convincing information related to the effects of Chernobyl on genetic damage.


We've just finished another similar study which makes use of all of the literature that's been generated in the last five years – almost eight years now since this paper was written – and this new analysis, which doubles the number of studies, actually is far more convincing, it's done in a quantitative way, it should be published in about a month or two, hopefully, you'll see it, I'm sure.

Many of you probably have seen this suggestion, particularly by nuclear industry types, that the levels of radiation around Chernobyl and Fukushima are very low. The amount of radiation given off by nuclear power plants during their normal day-to-day operations is very low, in fact it's lower than the natural radiation levels that are found in many parts of the world; and since it's lower than the natural radiation levels, maybe it's not such a big deal, right?

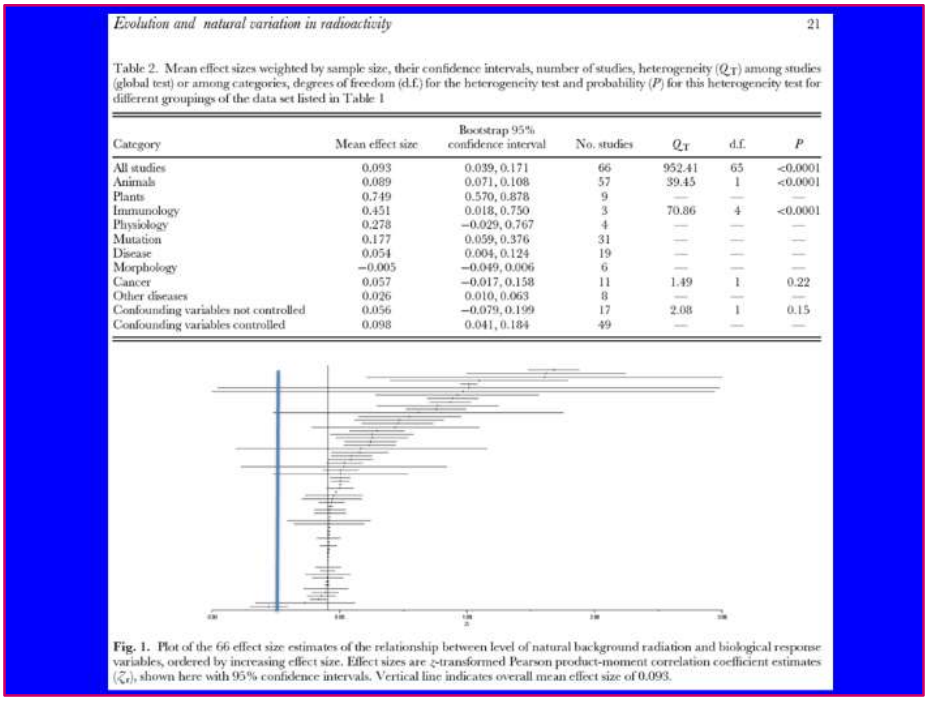
This suggestion has been made over and over again, I've heard so many times that we decided to

actually do the same thing: go out to the literature, see what has been published concerning tests for the effects of radiation in these naturally radioactive parts of the world, places like Ramsar, Iran, and Kerala, India, Guarapari, Brazil, Lodève, France, many of these areas have naturally higher radioactivity as a result of the uranium or thorium where there are data, in the soil close to the surface.

And when we did this we found about 150 different studies that were relatively informative, put them into analysis and, lo and behold, even natural radioactivity leads to consequences.

Now there's no good study showing that natural radioactivity of this sort generates cancers. But many of you will probably realise that the second leading cause of lung cancer proven to be the case or shown to the case in North America and in China – anyone know? *(From public: Radon)* – Radon! Radon in your basements, it is natural radioactivity, causes cancer, in a big way.

This graph is just a summary of the different kinds of characters that are affected by natural radioactivity, most of which are significant.



*Evolution and natural variation in radioactivity* 21

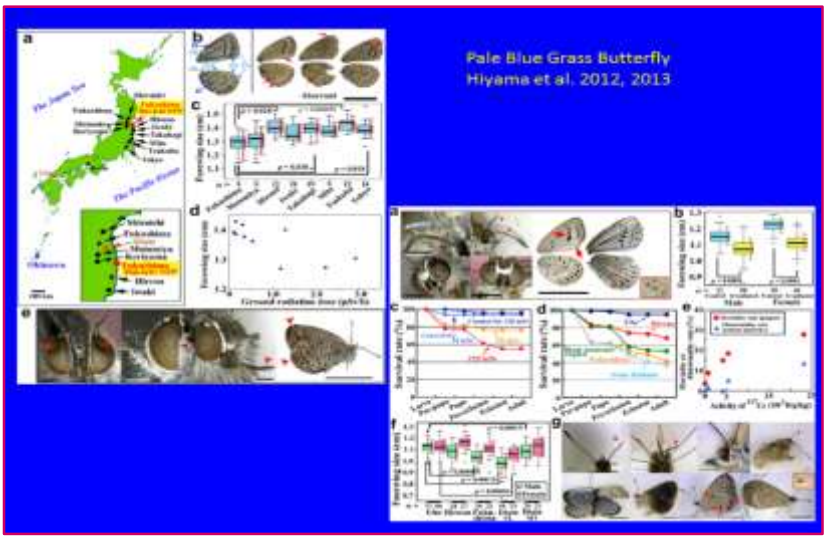
Table 2. Mean effect sizes weighted by sample size, their confidence intervals, number of studies, heterogeneity ($Q_T$) among studies (global test) or among categories, degrees of freedom (d.f.) for the heterogeneity test and probability ($P$) for this heterogeneity test for different groupings of the data set listed in Table 1

| Category | Mean effect size | Bootstrap 95% confidence interval | No. studies | $Q_T$ | d.f. | $P$ |
|---|---|---|---|---|---|---|
| All studies | 0.093 | 0.039, 0.171 | 66 | 952.41 | 65 | <0.0001 |
| Animals | 0.089 | 0.071, 0.108 | 57 | 39.45 | 1 | <0.0001 |
| Plants | 0.749 | 0.570, 0.878 | 9 | — | — | — |
| Immunology | 0.451 | 0.018, 0.750 | 3 | 70.86 | 4 | <0.0001 |
| Physiology | 0.278 | −0.029, 0.767 | 4 | — | — | — |
| Mutation | 0.177 | 0.059, 0.376 | 31 | — | — | — |
| Disease | 0.054 | 0.004, 0.124 | 19 | — | — | — |
| Morphology | −0.005 | −0.049, 0.006 | 6 | — | — | — |
| Cancer | 0.057 | −0.017, 0.158 | 11 | 1.49 | 1 | 0.22 |
| Other diseases | 0.026 | 0.010, 0.063 | 8 | — | — | — |
| Confounding variables not controlled | 0.056 | −0.079, 0.199 | 17 | 2.08 | 1 | 0.15 |
| Confounding variables controlled | 0.098 | 0.041, 0.184 | 49 | — | — | — |

**Fig. 1.** Plot of the 66 effect size estimates of the relationship between level of natural background radiation and biological response variables, ordered by increasing effect size. Effect sizes are $z$-transformed Pearson product-moment correlation coefficient estimates ($\zeta_r$), shown here with 95% confidence intervals. Vertical line indicates overall mean effect size of 0.093.

We are going to hear a lot more about this study after my presentation, so I'm not going to dwell on it.

It's just that it's one of the very most eloquent studies done so far concerning the genetic consequences of the acute multi-generational exposure to radiation, and this is the Pale Blue Grass butterfly story from Japan. I'll leave that for you *(turning to Chiyo Nohara)*.

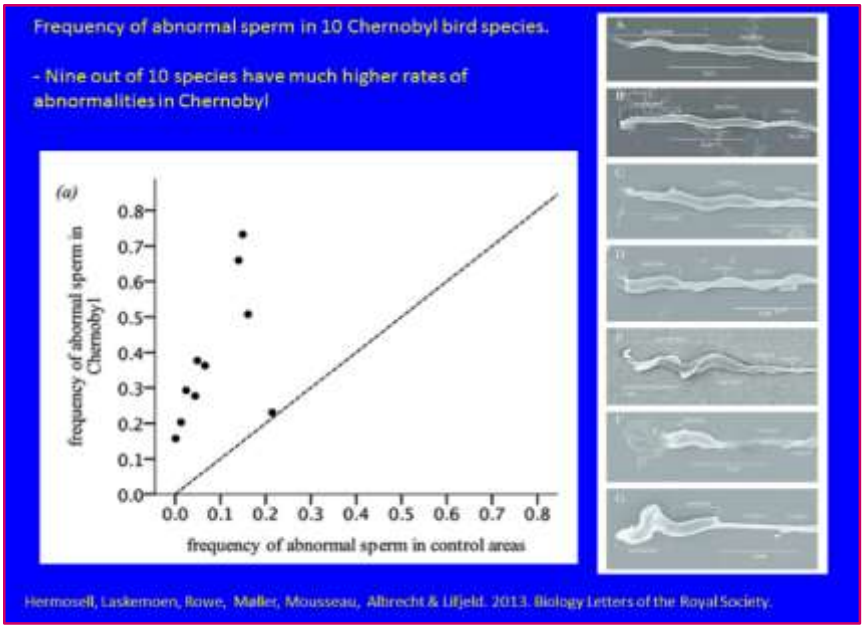


So, some people, I think we maybe have heard this early… Just because we have a mutation at the level of the DNA doesn't mean it does anything of any significance. We all carry around thousands, if not more, of quote unquote mutations, most of which are not expressed, most of which have no effect, and so it's quite possible that Chernobyl and Fukushima levels of radiation, maybe they up the background mutation rate a little bit, but it needn't have any consequences for the organism.

So we need to actually test this, to show this, empirically, so that's what we've done in many different ways.

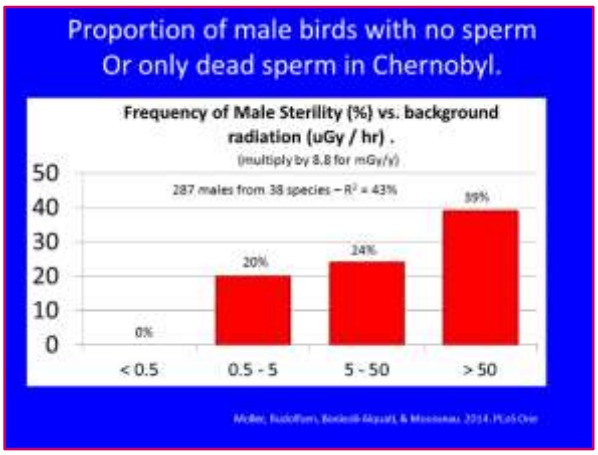
We published a paper last year, again, comparing the morphology of sperm of male birds.

One of the reasons for looking at sperm is that spermatogenesis tends to be very sensitive to environmental effects, including radiation. And when we compared species, the same species from Chernobyl to species from control areas of clean parts of Europe, we found out that in 9 out of 10 species there were dramatically higher level of damage, abnormal sperm in nine out of ten species. Again quite striking.




Even more striking is the fact that when we collected several thousand birds over the years in Chernobyl from very hot places to very cool places and looked at their sperm, – and some day I'll tell you but we don't have time today, how we used the special Japanese massage technique to get this sperm from these males *(laughter)* but we did this without hurting any males –, and in the hottest parts of Chernobyl about 40 per cent of the males were completely sterile.

Now this isn't very surprising, radiation is known to cause temporary or permanent sterility in humans undergoing radiation therapy, for instance, and if you're having radiation therapy you're usually advised to bank your sperm if you're thinking of having children later.




These birds I think they're probably permanently sterile in these areas and it shows a nice dose-response relationship, so again, very striking.


We also see many other kinds of bio-markers for radiation exposure that are probably quite benign with respect to survival of the birds. One of the first things we noticed was that many of the birds had patches of white feathers in places where they shouldn't have white feathers.

It probably doesn't affect their ability to fly or to do anything else, although this amount of white on this barn-swallow's chin may affect its ability to attract a mate.


In which case it might have a fitness effect, indirectly, but this was one of the first markers… again we don't see these kinds of white feathers with any frequency anywhere other than Chernobyl, again we've published on this a few times.

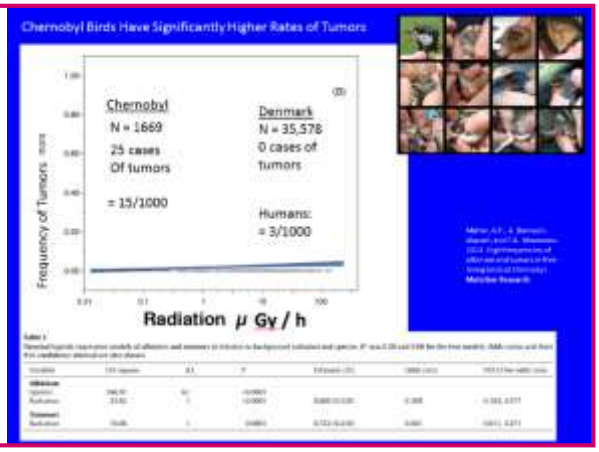
The only other place we see these white feathers on birds commonly is now in Fukushima: three years later we're starting to see patches of white feathers on the barn-swallows, which is the only species that we're looking at very carefully and again, about 20 per cent of the birds from Fukushima are showing these little tufts of white feathers.


And of course there are some other animals in Fukushima that you may have heard of that are showing white spots, including the cows that some of the farmers have been keeping.

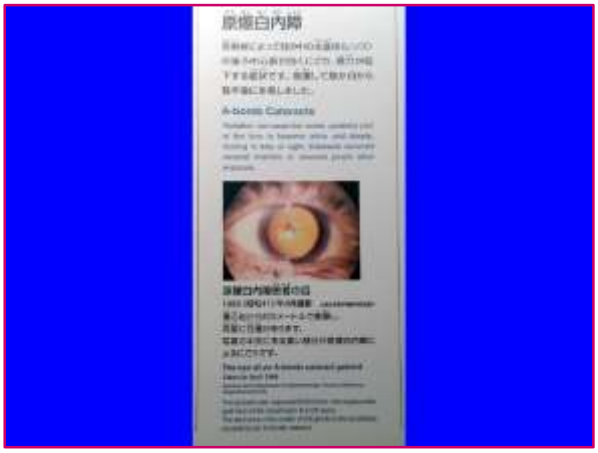
I apologize for showing the rear-end of a cow today, but it nicely shows you the little white spots. We don't know if it's the same reasons, if it's caused by the same effect but it's certainly worth investigating, it's an interesting coincidence.

Its not just little patches of white feathers or white fur that we're seeing, we're also seeing dramatically elevated rates of tumours and other developmental abnormalities again, that we're just not seeing anywhere else.

So, again, it may not be obvious but here is a great tit with a big tumour that's developed below and above the eye; we don't see a lot of these tumours on the head. We also see other developmental abnormalities you just don't see anywhere else in other populations, at least at any frequency. And, yes, we published this last year as well.

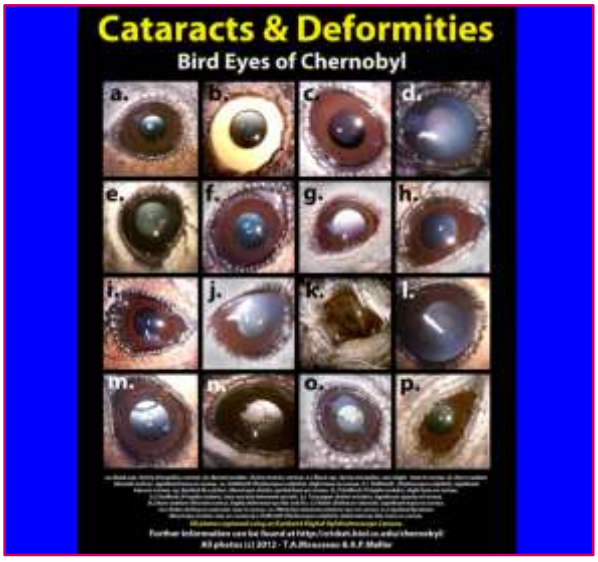




One of the characters that was first observed among the survivors of the atomic bombs was the fact that many of the people, including the children, developed cataracts within a year or two of the exposure.



No age effect per se, it was the radiation exposure that caused it.

So, we started looking at the birds, and the birds again show much higher frequencies of cataracts, the cloudiness in the lens of the eye of the PSC type, the posterior subcapsular cataract that's frequently associated with radiation exposure.

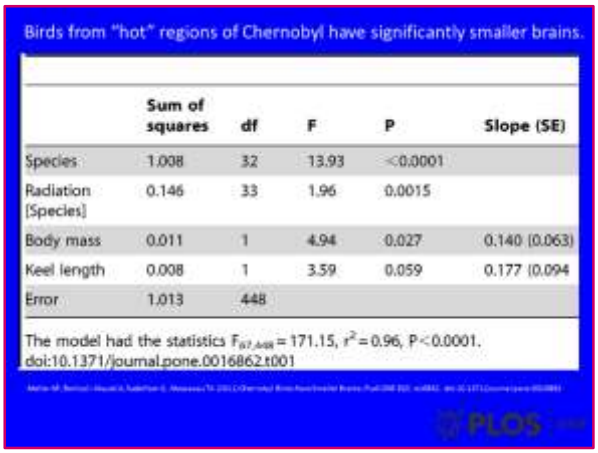


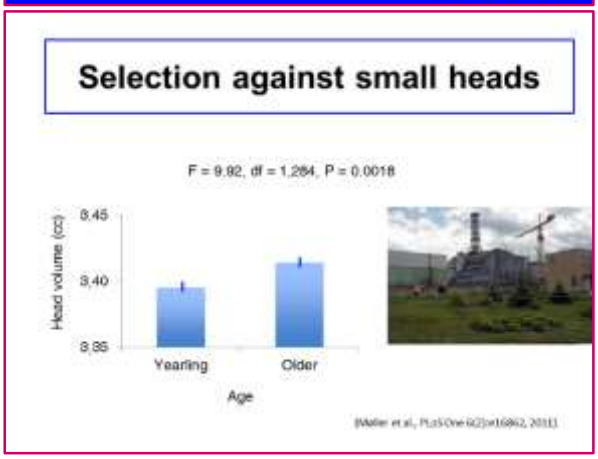

There were also mutations in the stem cells that make the lens of the eye, and when these stem cells accumulate enough mutations the cells become less clear and it manifests itself as a cataract. Again we published this last year as well.

Another little characteristic, again not too surprising: it's been well known that radiation has negative effects on neurological development. Neural tissue is particularly sensitive to ionizing radiation and to the oxidative stress that results from

ionizing radiation, and so we started measuring the brain size of the birds and found that the birds in Chernobyl have about 5% smaller brains.


Five percent, that doesn't sound like a lot, but in terms of survival of the birds it turns out that 5% smaller brains is highly significant, the birds with the 5% smaller brain had about half the probability of surviving from one year to the next. So those last two slides are cognitive results of this smaller brain.



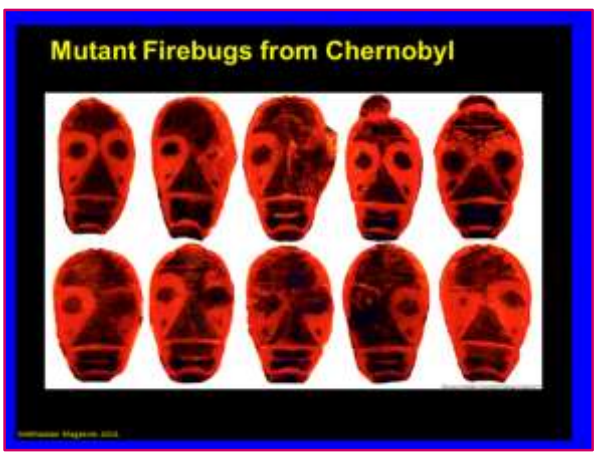




I don't have the slides, because we haven't published it yet, but we've been studying the brain size of the small rodents as well, the mice and the voles in both Chernobyl and Fukushima and, what do you know, they also have smaller brains. We're just looking into whether it matters to these mice in terms of behaviour or responses, but they're showing the same sort of effects; they also show elevated rates of cataracts in their eyes.

This slide right here of the common firebug.


Some of you may have seen in the pictures or drawings that some of you probably know by the Swiss artist Cornelia Hesse-Honnegger who has made a very good living out of drawings of bugs, especially bugs living next to nuclear power plants *(laughter)*.

And this is the famous species, you can all see the face-mask there, with this black note, you see the mouth, the nose, the eyes. You see that – this is a normal looking one. When you go to Chernobyl and start turning over rocks, this is what you find in terms of mutations resulting in strange developmental patterns.



It's just a very sensitive assay because they normally have such symmetrical colouration. And it's really just to remind me to tell you that basically in Chernobyl every rock we turn over we see some signal of the radiation effects.

You don't have to look too far. The trees show it again and again, strange developmental effects on the trees.

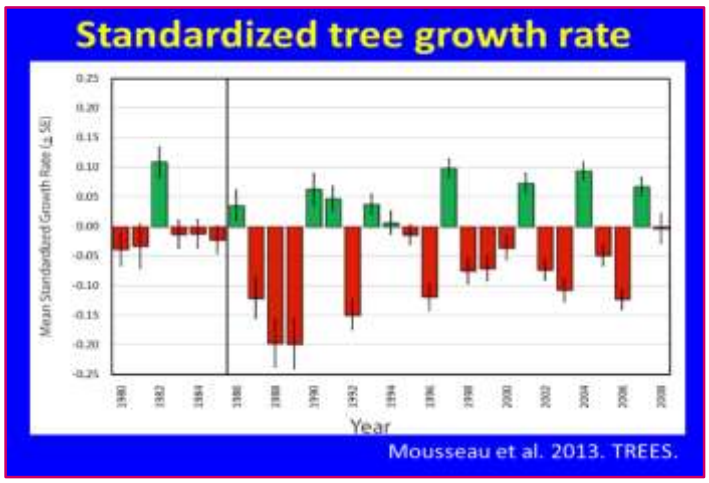
These are Scotch pines, they're supposed to be tall and straight, but in areas of high contamination you see all sorts of really unusual growth patterns that result either from the direct toxicity or from the mutagenicity of the radiation.


You even see changes in the quality and colour of the wood, again these logs, this is an interesting story. A few years ago we were trying to assay the number of mammals, small mammals in Chernobyl and we came upon the idea of going there in the winter time and looking at the tracks, the footprints of the mammals in the snow as a way of counting the numbers in the area and diversity in the area. And we were stuck behind a logging crew who were cutting fire-breaks in the forest, and they had very nicely stacked up all these logs.

And I looked outside my window at the stack of logs and thought, "this is a very strange change in colour and in fact it looks like this change in colour occurred at the very same time for young trees and all the trees."

Pine trees have the advantage of having big rings, so that you can actually count how old they are visually, you just go out and count these rings out. When I counted these rings it was clear that this change on colour had happened about the time of Chernobyl.


And in fact when we actually went out and took samples from 300 trees and looked at the patterns of growth, again of the dramatic negative effects on growth following the Chernobyl disaster, which tend to pop up in these years when there's also drought.



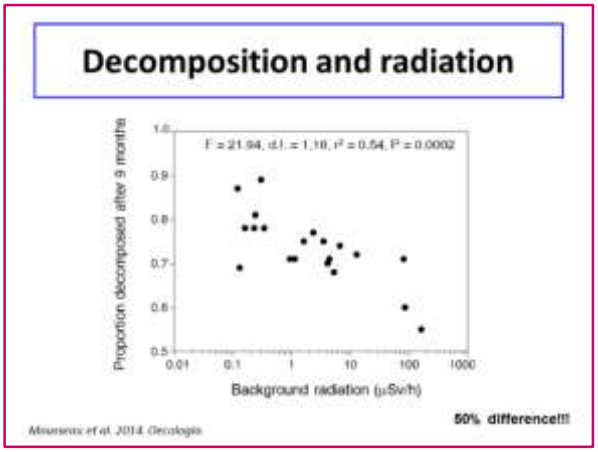
Another interesting observation, when we first started wandering around the Red Forest of Chernobyl. This is the area of Chernobyl that was killed, very quickly, the pine trees just downwind from the reactor were hit with a major dose of radiation and all the pine needles turned red fairly quickly and so this forest became known as the Red Forest. Some of the trees were bulldozed and a lot of them were just left to their own. This is an old pine forest in the area.


When we showed up in 2002 in this area we were walking around and, you know, we'd step on these logs and we'd kick these logs and we realised they were hard, these tree trunks that had been there for more than 15 years were really not very decomposed, they were quite intact, and this kind of surprised us.

One thought was that the radiation was preserving the wood in some way, but then it occurred to us that maybe the radiation was acting more like radiation acts for sterilising food, you know, we sterilise food with radiation to kill all the microbes, right? To keep the food from going bad. We thought maybe the radiation here was having the same effect on decomposition of the wood in this forest, and so we actually went out and did an experiment.

We took leaves and pine needles, put them into about 600 bags, little mesh bags, and put them throughout the Chernobyl zone in "hot" and cold areas.


We came back one year later to look at how much of the plant material had disappeared as a result of the microbe activity, and lo and behold, we again found that the decomposition rate, the rate at which the material decomposed by bacterian fungi, was much, much less in areas of high contamination.




The radiation was affecting the microbial community in some way. This is pretty profound because of course this natural decomposition is what is responsible for the re-cycling of nutrients in the ecosystem, so this is having potentially an ecosystem-wide consequence and may be partly responsible for the slower tree growth that we also see in some of these areas.

But I want to tackle one last consequence and this is one that was really stimulated by the Chernobyl Forum report: are animals affected? Is the abun-

dance and biodiversity of animals and plants in these areas affected by the radioactive contaminants?

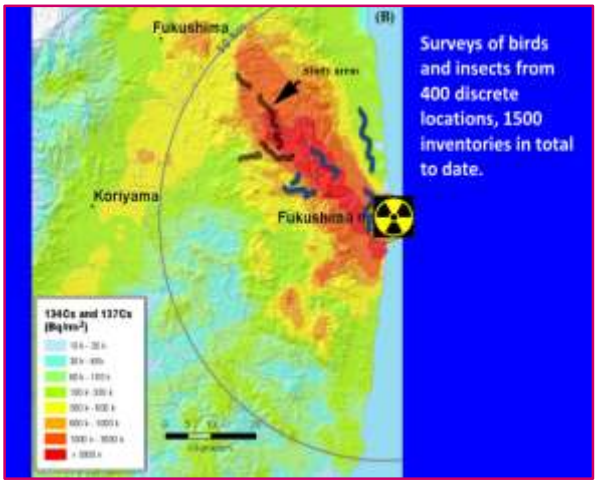

We've done quite a few papers, maybe about a dozen and a half papers now on this topic, and we get at this question, because it's not a simple question to ask.

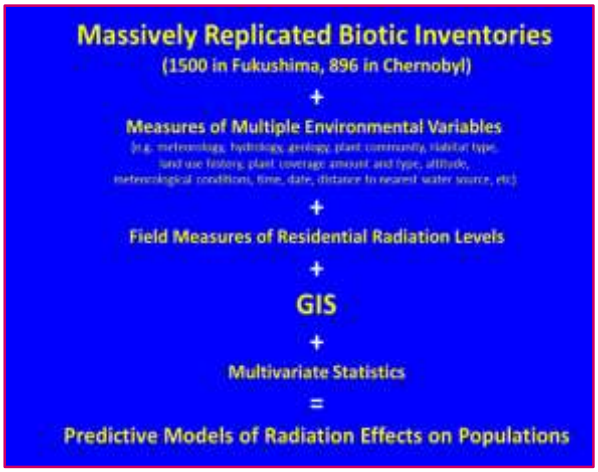

You can't just go to one or two places in Chernobyl that are hot and then one or two places that are clean and get any idea on what the effects are on animal abundance, because animals and plants are affected by many different things: they're affected by the soil type, the different kinds of plants that are there, the other animals that are there, and so you actually have to do a much more comprehensive kind of study to get at this question.

The way we've done it is to go to about 400 different places in and around Chernobyl, both on the Ukrainian side and the Belarusian side that vary in their level of radioactivity.


In Fukushima we also go to about 400 different locations, we've been to them four times now, and again we go from almost clean to very, very contaminated, and we measure.

We take those measurements of abundance at each of those 400 locations, done three times for the most part. Then we also measure anything else that is of importance to a bird or an insect: what the plants are there, what the soil type is, whether there's water close by, whether there are fields, agricultural fields close by, everything that might be important to a bird, plus the radiation levels.

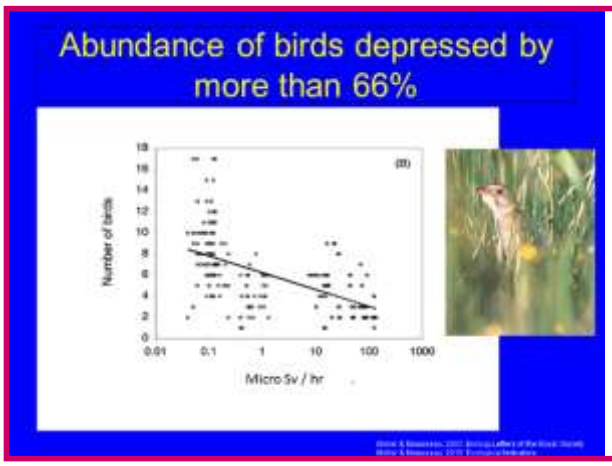


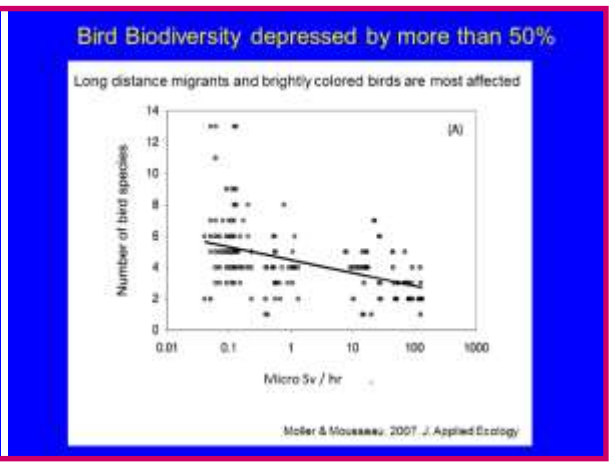



We use the GIS, Geographic Information System, and some fancy multivariate statistics to generate a model that predicts what the effects have been.

This approach is kind of novel, there aren't very many people doing, it's a lot of work to get the data, but it allows to predict what should be in place. Even if we don't know for sure what was there before, we can predict what should have been there, based on this landscape scale.

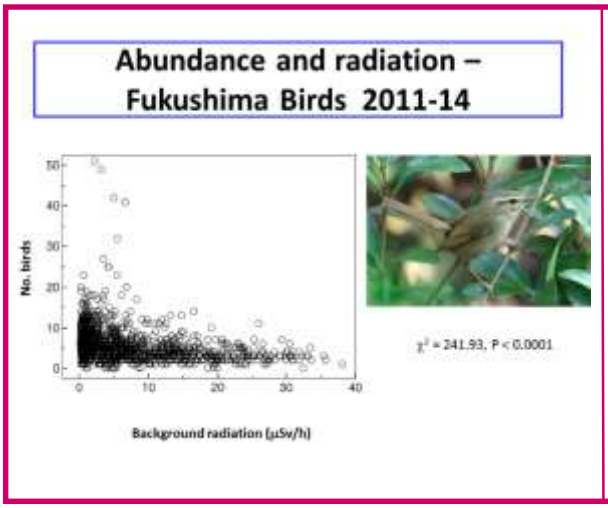
And when we do this, for Chernobyl, what we find is there are many, many fewer birds in these areas of high radiation than there should be. Many, many fewer, about one-third as many. There are about half as many species – the number of species a given spot is about half in these radioactive areas as in the clean areas.

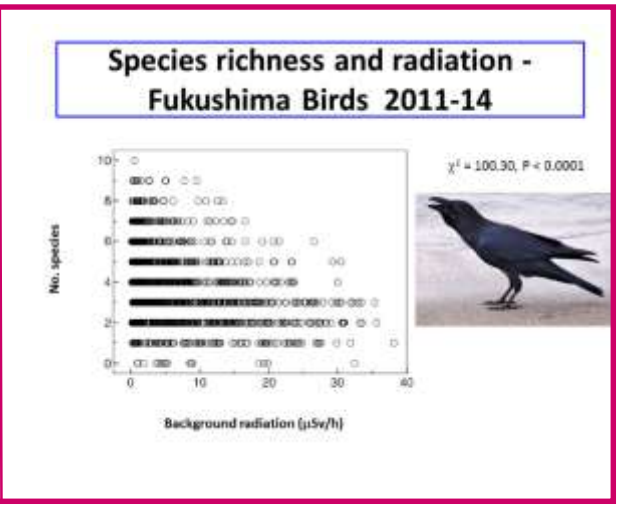



It turns out that radioactivity is the major predictor of the abundance and distribution of many of these species.

But these data are not in the package, these are just hot of the press.



We've just finished our fourth survey of these 400 locations in Fukushima this year. These data here represent four years of observations for Fukushima. We're seeing the exact same thing: many, many fewer birds in these areas of significant contamination, and this is even more striking, many fewer species of birds in these areas of high contamination. Very, very clear signal, very strong.

What I thought I'd do, just to almost end off here, is to show you a little video of how it is we get this data, because a lot of people don't realise how we do it. Are there any bird-watchers in the room?

There's a few of you, so you know about "point counts" of birds. We're just doing point counts, we go to this spot and look at how many birds are there. We're going to play this little video, if my assistant over at the computer can stop texting we can put the microphone to the computer. Can you play the video? You have to.

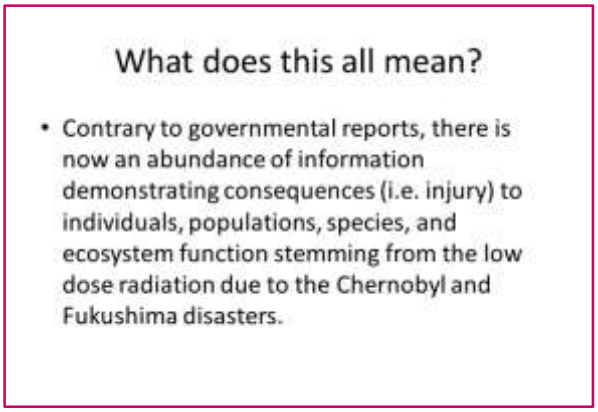
So this is a normal spot in Fukushima in where are bird-watching. We just sit there and listen and watch for about 5 minutes

There are about ten, eleven species of birds in this typical spot…


And this is about five miles away in a very highly contaminated spot.

It's a "silent spring", there are very, very few birds and its quiet as can be, there's actually nothing happening there, very few butterflies, very few birds. It's very overwhelming and unmistakeable. And specially when we do this in 400 locations we get a very good idea of what's going on, it's radiation that has changed most of it.


So, let me just move to the conclusions. What does this all mean?




Well, I would suggest that the main result here is that, contrary to the governmental reports, those like the Chernobyl Forum report, those like the UNSCAER report, there's an abundance of information demonstrating consequences or injury to all levels of biological organization from DNA to individuals, to species, to communities, to the ecosystem.

Lots of data now demonstrating these effects and we need to pay more attention to it, it certainly needs to be considered when we start thinking about the effects of radiation.

What should be done?


Well, we're calling for more funding. In the United States last year the National Science Foundation spent more than one billion dollars on global climate change research, and I think its much more than that actually. And they spent about a hundred thousand dollars on Fukushima and Chernobyl research, and actually that was just for meetings. The Japanese government is putting a hundred billion dollars into clean-up of the area, which means moving dirt off of the roadsides and around people's homes and zero, nothing, on environmental research related to the effects of radioactive contamination. They're not doing a very good job on the medical research either.

This last point here I think is really important: the research efforts that need to be done should not be done by the International Atomic Energy Agency-sponsored people. We know that scientists are also biased by their sources of funding, it happens, and so these need to be independent scientists whose careers do not depend on the funding, which means that they have to be at universities with a paid salary that's not associated with this.

And I think I will just stop there for now and take any questions you might have, and I want to point out that most of the papers that we have are there available on the website.


So I'll stop here and take questions. Thank you very much. ◆

# Question and answer session

***Ruth Stégassy***

Thank you very much for your presentation. There are several questions 1, 2, 3, 4 ...

## Question

You've collected very good phenotypic information. Has any one of them related to molecular data that can be sort of universalized the understanding and also may be extrapolated to what can happen on humans?

***Timothy Mousseau***

Yes, very good question. So the first question was to the limitations of genetic studies, and I think that's what you are asking, whether one can directly correlate, directly connect a change at the level of the DNA to a change in the phenotype?

And what I can tell you is that has been the Holy Grail of evolutionary biology, evolutionary genetics for many, many decades because it's kind of an abstraction.

The best we can do for the most part, because of resource limitation and other technology limitations, is to associate a piece of DNA, maybe a chromosome or a proto-chromosome, to a change in the phenotype. And so from that we can deduce that there is a direct genetic relationship.

But for many of the characters, many of the species, species that cannot be reared in the laboratory, for instance, where you can't do the crosses that you need to actually verify these genetic associations, for the most part its just an assumption that there's a relationship between the genetics and the phenotype. There's undoubtedly many other kinds of mechanisms involved. You've heard about some from Dr Baverstock earlier, epigenetic interactions, and there are other ways to influence inheritance of characters and how they're expressed. And it's probably much more complicated than I have presented, but it's still there, there is an association, and we need to better understand how these mechanisms work to transmit the genetic damage from one generation to the next.

The second part of your question is whether this has any relevance to humans, and you know, again I get that question a lot ... Are we different from other animals, are humans different from the monkeys running around in Fukushima?

Most medical research, a lot of which is done in Switzerland for drug testing, of course we use rabbits, we use mice, we use rats, we use fish, we use birds, and sometimes we just use sour wines. Why do we do that? Because we can't do these kinds of experiments with humans. And these other animal models, these plant models, and so other models, provide the information we need, because we all basically behave in the same way, we have the same basic bio-chemical machinery, we have the same basic genetic systems, we all share the same genetic code. And so, yes, of course this has relevance to humans.

## Question

First, thank you for your research and communications which are very enlightening, and I think also very important faced with guilt-inducing and insulting speeches, which encourage people to more optimism. Such was the case in Chernobyl and also in Fukushima, faced with what is called radiophobia. So, people are accused of radiophobia and I think it's insulting. And I think we cannot accuse animals with being radiophobic and therefore having symptoms due to radiophobia.

My question is: do you have knowledge of research on marine environments? A number of observations have been made, particularly in the Pacific. Do you have any information on this? Where there would be widespread extinction of species... Thank you.

***Timothy Mousseau***

Let me just start by saying, you know, in a longer presentation I usually put up a board with a cigarette. I've never seen birds smoking, I've never seen birds drinking vodka and as far as I know they don't engage in unsafe sex and they don't get depressed. I don't think birds get stressed out and depressed, they get stressed out because they're always stressed out, because they don't want to be eaten by a predator, not because they're worried about the disaster. I think that's one of the big advantages about using animal systems because we don't have to worry about the psycho-social aspects. In terms of the Pacific Ocean and the consequences, the biggest problem is that we have no funding to go and to look at these potential consequences.

There have been all sorts of stories of major die-offs of various species. And, you know, to my mind most of them are very unlikely just because we know that, even though the levels of contamination are measurable they're probably not biologically significant, at least from a radiation standpoint because they're very, very low. If it was the case that these kill-offs and die-offs that are being seen were directly tied to Fukushima releases, then the whole of Japan would be one death zone, they'd all be dead because it's much higher level there, and that's just not the case. So my suspicion is that there are other factors involved, although there may be some reactions with the radioactive releases, but the bottom line is we don't know, we'll never know because there's been no investment in the basic science to go address these questions.

And so, as somebody says, "there's been a die-off of elephant seals in this location, please help me, tell me, is this due to radiation or is due to something else?" there's no funding to go, to send experts to investigate, for instance. Right now the monitoring that's being done off the U.S. West coast for radiation in sea water is being funded by crowd-sourcing, by crowd-funding. The gentleman at La Jolla, California, Ken Buesseler, a very famous marine geo-chemist, he's having to have people send money with the samples to have them analysed. There's no government funding of this; so this is the problem, we have insufficient information and there's nobody willing to pay for the information.

## Question

Thank you for showing that harmful effects of ionizing radiation are actually exactly the same in different animal species as concerns the human species.

I was particularly struck by the similarity of what you said on brain size reduction in several animal species and the existence of microcephaly in children, so a brain size also below the average is observed among children living in contaminated areas of Belarus and Ukraine.

And the question, which has to be very difficult to determine in animals, is what are the consequences of this reduction in the size of the brain?

In humans we can imagine that is a reduction of intellectual ability and I think it is already the case, it is already observed in Belarus: whole classes of little children are actually showing signs of slight debility.

Ionizing radiations will in fact produce more and more stupid children.

Is there any way to prove it in animals, with a smaller time interval than in the human species?

***Timothy Mousseau***

I think Dr Wertelecki can probably speak more to this general topic, but I think there are data showing effects on head-size, certainly, in humans but I don't know how significant it is. I think they do require head circumference… I think the relationship between brain size and cognitive ability in humans may not be as strong as it is in birds, where there's very intense selection to be as small and as compact, as light as possible, so the head size very much reflects the brain size and we're presuming that the brain size very much reflects the cognitive ability. But much more needs to be done. Wladimir,

do you have any data on the head size? No… it's certainly worth investigating. There's clearly evidence of neurological effects to children who were *in utero* during the Chernobyl disaster, not just in Ukraine, Belarus and Russia but elsewhere in Scandinavia and Germany where they see some measurable consequences – it's small but significant.

## Question

If the objective is to know what are the effects on humans of ionizing radiations, why don't we use DNA chips – obviously culture DNA and DNA of human cells – instead of doing it on animals? When we know very well that the transposition is not always good.

Experience proves it, since out of ten drugs that have passed all tests on animals, nine are recalibrated when one passes to humans.

Furthermore, you should know that we recently had a European citizens' initiative, with more than one million validated signatures, to request the removal of all animal testing. So why not test mainly on DNA chips?

### *Timothy Mousseau*

Very good point, and the answer is that we have tested some of this on DNA chips just a couple of years ago, so we're waiting for the technology, basically, that's what it amounts to. Just a couple of years ago the DNA sequence was made for more than one bird species, and so this has allowed the production of these chips commercially to make them available. But it still costs three hundred dollars approximately, I think, for each one of these chips, so to do a population survey with several hundred individuals requires several hundred thousand francs or a million francs to do that kind of study.

We actually have just started a study in collaboration with the neurological institute in Montreal, at McGill University in Montreal, to look at the whole human genome, actually taking a population of children from Ukraine, some born to liquidators, some born to people who were not involved in the clean-up and so the doses to the parents were known. We're actually going to take their whole genomes to look at *de novo* mutation rates at the level of the DNA. We'd love to do this with some of the animals that were there as well but it means knowing the parents, having the offspring, so that one can look with detail but this also means having a million francs to do a research at a time, its not cheap.

Most of what I talked about today, I'd say, is much less expensive and we've done what we could with what we had, but much more needs to be done, I agree.

### *Ruth Stégassy*

Thank you for this discussion. We'll now move on to our final presentation.◆

# The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly

***Chiyo Nohara**, University of Okinawa, Japan*

## Introduction *by **Ruth Stégassy***

***Chiyo Nohara** is a member of a team from the BCPH Unit of Molecular Physiology, Department of Chemistry, Biology and Marine Science, Faculty of Science at the University of the Ryukus in Okinawa (Japan) which has evaluated the effects of the Fukushima nuclear accident on the pale grass blue butterfly Zizeeria maha, the most common butterfly in Japan. Their findings imply transgenerational accumulation of genetic damage. Before moving to Okinawa, Ms Nohara was lecturer on government auditing and later associate professor in business administration at Aichi Toho University, 1993-2005; associate professor in business administration at Aichi University, 2005-2009; former member of the Evaluation Committee for Incorporated Administrative Agencies at the Ministry of Land, Infrastructure, Transport and Tourism; former member of the Public Sector Evaluation Committee of Nagoya city, Tokai city and Mie prefecture.*

# Presentation


Thank you for the wonderful introduction. I would like to thank all staff of the Independent-WHO for inviting me to participate in this conference. My name is Chiyo Nohara, and I'll be speaking on behalf of our research group which has been working on this project at the University of the Ryukyus in Okinawa, Japan.

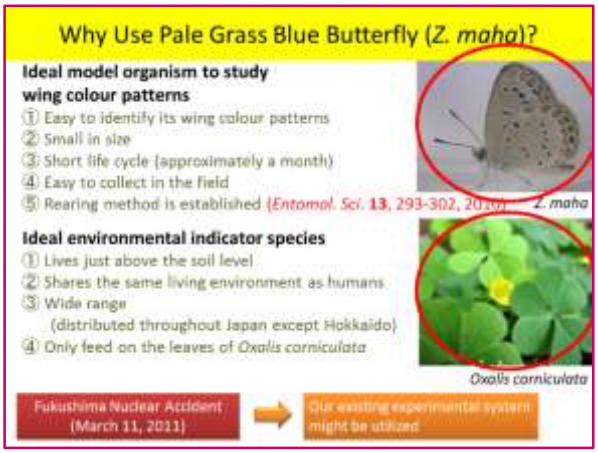
We've been studying the biological effects of the radioactive materials released following the Fukushima nuclear disaster, by monitoring the pale grass blue butterfly from the first generation after the accident.

And I'm here today to share with you all some of our significant findings that are much more serious than what we initially expected.

First of all, to begin with, the pale grass blue butterfly, *Zizeeria maha*, is a small butterfly of just over a centimeter in size, and it belongs to the family *Lycaenidae*, in the order *Lepidoptera*.


As you can see, it develops through the stages of egg, larva and pupa, before becoming adult. There are mainly two reasons why we chose the pale grass blue butterfly to study.

The first one is that it is an ideal model organism to study wing color patterns.




As you can see, its wing colour patterns are simple, and therefore easy to determine whether the patterns are normal. It's also very small in size, so it's easy to take care of, in our tiny lab of limited means. It has a short life cycle, which makes it easy to monitor the changes from generation to generation.

Also, this species is very abundant in Japan and easy to collect in the field. But above all, because our lab had been studying its wing color patterns since before the accident, we had the accumulation of experiences in rearing this butterfly under standard conditions. And that allowed us to give an elaborate analysis of their abnormalities.

Secondly, the pale grass blue butterfly is also an ideal environmental indicator species. Because it lives just above the soil level, it's directly affected by the radiation dose in the air just above the ground. It also shares the same living environment as humans, whether in cities or in the countryside, and therefore serves as an indicator of what might be the effects on the environment where people live.

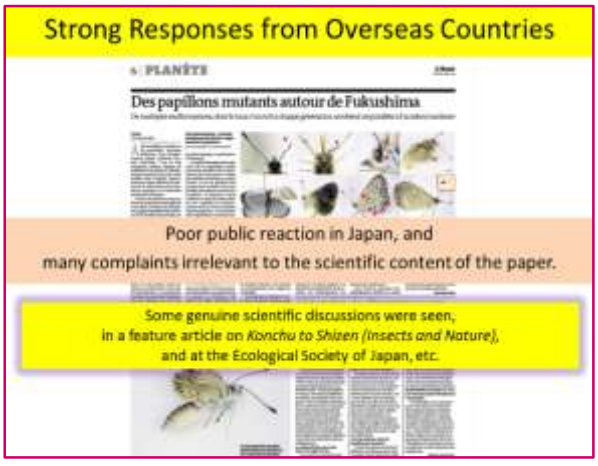
Furthermore, this species is distributed throughout Japan with the exception of the very North part of Japan, Hokkaido. It only feeds on the leaves of *Oxalis corniculata*, which makes it suitable for internal exposure experiments. These conditions led us to think that our existing experimental system

might be utilized, when the accident occurred on March 11th in 2011.


We published our first paper on this research on August 9th in 2012, the day when the atomic bomb was dropped in Nagasaki around 70 years ago. And immediately, we received strong responses from countries overseas, including Germany and France.

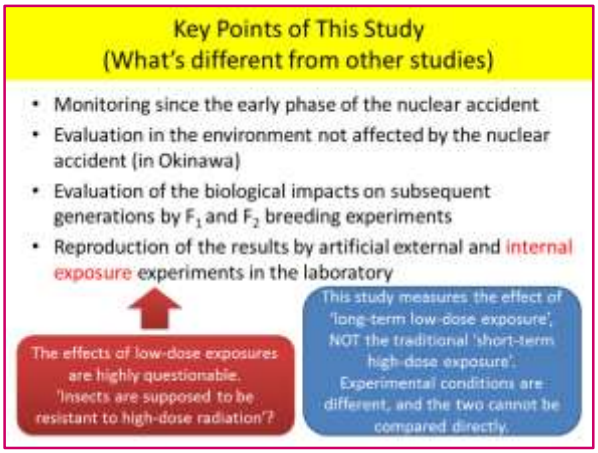

NB: please, find page 102 the active web links

This is a copy of the article in "Le Monde".




In Japan, however, we received not only very poor public reaction, but also many criticisms that were emotional and irrelevant to the scientific content of the paper. But despite all this, some journals and academic societies gave fair evaluations on the research.

This study is different, and therefore superior to other studies, in that we've been monitoring since the very early phase of the nuclear accident. That is, we've been monitoring the *Z. maha* butterflies since their first generation to be exposed to radiation. Secondly, experiments to evaluate the possible effects were carried out in Okinawa, which is one of the areas least affected by the accident.




Also, with our breeding experiments, we examined the effects on their progeny and grand progeny. Lastly, we designed artificial external and internal exposure experiments to reproduce the results observed in the field.

However, our conclusion that low-dose exposures do affect this species of butterfly was not accepted, based on the results from the existing studies, in which insects, especially moths, were shown to be resistant to high-dose radiation.

However, unlike the traditional short-term high-dose exposures, this study examined the effects of long-term low-dose exposures: the experimental conditions are not the same, and therefore it would not be appropriate to compare the two directly.

We've done four sets of experiments so far, and the first is the field sampling in the Fukushima area in early May of 2011.

## What Was Done In This Study

1. **Field sampling in the Fukushima area [May 2011]**
   First-voltine adults (first generation in the field)
   ➔$F_1$ and $F_2$ breeding experiments in Okinawa to evaluate the effects on their offspring
2. **Field sampling in the Fukushima area [Sept. 2011]**
   Fourth-voltine adults (fourth generation in the field)
   ➔$F_1$ breeding experiments in Okinawa
3. **Artificial external irradiation of $^{137}$Cs**
   Individuals caught in Okinawa were exposed to $^{137}$Cs radiation to experimentally reproduce the results obtained above.
4. **Artificial internal exposure using contaminated host plant**
   Contaminated *O. corniculata* leaves collected in Fukushima were fed to individuals caught in Okinawa. IMPORTANT

Here, we collected the first generation to be exposed to radiation, and obtained the F1 and the F2 offspring in Okinawa to observe possible effects.

Next, we did another field sampling in September of 2011, to collect the fourth to fifth generations in the field, and also obtained their F1 offspring.

Third, we carried out an artificial external irradiation experiment using radioactive $^{137}$cesium, with butterflies from Okinawa.

Lastly, we did an artificial internal exposure experiment in Okinawa, in which contaminated leaves collected in the Fukushima area were fed to butterflies from Okinawa.

Shown on this map are the ten sampling sites for the field sampling of butterflies in May 2011.

## Collection Sites (Field Sampling in May)


- Tokyo
- Tsukuba, Mito, Takahagi (Ibaraki prefecture)
- Iwaki, Hirono, Koriyama, Motomiya, Fukushima (Fukushima prefecture)
- Shiroishi (Miyagi prefecture)

**10 localities in total**

The Fukushima Daiiichi nuclear power plant is located here.

We used sampling sites from four prefectures, Fukushima, Tokyo, Ibaraki, and Miyagi.

In total, approximately 6,000 individuals of this butterfly were used for these sets of experiments.

## Number of Individuals Used in the Experiments

- Field-caught adults in May (first generation <P>): **144**
  - Their $F_1$ offspring: **2,516**
  - Their $F_2$ offspring: **538**
- Field-caught adults in Sept. (first generation <P>): **238**
  - Their $F_1$ offspring: **1,563**
- Artificial external irradiation experiments: **400**
- Artificial internal exposure experiments: **542**

Approximately 6000 individuals

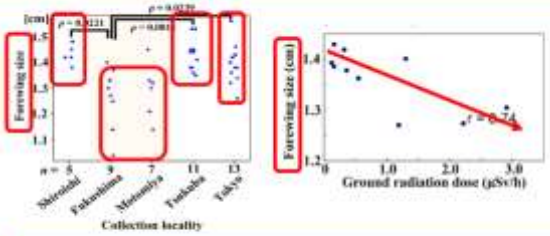
And here are the results. First, the results of the field sampling of the parental generation, and the subsequent breeding experiments of the F1 and the F2 offspring.

## Results

**Field Sampling in the Fukushima Area, and $F_1$ and $F_2$ Breeding Experiments in Okinawa**

## Wing Size (Body Size)

(individuals collected in May 2011)



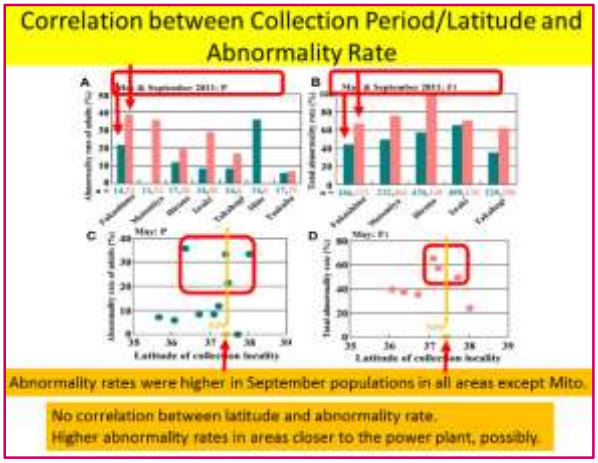

Significant reduction in the forewing size in the Fukushima population.
The forewing size inversely correlated with the ground radiation dose.

The results violate the temperature-size rule (bigger size in colder regions).

For butterflies, the state of their development can be evaluated by looking at their wing sizes, just like heights and weights for humans. As you can see, we observed a significant reduction in the forewing size in the population collected in Fukushima, compared to the populations from Shiroishi, located directly north of Fukushima, Tsukuba, located south of Fukushima, and Tokyo.

In addition, the forewing size seems to decrease in response to the increase of the ground radiation dose. This does not follow the standard rule in which butterflies in colder regions tend to have bigger wing sizes.

Next is the correlation between collection periods and abnormality rates.




The green bars indicate samples collected in May, and the red bars indicate samples collected in September of 2011.

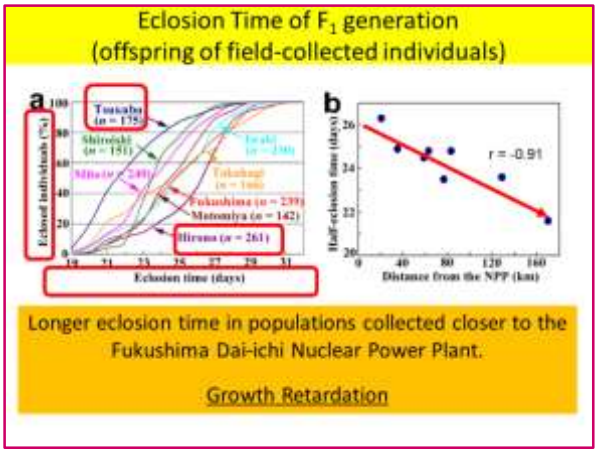
The graph on the left is for the parental generation, and on the right is for the F1 generation. The abnormality rates were higher in September populations for both the parental and the F1 generation in all areas except for Mito.

Also, among the criticisms seen on the internet, there was a comment suggesting that abnormality rates in butterflies would increase with latitude. Our conclusion is that no correlation was seen between latitude and abnormality rates.

And this yellow dot indicates the latitude of the nuclear power plant. In terms of correlation, our results possibly suggest higher abnormality rates in areas closer to the power plant.

We then looked at the growth and development of the butterflies.

The y-axis indicates the percentage of individuals who had undergone eclosion. The x-axis indicates the number of days it took for them to undergo eclosion.



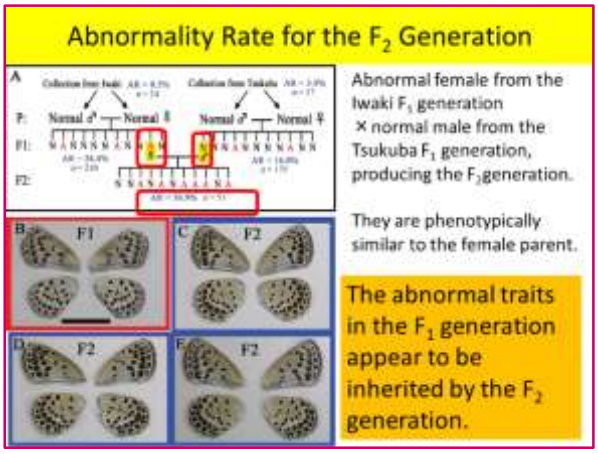

The population from Tsukuba, located farthest from the nuclear power plant, grew up faster than populations from other areas. The population from Hirono, located 20 km south of the power plant, which is the closest of all areas sampled, showed the slowest growth.

This plot shows the number of days it took for the half of each population to undergo eclosion, against the distance from the power plant.

As you can see, it takes longer to undergo eclosion for the populations closer to the power plant, thus displaying growth retardation.

For morphological abnormalities seen in the F1 generation, we observed individuals with truncated leg segments, dented compound eyes, smaller wing on one side, and broken or curled wings.


We also looked at the F2 generation for their abnormalities.



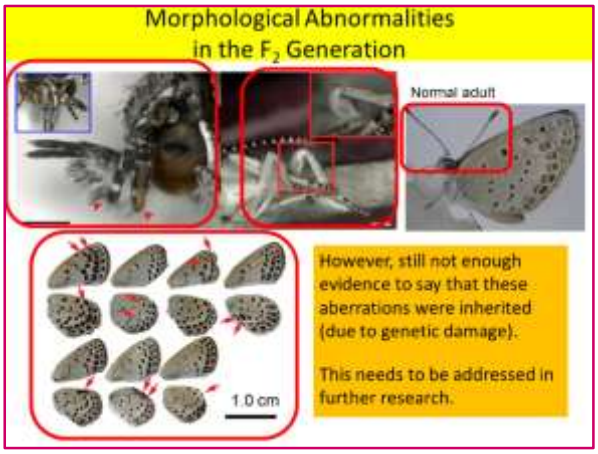

We chose females that displayed abnormalities from each locality and mated them with normal healthy males from Tsukuba, thus creating a total of eight breeding pairs. Not very many eggs were produced, and many individuals didn't survive in the first place, for us to look at their abnormalities.

The population from Motomiya of Fukushima prefecture, which experienced the highest radiation dose, showed the highest abnormality rate, and the F1 generation from Iwaki showed an abnormality rate of over 50 %.

Also, the abnormal traits seen in the F1 generation appeared to be inherited by the F2 generation.

Morphological abnormalities seen in the F2 generation included an individual with an antenna that was split into two.

This is an individual with normal antennae.




We also observed individuals with a short leg or with abnormal colour patterns.

However, these experimental results are not sufficient as evidences to prove that these aberrations are the result of genetic damage.

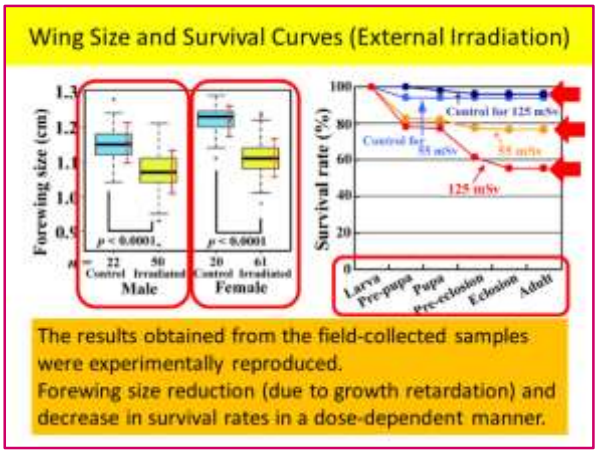
Therefore, we've started last year a new project to address this by mutation analysis at the genetic level. We've been looking at the results from observations made in the field sampling and the breeding experiments of the F1 and the F2 generations.

Next, let me show you the results from the artificial external irradiation experiment using butterflies in Okinawa, the part of Japan located farthest from the nuclear power plant.


We did two sets of experiments by exposing the butterflies to doses of radiation at 55 mSv and 125 mSv, for a long period of time throughout their larval to pupal stage.


The morphological abnormalities seen as a result were similar to what was seen in the Fukushima individuals and their F1 and F2 offspring. Those are abnormalities of legs, antennae, color spots and compound eyes.

Wing sizes, which are the indication of their growth, were significantly smaller both in males and females for the individuals exposed to external radiation.

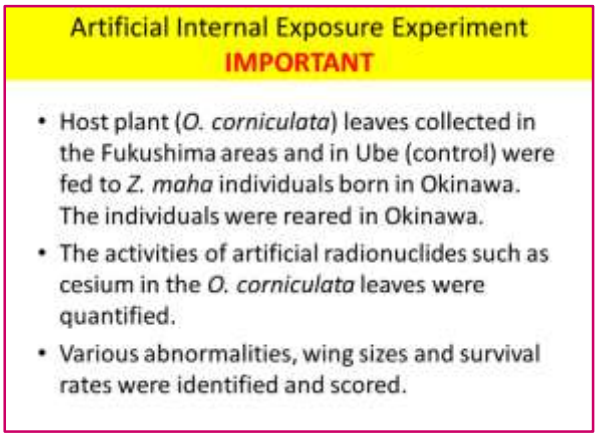



We also looked at the trend in the survival rates as these butterflies develop from larva through pre-pupa, pupa, eclosion, and to adult.

While the control populations showed survival rates around 95%, the population exposed to 55 mSv of radiation showed a survival rate in the 70 % range, and the population exposed to 125 mSv showed a survival rate in the 50 % range.

It is apparent that the survival rate decreases in a dose-dependent manner.

Lastly, I'd like to show you the results from the internal exposure experiment.



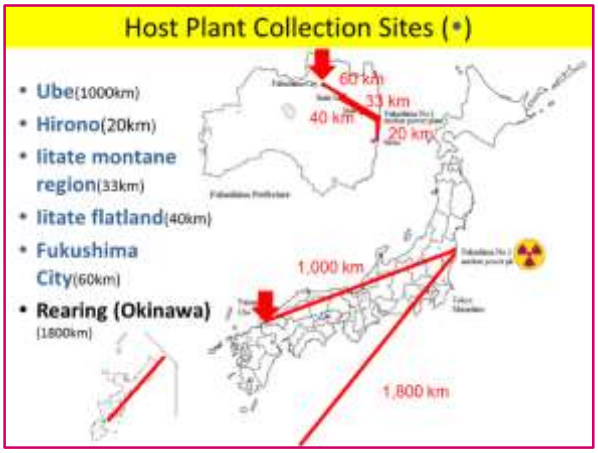

Here, we exposed butterflies in Okinawa to internal radiation by feeding leaves collected in the Fukushima area.

I'd like to emphasize the importance of this experiment, because the results from the fieldwork, which I've talked about earlier, were shown to be reproduced in this experiment. In other words, internal radiation is responsible for what was observed in the field, at least partly.

In this internal exposure experiment, leaves collected at various locations in Fukushima and also at a control site located approximately 1,000 km from Fukushima were fed to butterflies born in Okinawa, where the butterflies were subsequently reared.

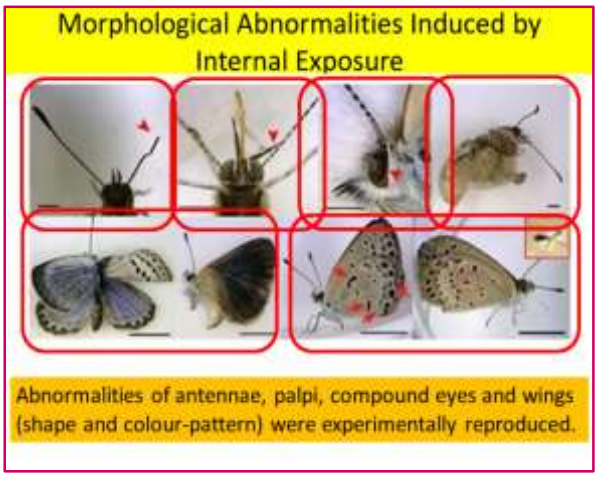
We quantified the radioactivity in the leaves such as the amount of radioactive cesium, and identified abnormalities of adult butterflies, measured their wing sizes and scored the survival rates.

For the experiments performed in the year 2011, leaves were collected in Ube as a control, which is located approximately 1,000 km from the power plant, in Fukushima city, about 60 km from the power plant, in the Iitate flatland, 40km from the power plant, in the Iitate mountain region, about 33 km from the power plant, and in Hirono, located 20 km south of the power plant. All butterflies were reared in Okinawa, located approximately 1,700 km from the power plant.



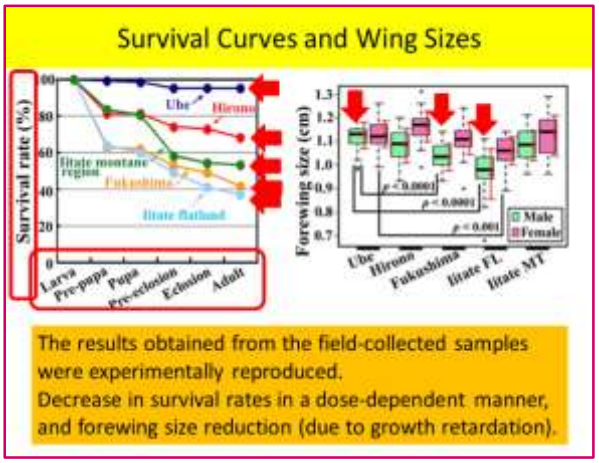
As a result of internal exposure, we identified various morphological abnormalities in the butterflies.

As seen in these images:




abnormalities of antennae and palpi, depressed compound eyes, eclosion failure, bent wings and abnormal wing colour patterns were seen. Abnormalities very similar to those observed in the field were reproduced here.

Next, shown in this figure is the transition of the survival rates.

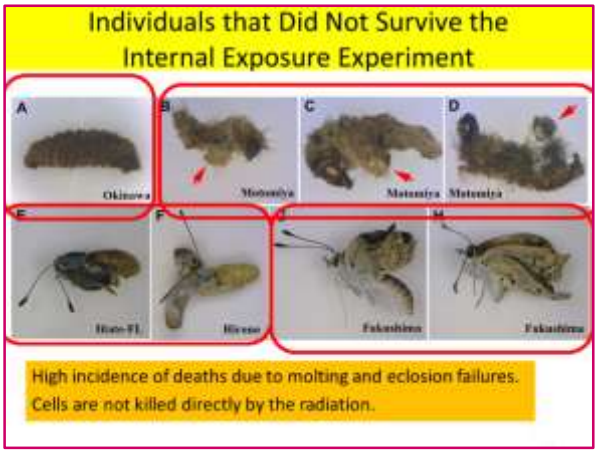



The x-axis indicates the developmental stages from larva through pupa, pre-eclosion to adult after eclosion. The y-axis indicates the survival rates.

As you can see, butterflies raised on the control Ube leaves showed a survival rate of 95 %, whereas butterflies raised on leaves from the Fukushima areas showed survival rates of 68 % in Hirono, 53 % in the Iitate montane region, 42 % in Fukushima city, and 37 % in the Iitate flatland.

Next, when we evaluated their growth by measuring their forewing sizes, in males for example, we observed a significant reduction in forewing size in the Fukushima city and the Iitate flatland populations, when compared to the Ube population, which suggests growth retardation.

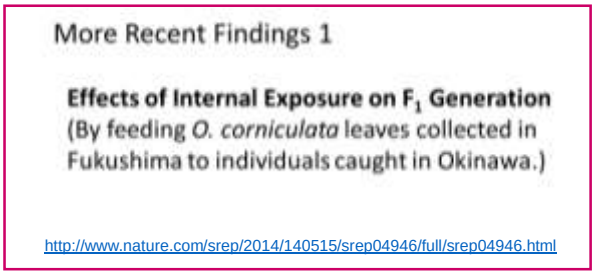
When we looked at the individuals who did not survive the internal exposure experiment, those larvae that were raised on leaves from the Fukushima areas were often found to be dead in the process of molting, whereas a control Okinawa individual shown here is dead in a natural form.



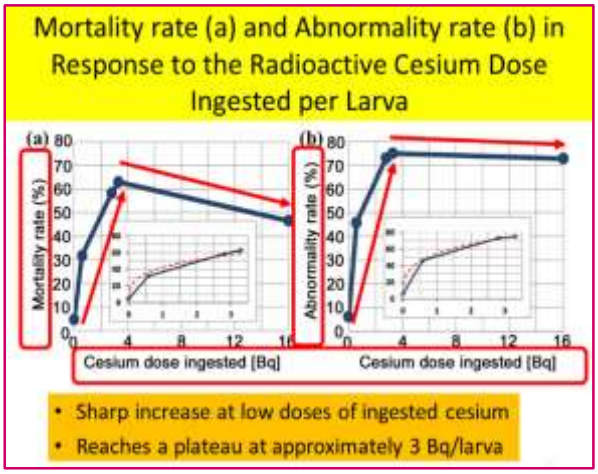

There were also cases of eclosion failure, which is the final molting from pupa to adult. Even if they survive eclosion, those adults were unable to stretch their wings after eclosion.

These observations suggest some kind of physiological change to have taken place inside the body.

Now, I'd like to talk briefly about more recent findings from our internal exposure experiment.



We plotted the change in mortality rate and abnormality rate in response to the cesium dose ingested by a larva throughout its development.

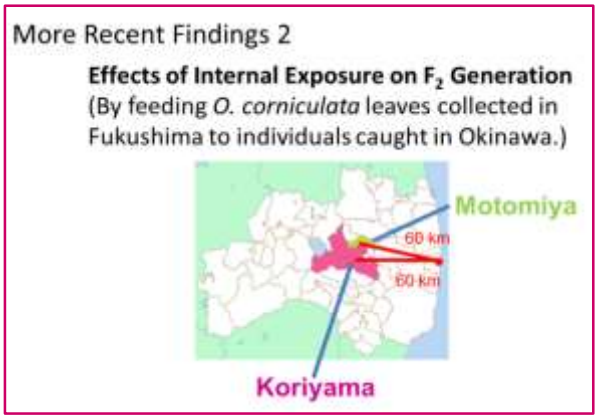



The x-axis indicates the cesium dose ingested by a larva until its pupation, and the y-axes indicate the mortality rate and the abnormality rate.

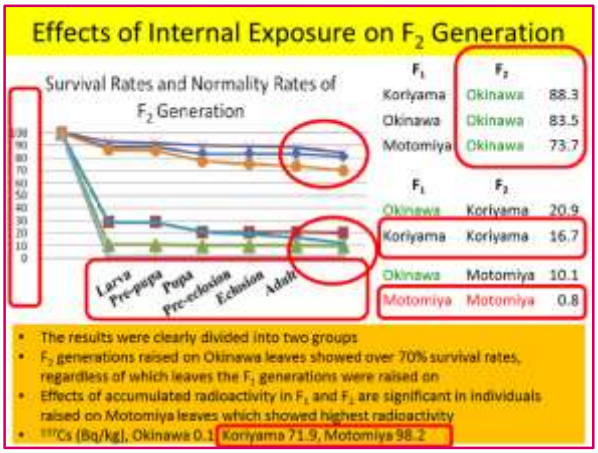
As the graphs indicate, we observed a sharp increase in both mortality and abnormality rates at low doses of ingested cesium. Both mortality and abnormality rates then reached a plateau at approximately 3 Bq/larva, without further increase in response to increasing cesium dose.

So far in our internal exposure experiments, we've been using leaves collected in the areas of high contamination in Fukushima prefecture that are located inside the evacuation zone.

On the other hand, the results I'm about to show you are from the internal exposure experiments performed in 2012, in which we used leaves collected in areas such as Koriyama and Motomiya of Fukushima prefecture, where people live normal lives. Both areas are located approximately 60 km from the power plant.




I'm just going to present to you the effects observed on the F2 generation.




The y-axis indicates the survival rates and the normality rates, and the x-axis indicates the developmental stages from larva and pupa to adult.

As a result, the graphs were clearly divided into two groups.

Regardless of the origin of the leaves consumed by the F1 generation, individuals of the F2 generation that consumed Okinawa leaves showed survival rates over 70 %.

On the other hand, individuals raised on Koriyama leaves over two generations showed a normality rate of 16.7 %, and those raised on Motomiya leaves over two generations showed a normality rate of 0.8 %.

As you can see, the effects of radioactivity accumulated over the F1 and the F2 generations were significant in individuals raised on Motomiya leaves, which measured the highest radioactivity.

Concentrations of $^{137}$cesium in the Koriyama leaves and the Motomiya leaves were 72 and 98 Bq/kg, respectively.

And that concludes my presentation.

In closing, I'd like to thank those who live in Fukushima for their help with these experiments. Also, I'd like to send my heartfelt support to those who still live with hardships.

Thank you so much for your attention. ◆


*Active web links of slide p.95*

### *News Coverage and Media Appearances*

- Abstract of the original paper in Japanese
  http://www.natureasia.com/ja-jp/srep/abstracts/39035
- Rated as the most noted paper of the year 2012 on social media by Nature
  http://blogs.nature.com/news/2012/12/what-were-the-top-papers-of-2012-on-social-media.html
- ARD (Germany) with Japanese subtitles
  http://kingo999.blog.fc2.com/blog-entry-914.html
- Spiegel (Germany) "Nuclear disaster: Researchers Discover Fukushima mutations"
  http://www.spiegel.de/wissenschaft/natur/fukushima-strahlung-fuehrt-schmetterlingen-zu-mutationen-a-849972.html
- BBC (UK) "'Severe abnormalities' found in Fukushima butterflies"
  http://www.bbc.co.uk/news/science-environment-19245818
- Le Monde (France) "Mutant butterflies around Fukushima"
  http://www.lemonde.fr/planete/article/2012/08/15/des-papillons-mutants-autour-de-fukushima_1746252_3244.html
- Japanese translation of the Le Monde article
  http://besobernow-yuima.blogspot.jp/2012/08/blog-post_18.html
- ABC (Australia) "Fukushima radiation spawned mutant butterflies"
  http://www.abc.net.au/news/2012-08-13/fukushima-mutant-butterflies/4194240
- CNN (USA) "Mutant butterflies found near Fukushima"
  http://www.youtube.com/watch?v=1yVNn0tlz5k
- FOX (USA) "Mutant butterflies reportedly caused by Japan nuke disaster"
  http://video.foxnews.com/v/1786844712001/mutant-butterflies-reportedly-caused-by-japan-nuke-disaster

### *Press Release by the University of the Ryukyus*

http://www.u-ryukyu.ac.jp/info/yamatoshizimi2012081501/

# Question and answer session

***Ruth Stégassy***

Thank you very much, you may come back and sit down for the questions.

We'll wait a little moment so that Chiyo sits down and puts on the earphone.

## Question

I have only one question for clarification myself. Can you please show the last but one slide with the F2 breeding?

***Ruth Stégassy***

Wait just a second because there still are people who are writing down the web site.

***Chiyo Nohara***

This one?

## Question

Yes, this one. Am I right in supposing that if you have parents who were exposed internally to caesium in the generation F1, and the offspring is not exposed internally to $^{137}$caesium and raised in Okinawa, this means that the survival rate is practically unchanged? Because we see Koriyama, F1, 71.9 Bq/kg. F2 is background 0.1 Bq/kg, and the survival rate is 88.3. And when we take Motomiya 98.2 Bq/kg F1 is feed with this high caesium, F2 is normally raised in Okinawa offspring and it drops to 73.7, but is not so dramatic. Do you have explanation for this?

***Chiyo Nohara***

Yes, that's right. Thank you for your good point. The difference within ten percent it's just a small difference for us. Ten or fifteen percent the difference of such marginal level.

## Comment

I think the question was really to confirm what is in the upper right hand side of the chart, which means: if the F1 generation the parents which were fed with very bad food from Koriyama or Motomiya, if the F2 generation is fed in Okinawa with good Okinawa food, then there is basically the same survival and normality rates. So we have seen your conclusion is that the exposure to cesium in the first generation can be, so to speak, cured or has no effect on generation 2, if generation 2 is fed with proper food. I think this was the question. Just to confirm that this is the conclusion at this stage of your study.

***Chiyo Nohara/Miho (translator of Nohara)***

This is the conclusion, as Philip confirmed, that she also wants to confirm here that this is the conclusion she wanted to show you.

## Question

So there is certain effect which is undeniable but it's not dramatic. This means that there is no at least to the second generation, hereditary effect in this particular species. Yeah? I'm a right?

## Comment 1

Sorry. I'm not biologist but I think what you show is that the food in Motomiya has these effects on the second generation. So you are not talking here about hereditary effect but about the effect of the food in Motomiya, on the second generation.

## Comment 2

No, I think what you pointed out was based on this finding you would like to say that there is no effect for the F1 generation to eat contaminated food. But probably this only indicates the survival rate, and it doesn't say much details about the health. So you cannot really conclude that I strongly believe.

### *Timothy Mousseau*

This is not a test for heritable genetic effects, it's a direct effect on the F2 generation. But they have done experiments monitoring from one generation to the next. This is just a single generation test.

## Comment 3

Let me draw a parallel with what is actually happening in contaminated sites, whether Fukushima or Chernobyl. Unfortunately, Chernobyl gets already into the second generation. As I explained to you before, since the disaster we bring kids here, and the children of children of that time are still in the same situation and eat contaminated products.

So if we can actually resolve things through diet, it is even more unfair today.

We saw that the survival curves between first generation who ate contaminated products with caesium is not hereditary. We saw that the problems are not hereditary, that hopefully things could be corrected by feeding their children with clean food. This is not the case today. It is all the more unfair that today in all these areas, including Chernobyl, which I know well, in this whole contaminated area, children continue to eat food unfit for consumption.

So they are more in the F2, they will soon in F3, and the situation is still the same.

We are now in an emergency situation. We are no longer in the laboratory, this is the reality. And it continues. So the urgency is today. The Chernobyl disaster was not 28 years ago, Fukushima was not 4 or 5 years ago, today is the catastrophe. It continues, while we are discussing here, the catastrophe continues. And we continue to fuel statistics.

### *Ruth Stégassy*

We did not see that there was no inheritance. We just saw a test concerning a generation, and the feeding of a generation. One could not reach the conclusion that there is an absence of problems that cross generations, right?

I would like, if you have any questions, that these specifically concerning points to be clarified in this presentation speech, since at 4:00 p.m. we will have a broader discussion in which all those questions could be asked.

## Question

The second from the last slide you have 71.1 Bq/kg and 80 something per kilogram. And Japan's food regulation is 100 Bq/kg legally. And in Europe actually it is very high, six hundred and Switzerland maybe one thousand two hundred and fifty, and US is about thousand. So, what do you think of… what can you guess from this to effect on humans. If you can guess, scientific guess.

### *Chiyo Nohara*

I cannot say because we didn't have any experiment on human beings. I cannot tell you anything. The reason why I chose Koriyama and Motomiya City as control locations, is that people are living normally there although the radiation is very high. So, I wanted to see the effects of the internal exposure such as in these locations.

Actually experiment was conducted in Okinawa which is maybe least contaminated location in Japan, but maybe the result will be different when we have the similar experiment in Koriyama and in Motomiya City.

## Question

I find your presentation absolutely brilliant, and I would like to salute your courage confronting the Japanese and international nuclear lobby.

Especially as a woman, a young woman, so particularly vulnerable in Japanese society which is quite misogynist, as I know.

And I just wanted to ask you: has your work been circulated among Japanese doctors?

Because for me it obviously can be extrapolated to humans.

We will see it in a few generations, perhaps, no doubt. What was the reaction of the Japanese doctors in your country?

***Ruth Stégassy***

We just take one last question. We'll listen to you.

## Question

You said that you were surprised that the insects respond to low doses of radiation. I was always taught that the insects were highly resistant, very resistant to radiation. Was it because we did tests on external radiation, and there you have used internal irradiation?

***Chiyo Nohara***

I would like to just ask your question again. Also you talk about moths they are resistant to high exposure radiation. So it is related to external exposure or internal exposure. This is your question?

***Timothy Mousseau***

While we are waiting, I can so tell you that there is a tremendous variability among different species and even in individuals within the same species in sensitivity to the doses. And birds and butterflies seem to be the most sensitive to intensive environmental consequences. Maybe because they are similar genetic sex determining systems.

***C. Nohara/Miho (translator)***

Actually they are doing this experiment on moths because they are very resistant against high exposure. They were exposed to like a 70 to 80 Sv of radiation, just to see a very short time effect of radiation.

But what I did in my experiment is to see the long-time effect of internal radiation with low dose, so the nature of the experiment conducted on moths and these butterflies is different. And as long as I know – I just checked the past experiment –, there was only one kind of internal exposure experiment … with tritium in water.

***Ruth Stégassy***

We'll stop... We will stop otherwise we cannot take a break before the debate. So we will resume in 20 minutes, for two hours of questions and answers. ◆

# Question and Answer Session

***Ruth Stégassy***

Before beginning the debate, we will give the floor to Paul Roullaud, who is the instigator of all this.

***Paul Roullaud***

I've done a lot of really dumb things in my life, this is another one. I'm just kidding. I'll speak for a minute, first to thank all participants for their presence and for what they have told us.

And to bring all this to WHO, – since there are no representatives of WHO here today, we do not see Mrs Chan in the audience, so WHO is not there –, they will have to know it.

And the best way to transmit the message is that the Vigil continues. We are several dozens, almost a hundred, who want it to continue for a long time. We vote for the renewal of the Vigil at all general meetings, which take place every six months. People who want to participate in the Vigil are welcome. You can find on our website my phone number, and then I enter your dates in the notebook. One can participate for an hour, a half day, a day, a week, a month.

People come from quite far away. Next week, Bretons will hold the Vigil. It is often people from the Atlantic coast who make it, but the locals too, thank you to them. They host them. There is a whole group of people from Geneva and surrounding areas, who provide lodging and meals free and warmly to all the Vigils who come to Geneva. I ask that we applaud them. Well, I hope that we can hold

firm for a very long time to bring this message. Thank you.

***Ruth Stégassy***

Thank you Paul and I want to associate myself with the hope that this very beautiful action will last. Well, the moment we have been waiting for has arrived. There is already a question.

I wonder if we shouldn't take four or five, in order to facilitate the discussion. So, we will listen to the first one.

## Question

Some say that the level of the word's ambient radioactivity has increased since the beginning of human activities around uranium, civil and military industrial activities. And I have the feeling that this view was not shared. If we could have details, thank you.

***Ruth Stégassy***

A second question.

## Question

This morning, someone talked about food related to what concrete action we can do for trying to help irradiated people. First to help all of us, because we're all irradiated in one way or another.

I heard of an opportunity to clean the body, – I say this to the gentleman who is very interested and has spoken several times of food –, with wheat-germ.

I personally think that if food is one of the concrete answers we can give, here we are in the concrete, to heal the harm that was done…

***Ruth Stégassy***

Please synthetize your questions. You mentioned wheat-germ, that's fine, we'll move on to the next question.

## Question

I would ask a question to Mrs Feuerhake about life around nuclear power plants. I know she

has done several studies on this, and I would be very interested to hear more details about what is going on around nuclear power plants that are in daily operation. And also the radioactivity peaks, it seems, when they do the famous maintenance.

## Question

The question is for Mr. Baverstock. I would like him to explain a little better the new paradigm he has told us about, which is the complex dissipative system. And I would also like other speakers to comment on this new concept.

***Ruth Stégassy***

We'll start with the most general questions. The first one was: some argue that the level of environmental radioactivity has increased since the beginning of industrial activities related to atomic energy. Does anyone want to answer that question? Inge.

***Inge Feuerhake***

I think you mean uranium mining. Of course if you have uranium mine you will have the material. But radon is follow product of uranium. Uranium decays to radium and radium is in the earth, in the soil. If you dig in the soil and in the mineral, you will have elevated weights of radon, and you will have dust. The dust consists of heavy materials, they will be locally deposited. And the radium goes around. The half-life of radon is only 3 days, or something, so that's not a relevant thing far away from the mine. You mean maybe you may have

tritium which is… no, tritium is artificially produced. It is also in the nature but it is artificially produced. Is that your question?

## Comment

If I can clarify, thank you. I read such statements by representatives of the International Association of Physicians Against Nuclear War, denouncing the rise of the natural background radiation around the planet due to civil and military activities since the beginning of the use of uranium, thank you.

### *Ruth Stégassy*

Monique? Monique Sené will respond. Monique Sené needs no introduction. Physicist…

### *Monique Sené*

Natural radioactivity has decreased since millennia because the radioelements decrease. They divide in half, and at last disappear in their life time. For example, uranium is still 4.5 billion years. So you see… and thorium 11. One drops the commas periods, but that's quite enough. And it gives the age of the Earth. And now, if you think of the increase, yes, actually it's due to all the nuclear testing we did.

Obviously, we emitted 110 kilograms of tritium. This doesn't tell you much, but it's an absolutely huge number of Bq. And it still remains, since the half-life will be 12.5 years. In twelve years, half disappears. Well, there are still another 40 or 50 kg. If not more, because we still emit it.

Now, if we compare the radioactivity emitted by all plants, it's still limited to them. It is limited to around 100 km, let's say, but no more. That's long enough, because the tritium radioactivity emitted by nuclear plants is not negligible compared to natural tritium. Beware, this is not a small factor.

And you have other products which are emitted by the plants and actually ... so, if they are liquids they go to sea, but they also settle in all sediments. In the river Loire, for example, we know that there is some plutonium contamination that occurred as a result of accidents in the years 1969 and 1980, so it's inevitable, that's it.

And in the sediment of the Seine, same thing.

And then you have pollution that actually comes from all the plants of the North Cotentin and then goes up to Norway. So you see, you actually have an increase because it did not exist, but never forget that there is natural radioactivity. But above all, even if we do not see it, the sea takes it, so this means that fish can actually be contaminated. This is what indeed is happening in Fukushima. So that, so to speak, is the artificial radioactivity we have.

### *Ruth Stégassy*

Thank you. There was a second question concerning foodstuffs in contaminated areas: clean the body with wheat-germ. Have you heard of it and do you have something to say about food? Who wishes to reply? Keith Baverstock.

### *Keith Baverstock*

There are techniques to reduce caesium. It involves Prussian blue which is a chemical, is insoluble chemical and it binds caesium. So basically it is mainly used on cattle, I've never heard it to have been used on human beings. But basically you feed the cattle with this material and it binds all the caesium in the gastrointestinal tract. Then more caesium will come out of the muscles, because that's where the caesium goes, it goes into the muscles, and it would come out into the gastrointestinal tract, and that way it can be removed. It's alleged that eating a high pectin diet will reduce caesium by the same sort of mechanism: that the caesium would bind to the pectin. I never heard of the wheat, but it could well be that the similar process operates there. The

process that I'm pretty sure does not work is the sauna. It has been claimed that by heating the body to a high temperature and then allowing it cool down by jumping into cold water it will release the caesium. But I don't believe it will be.

### *Ruth Stégassy*

Thank you. We turn to Inge Feuerhacke, since a question was put to you concerning life around nuclear power plants and radioactive peaks during maintenance.

### *Inge Feuerhake*

Since 1970's we had observations in Germany that child leukaemia is elevated in the surrounding of the nuclear power plants, several power plants. And the government always said, "*No, it's not a real effect, it's just statistical deviation. And it's not possible because we register the environmental radioactivity regularly and there's a book where you can read that the dose is fairly low".* And then happened a very extraordinary high cluster of child leukaemia, it was in 1990, and the elevation was such a great peak in the very nearby neighbourhood of the nuclear power plant in Krümmel near Hamburg, and in the neighbourhood of this power plant there is another nuclear research institute running two research reactors.

Then it was decided, the authorities said, the mainstream researchers in epidemiology said, OK this is a significant increase, and there has be commission to study. That commission was installed by the state of Schleswig-Holstein. The Central Commission for Radiation Protection said that it's not necessary even to do studies there to look for radioactivity or something else, *"We know that it is impossible that leukaemia can be caused by these reactors there, we know the emissions and we know the doses, it must be an unknown source".*

And some people I was involved with try to solve the question. We found environmental radioactivity, we found increased dicentric chromosomes in sample of people living there. But the ministry who had the supervising of the reactor said they don't believe it, they make their measurements and they don't find anything. We then detected that there had been an illegal release, maybe in the institution of the nuclear research centre. It was in the year when Chernobyl had occurred, 1986. And nobody had looked, the environmental people were otherwise involved. It was in September and we could find things in other registrations, increase of nuclides fission, and at least we found plutonium and alpha emitters. So, it had been possible to explain the whole thing from the dose to the effect, but they said it's not possible, there was no such event.

But following all these things a study was made, you find it in the central registry for childhood cancers in Germany. In one of these studies which had been made over this period – the registry was installed in 1980 – they said there might be an increase. If you look at all German nuclear power plants you find in inside of 5 kilometre an elevated rate of children with leukaemia, leukaemia in very young children, below 5 years of age.

Then you may have heard that a new study has been made, published in 2000, I think, also by the central registry of childhood cancers, in which they found significant dependence of the leukaemia rate in children below 5 years and the distance to all German nuclear power plants. It was a so called KiKK study. *(Kinderkrebs in der umgebung von Kernkraftwerken – KiKK)*

### *Ruth Stégassy*

Inge, is there a website where we can read a detailed description of this study and the work you did?

### *Inge Feuerhake*

Yes. I try to be short. It is interesting because we speak about genetic effects, and I believe that genetic effects are involved in this. So, we find in Germany a significant dependence between leukaemia and neighbourhood to German nuclear power plants. You may have heard a point, so, this was not anymore denied by the officials, but they said: "*We know it's is not possible that the emissions from the nuclear plants can cause this effect, we have registered, you know the doses are much too low. And there must be unknown factors, we must do research in how leukaemia is induced, how it can be caused, by which factors, all known factors had been studied and there was no known combination control.*"

The new ideas are that the emissions are not correctly monitored. The phases where the nuclear material is changed deliver radioactivity. My personal experience is that, in the case of Krümmel, you could measure all these things. Indeed I believe that the measurements are not correct and not complete. I think there are alpha emitting nuclides in the environment.

### *Ruth Stégassy*

Wladimir Wertelecki would like to make a brief comment.

### *Wladimir Wertelecki*

I would try to remember what has gone on. So, from the prospective of Polissia… only. I want to underscore several points that have been raised.

First. Radiation incorporation is up, temporal rise.

Secondly, the food consumption is home-produced food. The home-produced food relates to wet pastures for cows, goats or whatever, and relates to wet gardens. The pastures: you don't toilet-train the cow. So it recirculates. And the bigger the organism is, the bigger is the concentration. Tiny fish, tuna, big fish. And the gardens they fertilize with ash from radioactive wood. Over half of the dwellings are heated by wood.

But, in addition, we are seeing the third generation of children. So, we talk about the mother was *in utero* who grows up to be a teenager, exposed every day, she gets pregnant, her embryo is exposed every day, that embryo becomes a girl, that girl gets pregnant, and her embryo is exposed every day. So you can do multi-generational of studies. Anybody who wants to volunteer? We have the data, we don't have the capacity to analyse everything.

And the third point is that upstream from Chernobyl there is more tritium than you can imagine. It cannot come from Chernobyl. It has to come from two power plants, and these two nuclear power plants you can go and find the record how often they are in upkeep. How often they go down. And every time they go down, they get depressurized. These are pressurizers cooking water; by the way. One of my mentors said that the most stupid way to boil water is to build an atomic nuclear power plant. There are better ways of boiling water than that. So, those plants, if you look at the number of down times, how many times had they been shut down because there was some emergency, it will give you an idea, indirect index of – maybe that's one – a lot of releases happen because of an emergency. So, keep in mind that in all of this, natural radiation pales.

But the reality is that in Polissia, under that wet ground there is granite, and the granite is radioactive. And that granite when they try to cut it and sell it abroad, goes to the frontier and it is too radioactive to be sold, so it goes back and they build dwellings in Kiev or in Odessa or in Moscow or whatever have you. So, it is an issue but is not necessarily a big issue in relative terms.

You need to have different perspectives of how you look at what is natural. Natural carries an implication of benign. That's no such thing. Radiation is radiation, period. So any non-natural radiation is an extra dose. Thank you.

### *Ruth Stégassy*

The question addressed to Keith Baverstock on his new paradigm of CDS is, in my opinion, a question that will take some time. So I suggest we keep it for later. It is not to remove it, but just wait for a while because I think the discussion is likely to be dense. So, are there any other questions?

## Question

A quick question. In the thyroid, what are the preventive examinations we can do, and what are the possible precautions?

## Comment

If allowed I would just quickly return on diet, since we talked about several ways to reduce or remove part of the caesium.

We talked about apple pectin. Indeed we know that giving apple pectin reduces internal contamination.

But I think the best way to reduce the internal contamination is to provide clean food. Since experience shows that children who come to France for example, reduce the internal contamination by 30%.

So if you want to clean the body of the people who continue to be infected, which is what can be done locally, it doesn't make much sense.

We do this. There's the Vitapect product which is manufactured and distributed, but these are people who unfortunately remain in contaminated areas and continue to contaminate themselves. It's like a snake eating its own tail. So, clean food.

## Comment

I would like to say a word about thyroid cancer in children. And I just wanted to mention two figures as a pediatrician. Thyroid cancer in children is a rare disease. It is considered to have a frequency between 1 and 2 per million children. There are 300,000 children who are followed in Fukushima, and after a few months the health authorities have begun to detect an increasing number of thyroid nodules, some of which were operated and have revealed the presence of cancer, and we have now a figure of ... we will not be too unkind, let's say 70 cases out of 300,000. Which leaves us 210 cases in 1 million. So one could say that the frequency of thyroid cancer among children in Fukushima has increased by 100 or 200.

***Ruth Stégassy***

Thank you. Next question.

## Comment

About decontamination. I had the opportunity to meet a French doctor named Jade Alegre, who did a doctoral thesis on the use of clay as therapy when it is ingested. She cites the case of caesium, which is encompassed by the clay if eaten. I am no expert but I would refer you to her site called *"L'Homme et l'Argile"* where you can read *(in French)* her entire doctoral thesis as well as a summary, and other articles, two by Nexus, including one that cites the role of WHO which prohibits the use of clay in Africa despite the absolutely extraordinary results. Well, her name is Jade Alegre.

***Ruth Stégassy***

Noted. We'll take two more questions.

## Question

Two brief questions. One for Mr. Dubrova: what is the role of low doses in the experiments he proposes? I did not understand if you give them importance.

The second question to Mr. Wertelecki: the curve of the Chernobyl cloud he has presented does not pass through the south of France. However, in France it is known that Corsica was deeply affected, so it would be good that he rectify his curve

## Question

I have a question concerning food. After these catastrophes, Chernobyl or Fukushima, have there been any soil decontamination tests, especially for agriculture and to enable people to return to a healthy diet?

### *Ruth Stégassy*

OK, thank you. We will group the questions because several of them are on diet. One concerning apple pectin and also calling for clean food for the people who are still in contaminated areas. We heard also about a doctor who wrote on clay which, if ingested, absorbs and envelops caesium, thus rendering it harmless. Then there is another question on soil decontamination trials, including for agricultural use. And then you spoke of the wheat germ. Does anyone know the Orgonites, still concerning food? Wladimir Wertelecki wants to answer.

### *Wladimir Wertelecki*

Coming back to what has been said, again I will refer, share with you experiences in Polissia. You can then generalize beyond there.

First of all the water table is very high. So, water wells are 1, 2 meters, sometimes 3, 4. So, people drink water, the same like as if it was flowing in a river, that's where tritium is. And so when you talk about 50 kilometres a river goes farther. So, let's be realistic, look at hydrology and geology together.

The second point is nutrition. If a Ukrainian agreed, and they don't, would stop eating mushrooms, – and they will eat mushrooms you can shoot them but they're going to eat mushrooms –, they would reduce body radiation by more than 50 %. And mushrooms are known not to have any known nutritional value, caloric or otherwise. If they would not drink the milk that they produce, they would reduce further their body load.

When we measure body radiation, incorporated body radiation, near nuclear power plants, we get the paradox that the body radiation is one half of what you would find in villages that surround these plants. And it doesn't matter how close or far they are, they are roughly twice then what you are going find next to the power plant, because they have grocery stores. And grocery stores bring food from God knows where, but the caesium and other loads of nuclides in those foods is much lower. So, the question of lowering body dose by diet control is absolutely yes. Clean food. But the tragedy is the children don't get clean food. And schools give lunch. So, there could be programmes to feed children clean food at least during the time they are in schools.

In Polissia every micro-mineral is deficient because these soils have been leeched by the ice age, and there is no zinc, there is no copper, there is no folate. All micro nutrients in those soils do not exist, and so, therefore, plants cannot absorb them. And the foetus needs them. And finally on a humanistic

ethics issue, how come Poland distributed iodine and the Soviet Union forbade it. They knew and they know how to do it, but they forbade it. They started giving out iodine at the beginning of the tragedy but the government in Moscow did not want to produce panic, and in the name of do not induce panic a lot of socially questionable actions were taken in Japan as well.

So, that's all that I have to share with you about this story.

### *Ruth Stégassy*

Thank you very much, then we will turn to Yuri Dubrova, since this is an issue that directly concerned your presentation this morning. You were asked for clarification about the role of low doses in the experiments you conducted.

### *Yuri Dubrova*

The simplest answer to this question, I wish I knew the doses. What we did? We collected blood samples from families living in the heavily contaminated areas. And that was it. I did my best at the beginning of my talk, try to convince you that we know next to nothing regarding the doses for inhabitants of contaminated areas. So the answer to your question is: we don't know anything about the doses. So, there's no further comments. And as far as our mouse studies are concerned, – we do a lot of mouse research – the lowest dose ever tried in my lab was 10 centigray.

### *Ruth Stégassy*

Thank you, it was a question addressed to Wladimir Wertelecki, and it was to report that in the map of the Chernobyl cloud he showed us, France did not appear. It is true that for the French it's even more shocking because we were told that the cloud had not flown over France, and it seems that this is not quite the case. This is not exactly a question, it's just an invitation, I think, to transform a little bit your map for future presentations.

There is Chiyo who would like to speak. So Chiyo Nohara.

### *Chiyo Nohara*

To return to the result that was shown on the last slide of the presentation with the second generation which, feeding in Okinawa on clean products, seemed to have a very big improvement in survival levels. For me it was a result that is in itself very encouraging, which would be in line with what has been said elsewhere. That is to say, by taking a second generation and giving it clean food one can, in any case, improve a situation that had been badly damaged.

But I should point out that, on the other hand, you can also look at the glass half empty. That is to say, even in Okinawa, even being 1,700 km from the Fukushima plant, if we eat contaminated ingredients then there is immediate damage. So for me the result of the study at this stage, can be seen as an encouragement, but I see it also as proof that there's a huge threat and that lastly we don't know who eats which ingredient and where, and it is very important to consider that the food security problem is not limited to the close neighbourhood of power plants.

I also wanted to clarify another point. As you have seen in the results, the second generation nourished with a quality product and outside the plant environment, in this case in Okinawa, has a level of survival which seems normal. But this can in no way reassure us on the risk that runs at the impact on DNA and genetic threats that could include exposu-

re to food, even at low doses such as the experiment we did. And that is why we developed a project, which started last year, called Genome Project, to analyse the impact on genetics. So I do not want you in any way to think that the results we have presented today are minimized, insofar as it would be enough to eat clean food in the second generation so that the problem is resolved. This is by no means our approach. And the next step for us, to put it in very general terms, is to tackle the problem of DNA.

### *Ruth Stégassy*

Thank you. There was a question about the thyroid. Are there any preventive examinations and precautions? So who wants to answer? Does that gentleman want to answer?

## Comment

There are measurements that have been done here in Geneva at the University Hospital. This is called anthropogammametry.

We put a sensor on the thyroid, and it measures the $^{131}$iodine or other isotopes of iodine that may be present.

Regarding prevention, we know about the famous iodine tablets, but we usually don't know that it's not worth taking them after the accident. After the cloud has arrived.

This means that the objective of the protection mechanism is to saturate the thyroid with stable iodine to avoid ingestion of radioactive iodine in the thyroid.

But if it is done too late, if the radioactive iodine is already there and the thyroid is already contaminated, that's it. So there is no need to take iodine tablets in a normal situation. Rather, it is a health hazard to adjust the level of iodine in the body.

So we do more harm than good. That's why it's very important to have an early warning system, so that people who are concerned may take these tablets.

There was a third question related to iodine. It is the need or the possibility to decontaminate the soil, I guess in Europe, during the Fukushima accident. I tell you that it wouldn't be a good thing. Why?

Because they showed colour maps, but they did not say that these maps are in logarithmic scale. This means, Fukushima is in black, then it is an extraordinary iodine contamination. And we find something yellow that is in Europe. But the difference in concentration is of 9 orders of magnitude, it means 1 billion. This means, in Europe during Fukushima, with all due respect for the victims of Fukushima, we had iodine concentrations that are 1 billion times below what there is in Fukushima. In this situation we will again do more harm than good… to decontaminate the soil with chemicals.

### *Ruth Stégassy*

Thank you, but I think it was to decontaminate the soil in Fukushima and Chernobyl.

Keith Baverstock would also like to say something about the thyroid.

### *Keith Baverstock*

First of all, yes is correct that iodine should be taken before or in the very early stages of the exposure. That is some very good advice that has been offered by the WHO, not primarily from Geneva but from the European Regional office. It's proposed in that advice that the iodine tablets are pre distributed, that households have the iodine in tablets and they are told when to take them; don't take them until you aren't told. And it is in fact only necessary for children to have them, it is not necessary for older people, and in fact it can be damaging for older people. I learned only last week

that Switzerland has finally decided it would pre-distribute its iodine tablets. So, that's the most effective way of preventing, or minimizing cancer. And that's what happened it was a pioneering action of Poland to implement a nationwide, almost nationwide distribution of iodine in the few days after the Chernobyl accident, and Poland has probably a lower rate of thyroid cancer than would be expected.

Now, the situation for the thyroid cancer in Fukushima is that the tablets were not pre-distributed, they were not distributed at the time after the accident. So, very, very few people actually got iodine tablets. The situation is that, in response to public concern, a major screening programme was set in place, and three hundred thousand (300,000) children under the age of eighteen, at the time of the accident, have been screened. And that's, more or less, the first round of screening is complete. And that round of screening has uncovered one hundred and four (104) thyroid cancers, fifty-four of which of thyroid nodules, as I say, 54 of which are so far been determined to be malignant. And some of them have extended to the lymph nodes and even to the lung. So, the debate is – because this is a very large number – about whether it is the effect of the screening which has revealed these cancers, or whether it is the result of exposure to iodine after the accident.

No, or virtually no, measurements of thyroid activity were made in the aftermath of the accident, so we have very little idea what the doses are. So, we don't know what to expect. It is true that the thyroids of Japanese – because they eat sea food and seaweed containing iodine – are not large, enlarged, like they were around Chernobyl, so we would expect the level of thyroid cancer to be less. However we now have to wait for the second round of screening, because what was measured in the first round, was the prevalence. Everything that was there, in up to 18-year-olds, no matter when the cancers started to develop. The second round, screening the same children a second time two years later, will show if even more cancers are found. If that is the case, it's almost certain that radiation has induced them. If no further cancers, or very few further cancers are found, then it would seem that the effect of these cancers that have been discovered, have been discovered through screening effect. So, that's the situation. We'll get the first result sometime in the spring of the first tranche of second screenings… so we will know fairly soon.

[see: http://fukushimavoice-eng2.blogspot.ch/2015/05/fukushima-thyroid-examination-may-2015.html
http://www.fmu.ac.jp/radiationhealth/results/]

***Ruth Stégassy***

Thank you. We will take one more question.

## Question

First, I would like to thank the speakers for all that they brought to us. I've learned two things which go against what has been established so far, which I thought was established anyway.

One thing is: the more a body is simple, the more it is resistant to radiation. At least that's what was affirmed, and there was evidence. Here it seems that simple organisms, among which insects, plants, may be sensitive to radiation including at low doses.

Even better is with a few Becquerels of caesium in larvae, something is observed. So we are no longer in low doses, we are in very, very low doses.

And by seeing something at this level it raises for me questions today and it squarely calls into question the use of atomic energy. Not only in accident situations but also during normal operation by discharges from nuclear facilities. Because we are at these levels, some Becquerels in the environment that can easily be found.

And finally I just wanted to point out the study on leukaemia around German plants, made by Alfred Körblein, which you can find on the internet.

You should know that IRSN did the same in France, it found the same results around French nuclear sites, and its conclusion is, I quote: "*It's quite random that there is a plant there in the middle of this circle we drew, it's tiresome, but that's how it is. We see it, we will not look further.*"

Obviously it would be interesting to go a little further, that is to say, to see if there was a correlation between contamination, that is to say the Becquerels rejected by the plant, and the location of these leukaemia in the circle, which is not uniform. So, was there a correlation? But the IRSN stopped before going on to do this work.

***Ruth Stégassy***

Thank you very much.

## Question

How our expert panellists perceive what comparative approach they can take concerning the emission of radioactivity in the air and the emission of greenhouse gases? Thank you.

## Question

I wanted to ask if you would agree to say that the only effective prevention against the harmful effects of nuclear power is simply to put a stop to civil and military nuclear industries. I thank you in advance.

***Ruth Stégassy***

Take one last question here.

## Comment

In the immediate aftermath of the nuclear accident, there are probably around the 60 or more different kinds of radionuclides coming out. And then there are approximatively two groups, I think: so high doses, acute effect, – with a lot of varieties of shortly living radionuclides, like iodine, xenon, tritium and so on – and then also a continuous long term long living radionuclides, such caesium, strontium or maybe plutonium. And then if we have these two different things, will it be more relevant to have two different mindsets depending on a location or depending on a situation, how to protect our lives, or how to look into it in the research.

## Question

A short question to follow that of the gentleman on simple organisms, which also suffer from radiation exposure. In Dr. Mousseau's speech earlier, I imagine that people who question the effects of the impact of radiation could say that the bird count depends on how you count them. I think the video was very eloquent with birdsong on one side and no songs on the other, but can be challenged rather easily. I found very interesting, and I would like confirmation on what is done in this field: no rot on the trees which seems to indicate that at a fundamental level there is a cessation of an activity of organisms

that would be single-celled, or in any case very small. And is there something that is being done in that area, because it seems more compelling if there were tangible results in this field, it might be easier to impose it rather than the bird count which is easy to question. Thank you.

### *Monique Séné*

About decontamination of territories and also about healthy food. I recall that once the radioactivity is in the environment it's not easy to go look for it. And if you eat healthy foods that capture your radioactivity, well, it is necessary that your stool, sorry ... and your urine have to be taken back, if not you will just re-contaminate. So it's not that easy to manage the post-accidental situation. That's it. It's just a question ... What do we do?

### *Ruth Stégassy*

Maybe we could start on the issue of simple organisms. Roland Desbordes noted that, in general, we think that the more an organism is simple, the less it is sensitive to radioactivity. And here he discovers that one sees traces of radioactivity in larvae, so at very, very low doses, which challenges atomic energy itself even during routine functioning, not just in case of accident.

And there was another remark on simple organisms, specifically addressed to Tim Mousseau. So there is the example of bird count that can easily be contested. However no rot on the trees is something quite interesting. Are there specific studies on this lack of rot that could be correlated with radiation-induced accident?

So, who wants to answer this question of simple organisms? I think maybe you can start Tim.

### *Timothy Mousseau*

I did want to make a comment about the food; people in Chernobyl like to comment on the fact that it's fine to eat the Chernobyl apples, but you have to deal with the pulp which is a toxic waste. But eating them is just fine.

So, one of the really interesting findings that we've had, is that there's tremendous variation among different species in their sensitivity. In fact early this year we published the paper in a British journal, called Functional Ecology, where we showed that there were maybe five or six species of birds now in Chernobyl, among the 60 or 70 species referred regularly, that seem to have adapted, seem to have evolved the ability to cope with radiation. This is a small proportion of the total number of species, but nonetheless, given 28 years of selection, 28 generations for most of these birds, looks like some of them have changed the allocation of one of their important antioxidants, away from coloration, and are using antioxidants GSH to protect against oxidative stress. And the oxidative stress is one of the outcomes of the ionizing radiation. In knows birds who can do that, they actually have lower levels of genetic damage, in areas of moderate levels of radiation than in areas that have much lower radiation. So, they've over compensated somewhat in terms of defending against the defects radiation. So, there's a tremendous variation among different species, there's a tremendous variation among individual within the same species, and so it's very difficult to generalize from one animal, as is often the case for the ICRP or the other regulatory agencies. They will generalize from one fish, one bird, one insect and generalize across everything else. That is the same of course for humans, and it's just not possible to do that, because of the variation in sensitivity. So, I think that's really all I have to say on that particular topic.

### *Ruth Stégassy*

Yes, Chiyo perhaps on simple organisms?

### *Chiyo Nohara*

Just to come back to food and the results presented earlier. We focused on the F2 generation, I would like to comment on the F1 generation, the one which has been directly affected by radiation.

For lack of time, the presentation that you heard was on generation 2, and the effects of good food in an uncontaminated environment. It turns out that you can refer to the full study, we made a very important study on the F1 generation, including in areas that are relatively close to Fukushima. As you move down from Fukushima, at 150 km we arrive in the area of the Tokyo metropolis. And we have studied the F1 generation which concerned the

Kantô region, so the Tokyo area, and a little further south, the peninsula of Shizuoka, which is well known for tea production and therefore, among other things, with the problems of ash that fell directly on the tea leaves.

The studies we have done on the generation number 1 are particularly worrying because they show that there is, whenever there is consumption even at very low doses of radioactive caesium, an increase of mortality rate. And most disturbing for us was, as we have seen in the graphs that I presented you, that with an increase of caesium rate there was an increase in mortality, but in fact we reach very quickly maximum levels. That is to say, it is not that a 10-fold higher dose will induce a 10-fold higher mortality. We soon reached the order of mortality rates, I translate freely, in the order of 50% with doses which are low.

So, that was in the study, you will find those elements in the first generation: even a surprisingly low exposure caused a major impact and significantly higher mortality, even in areas like Tokyo, the southwest of Tokyo, so areas that currently are not at all taken into account regarding the Fukushima problem. Thank you.

### *Ruth Stégassy*

Thank you. So, we still have some little points before getting to the question which I think will conclude the debate, at least to end or to open it widely.

So there are some in my opinion ... Roland, the question about the correlation between location ... is dropped.

The question, do you agree that the only prevention is stopping the civil and military use of atomic energy? I propose that we answer all together, 1,2,3: yes! That is answered.

There was a question about the relationship between radioactivity and greenhouse gases.

I'm sorry but I didn't quite get your question about the two groups of radionuclides released, the stable and not stable, what was the question exactly?

## Question

Should it be the time to think of… like different mindsets for the different sets of radionuclides. So that for the shorter, short living radionuclides, we try to do this type of preventive measures, and long living radionuclides we try to work on this type of measure. Of course out of 60, 70 different radionuclides, for even one or two we don't have enough medical knowledge, but at least we can develop some attitude and then, depending on the situation, mix those together.

### *Ruth Stégassy*

Who wants to answer? Keith Baverstock.

### *Keith Baverstock*

We don't need a new mind set. The short-lived isotopes affect people close to the site of the accident primarily, and that's the responsibility of the nuclear power company to ensure that it has a system to protect these people, and that's usually done by evacuation or sheltering. The long-life ones they are to a certain extent unavoidable to live with, because although they will clean up many areas around the heavily contaminated areas of Fukushima, and they will reduce the doses by perhaps factor 2, there will still be the forest, there will still be the mushrooms, there will still be the berries and the wild animals, that maybe use for food. So they will always be sources of internal radiation around these towns or cities.

For example only recently it was reported that the level of caesium in reindeer in Norway had suddenly risen, and that was because of the particularly good year for mushrooms, the reindeer ate the mushrooms and they've got the caesium. These are

long-term things, and this perhaps will bring me to a short remark. The industry cannot control this. They promised an industry that didn't have any effects on health. They promised that accidents would be at a very, very low level. Well, the level at which accidents are occurring in practice is much, much higher, and there are features that they cannot deal with. And I would just like to introduce you to a remark made in Fukushima by a WHO senior management person, Emilie van Deventer, and she said that, *in looking at the public health aspect* – and this is not her exact words – *of the Fukushima accident, we had to bear in mind the economic future of nuclear power*. That wasn't the IAEA, but was the WHO.

### *Ruth Stégassy*

It has the merit of being clear. So, we will come to the earlier question, which was addressed to Keith Baverstock. He was asked to explain a little better his new paradigm, the Complex Dissipative System. Could you explain it synthetically, and then we wanted to have the opinion of all the participants. Well, what is clear is that the issue here revolves around genetics and, genetic or not genetic, we spent a whole day to discuss and listen to things on genetics.

So it's actually interesting to have this general opinion, and perhaps more widely too, I seem myself what struck me is that there are at this table scientists who are immersed in extremely interesting research, very sharp but not necessarily intersect with each other. What I want to know is what connection, what bridge you can establish with each other. Or do you feel that your research fields are completely isolated from one another, or on the contrary, that there is a possibility of creating a corpus, a scientific corpus from your research. We start with Keith Baverstock and the CDS.

### *Keith Baverstock*

Well, it's really not possible to do this in a very short time. So, I'm going to confine myself to making three points. First of all, for the laws in nature we look to physics. And life is a natural process. So we should look to the physics, that underpins such at natural process, and ask if we're using the right physics. And I think few biologists ever think about this, because they are taught Newtonian physics they assume that it will apply, they are not physicists, they don't question that. And therefore there is really no thought given to that matter. But Newtonian physics isn't satisfactory, and then are other forms of physics which might be more applicable, because organisms cells, and organisms, have processing energy. They're like engines, in a sense, they take in energy like your car, and they use it to make a system go, but they have left over entropy. And that is usually wasted in cars, or it's used to heat up passengers on cold days, but it can't produce work, it's energy that can't produce work. But it does appear in the organism, the growing organism, the entropy appears as the body mass. So, you see the energy's consumed, and the organism grows, but the organism goes, as well, so it burns energy in two senses, utilizes the energy in two senses. Utilizes the entropy in terms of growth. So, that's one reason for arguing that we need a new basis in physics.

Now, the question is, we want a theory of life, and genetics does not provide that, because genetics is just statistical associations between what we assumed would be the DNA sequence and the phenotype. Now, in 1930 R.A. Fisher, a statistician, took Darwin's theory of evolution by natural selection and said, *we are lacking a theory of natural selection*. Being a statistician he made a statistical theory of natural selection. We can make a physics theory of natural selection, based on the *principle of the least action* and *the second law of thermodynamics*. Now, we have a choice, which do we do? I'm in favour of the physics approach, geneticists use the statistical approach. But have the geneticists considered using the physics approach?

And the third point, to keep it brief, I think organisms are systems, and systems are more, we say, than the sum of their parts. So, they are not just the additive consequence of all the bits that we've got, of all the DNA, the proteins and other chemicals acting independently of each other, they are interacting to produce something which we call greater than the sum of the individual parts. And this is an argument against reductionism. And reductionism has been the driving force in biology, because it's easy to do. We can take the system apart and we can study the bits of it. What we can't do is put the bits

pack together and get the whole thing. We can just get something which doesn't work.

So, I think those are three reasons why we should reexamine the issue of whether working on the genetic paradigm is the best way to solve our problems in biology.

### *Ruth Stégassy*

Thank you. Who wants to give an opinion ... Wladimir?

### *Wladimir Wertelecki*

I am daring and therefore don't believe what I'll say. I agree. I was never convinced of statistics. And in fact it's very interesting that one challenge to Darwin and Dalton, and Fisher and all that school of Haldane and so on, was posed by an anarchist, and a prince, and who was very beloved when he left Russia to go to Oxford. And it is evolution without Darwin, and without Malthus. And it was based on populations of symbiosis of Siberia, where species are highly separated and need each other, so therefore Siberia was one organism. Contrary to Galapagos where species were highly packed and competed and killed each other. The second concept challenge by that was by Vernadsky. Vernadsky was a man whose life was saved by a teenager called Dobzhansky. And Dobzhansky was part of the team of the Muller that you heard of radiation. And Dobzhansky and Muller sustained an argument that Muller lost. And Dobzhansky is, let's say, the successor of the man who created the Academy of Science of Ukraine, who came with the concept of GEA, that the whole earth is one organism, one interacting organism.

So, you cannot even separate one individual, you cannot even separate one population, but you have to actually look at it in ecological context. So I'm proud and very pleased to say that we have a spokesman for a new concept that should be promoted because epigenetics today is the new perspective of genetics. Just like we saw Dobzhansky uniting the evolutionary ideas of Darwin with the Mendelism of single genes, the grand modern sentences that he published in the '40s or '50s. So, my response is, let's listen more to our colleague here. Thank you and I congratulate him.

### *Yuri Dubrova*

Just a few words. In 2000, completely out of the blue, we got an incredible set of data. So, what we did? We irradiated male mice, and then analysed what was going on in the non-irradiated offspring. So, the current wisdom in biology tells us, that they should inherit some extra mutations, and they're either dead or OK, depending on the severity of the mutation. The bigger surprise, it turned out, the mutation rate in these animals which had never seen a drop of ionizing radiation was fivefold higher than the ones in controls. So, that was the beginning of new era in my lab, where we analysing the phenomenon of transgenerational instability. And there's no way you can explain it using conventional genetics. They are something else. We spent 10 years since then, never mind how much British pounds to analyse it. And we still don't know what's behind. But what we know for sure, that standard genetics doesn't work here. Because what we see: hundreds of animals genetically unstable. And this is a new way of understanding of the genetic effects of paternal exposure to ionizing radiation.

### *Inge Feuerhake*

I'm interested in the improvement of radiation protection, because I'm in contact with people who have damaged children. We know that if you irradiate parents, you will get malformations and other damages in children. And therefore we have to demand better protection of the gonads perhaps in medical diagnostic, and in the standard dose limits. We must fight against the interpretation of the ICRP and UNSCEAR. And the role of physicists in this field is very bad in my knowledge, because they claim that they are able to calculate the dose, which is not really true, they are not able. They can't model the complicated metabolism of incorporated radioactivity. So, my aim is primarily that we accept the phenomena. There are phenomena, there are effects in children. And the second aim may be to try to get the better theory to how they are caused in human cells. We know that it is dangerous. I would like to know why can we not decide if a malformation is caused by an exposure *in utero*, or is it genetic. These would be practical questions that at the present

would be important in order to do these things, to demand the better protection.

### *Ruth Stégassy*

Thank you. Chiyo, maybe can you say some words?

### *Chiyo Nohara*

I live as you know Okinawa Island, which lies 1,800 km southwest of the Fukushima plant, so a place that is completely safe. We're seeing on the island people who come to take refuge. They come from Fukushima, from the Tokyo area that is much closer. And I see these people arrive on our island and everyone, each person, each of them suffer from exposure received following the accident at the plant three and a half years ago. I myself started my research, as you know I worked in the field of social sciences, and I completely changed the goal of my research following the Fukushima accident. And my wish is that the sciences, social sciences for me but science at large, can realize the situation that is generated by, in my case, the Fukushima accident, and that we can have an approach similar to that I knew when I was working in a field that was largely anecdotal but where we had a discipline and a recognition that we will not be able to achieve at this point in the nuclear field.

That's why I think that the science which we do, must be at the service of those people who are now, at this very day, in suffering, and offer them at least the possibility of hope. And this approach, that should be ours, is not to produce data, but actually we have to get in a position to at least give hope to those who are now suffering.

### *Ruth Stégassy*

Thank you. Tim?

### *Timothy Mousseau*

I want to be short. I agree with Dr Baverstock and some of the others who suggested that a new way of looking at some of these issues is needed. It's clear that if you listen to conventional wisdom, you think there will be absolutely no danger from living downwind near from a nuclear power plant, no danger from Chernobyl, no danger from Fukushima. In fact that's what they are continuing to suggest, that these levels are not dangerous. But clearly these predictions, these models, mostly generated by physicists, are not doing the job, and so there's clearly needs to be a change in perspective. Starting I think first with, you have to have the data, you need empirical observations to begin with. I think generating predictions in the absence of empirical data leads to the wrong predictions, and I think this is a tendency we've had in this particular field. I also agree that genetics, simple Mendelian genetics, we've gone beyond this now. And our models need to incorporate the greater complexity that exists.

Being biographical, autobiographical, as some of the others have been, in 1998 I edited a book for Oxford University Press – and several other papers actually – called *Maternal Effects As Adaptations*. And what it focussed on was the fact that, you know, offspring inherit much more than just the DNA. They inherit all of the cytoplasm, all the other kinds of DNA, all the other biochemicals that come in the egg. And these are influenced by the maternal environment. And of course the same as true, to a much smaller extent, but to some extent, from the fathers. This has really not been incorporated in most of the biological models of the past. Now we know that there are these interactions going on, we called "epigenetics", but really it captures these complexities or attempts to capture some of these complexities. So, I agree that we do need to move forward, we need to incorporate a more modern view of biology, and we certainly need to incorporate a much more realistic view of how physics works, as applied to these kinds of environmental systems. And that's really all I had to say, unless there's anything else, thank you very much.

### *Ruth Stégassy*

Thank you very much, it was a beautiful final word, thank you all for the richness of these exchanges for all that we have learned. Also thank you for being placed on the side of complexity, difficulty, doubt, of research, of the issue and not on the side of over-simplification, on the stupid and obvious statement, which is that of ... well I will say it, that of the nuclearists. ◆

# Conclusion

***Ruth Stégassy***

Françoise Bloch will conclude this very rich Forum.

***Françoise Bloch***

I'm going to sit here because I am very short and you would not be able to see me behind this thing, it will be better like this. In fact, you have no need to see me because I am speaking on behalf of IndependentWHO of which I am a member and so it is not my text that I will be reading, unlike all these magnificent scientists who have made such fascinating presentations today. So I would like to sit down but I don't want anyone to move. I was fine back there. Yes I'm not going to sit behind of course. Thank you.

So first of all of course, thank you to all the presenters and to Ruth Stégassy for moderating this forum. Thank you again to all those who supported the forum and our collective IndependentWHO – Health and Nuclear Power.

Does this work, then I wouldn't have to hold this thing. Can you hear me? I can hear but I don't need to hear myself.

So I would like to start with three observations about the holding of this forum today in Geneva. You can't hear, is that it?

So three observations in the form of " ifs".

Firstly, if our public institutions, international and national, were functioning properly and that means independently of any financial or geopolitical interest, this is a forum that would have been organized by the World Health Organization, in the decade following Chernobyl.

A second "if": Independent researchers, our six brilliant presenters here today perhaps, would have been invited by the international health authority to present their findings. They would have been in regular communication with the WHO, they would have served as independent experts and their findings would have been disseminated to the public.

Third "if": If such a forum had been organized, it is possible that today, there would be serious, reliable radioprotection norms that would protect our genetic inheritance and that of all life forms. From what we have learned today, I think we can conclude that radioprotection norms would apply uniquely to diagnostic, medical radiology. This application is possibly the only one that can be qualified as a "peaceful use" of the atom.

It is worth repeating what the WHO said in 1956, if only to illustrate that more than half a century ago, we already knew enough about the dangers of radiation – especially in terms of its mutagenic properties – to take responsible decisions. First statement, I quote: "*All man-made radiation must be regarded as harmful to man from the genetic point of view*". Second statement, I quote: "*The well-being of descendants of the present generation is threatened by developments in the use of nuclear energy and of sources of radiation*".

Instead, unimaginably huge quantities of radionuclides – known mutagens – have been wantonly spread across the world, in air, soil and water, not just from nuclear accidents, not just from nuclear weapons but from routine functioning of power plants and of course from the colossal quantities emitted during the nuclear testing era.

Clearly, our authorities have abdicated their responsibilities in this critically important area of public health, one that concerns damage that is long term (meaning centuries perhaps more), and that is largely irreversible.

In order to understand how this happened, we need to remember that we are confronting the most powerful lobby on earth, which has hidden and continues to hide the health consequences of ionizing radiation because it is well aware that if these were taken into account it would be very worrying economically for the nuclear industry.

In fact, it is much more than a lobby. We call it the nuclear establishment because it includes the world's most powerful nations, international and national authorities, and even the United Nations family – including to its eternal shame, the WHO. Geopolitical power has wanted and has organized these lies.

It is therefore not surprising that there has been an international, high level, institutional cover up of the health consequences of nuclear activities. Any suggestion of serious health effects would have been fatal to the project of Atoms for Peace.

Radioactive contamination affects all of us, without discrimination. It affects powerful decision makers and their children, their grandchildren and all their descendants.

So, in a sense they are victims of their own disinformation. For over half a century, the nuclear establishment has promoted a policy of ignorance and uncertainty in relation to the health effects of ionizing radiation. And it has done this through the international health authority – an authority that belongs to the world's peoples.

Let me quote the concluding statement from a WHO report published in 1958 on mental health aspects of the peaceful use of atomic energy. I quote (quotations from our enemies are not bad, I find them interesting): "… *In the long run, the greatest hope of mental health in the future of the peaceful uses of nuclear energy is the raising of a new generation which has learnt to live on terms with ignorance and uncertainty.*" (Mental health aspects of the peaceful uses of atomic energy)

You can see that in the end, having a smaller brain does no harm.

What hope could there possibly be for a generation that lives on terms with ignorance and uncertainty? No hope at all in terms of either their physical or their mental health!

Such conditions are noxious to human beings but they resist and they will resist more and more through citizen initiatives such as this forum. They have not learnt to live on terms with ignorance and uncertainty. They have not been convinced by the invention of new illnesses such as radiophobia and they suspect that the whole truth has not been told but, the fact is that on the whole, they have been maintained in ignorance and uncertainty.

Today, resistance to the policy of ignorance and uncertainty is a question of survival. Not survival of the planet, which as we know, will do very well without us, but survival of our genetic inheritance and the genetic inheritance of all life forms.

How much knowledge do citizens need in order to resist?

At the most basic level, it is probably enough to know that ionizing radiation is mutagenic, that low level ionizing radiation (which is the concern in the case of nuclear accidents and routine functioning of nuclear reactors) induces mutations, that there is no level of ionizing radiation that is not mutagenic AND, very importantly, that the vast majority of mutations are harmful or neutral; very few are beneficial.

Our presenters have provided us with a huge amount of information that will certainly take us a lot further in countering the policy of ignorance and uncertainty.

We are deeply grateful to our presenters for participating in this scientific and citizen forum and for their understanding of the importance of providing information to the public even in such a technically difficult area as genetic effects of radiation.

Citizen science of course implies more than just understanding. It implies involvement of ordinary people, most of them non-scientists, in democratic decision making related to the use of science and technology. We organized this forum and the previous one in 2012 in order to bring scientists and citizens together in support of serious, independent science

As a first step, citizens need to be aware that today, there is no credible international health authority in the area of radiation and health. The World Health Organization no longer has a department of radiation and has no senior scientists in this area. It states quite openly that it gets all of its information on matters of radiation and health from the International Atomic Energy Agency. As we have often pointed out, this UN agency has no mandate or competence in public health. Part of its mandate however, is the promotion of the peaceful use of nuclear energy. There is an evident conflict of interest in the fact that the IAEA is in part, an industrial lobby, and it simultaneously evaluates the health consequences of the industrial, nuclear activities that it promotes. I think you can see that, just as everyone can. We all agree on that.

As a final point, I would like to say a few words about how the nuclear establishment still pursues its policy of maintaining the public in ignorance and uncertainty in this domain.

The best known method is quite simply to dismiss all studies that show adverse health effects as work of "inferior scientific quality". The nuclear establishment, through the WHO, claims that it only takes into account "studies of the highest scientific quality". IndependentWHO has analysed some of the publications of the nuclear establishment and compared them to publications emanating from independent sources.

The fact is that on the basis of this criterion, i.e. by their own declared standards, the scientific quality of reports from the nuclear establishment is quite substantially lower than those published by independent researchers. Note that the studies presented today by our presenters are published in the peer reviewed literature, but they may still be ignored, as one of our presenters has noted.

The second most common trick is to claim that if significant genetic effects have been observed, they cannot be due to radioactive contamination because according to the ICRP, the levels are too low to produce such effects. As citizens we should adopt a different logic. The possibility must be considered that populations were exposed to higher doses than were reported or that the effects on health of low level radiation are more serious than was previously thought.

As citizens we must become familiar with the commonest ruses used by our authorities to discredit independent research.

Finally, we must support citizen science and publicly funded research that is undertaken in the public interest and we must remember that a basic understanding of the genetic effects of ionizing radiation is easily within our grasp.

Thank you for your attention, your patience and your presence. ◆

# Acknowledgments

The Forum was supported by many people, associations and institutions. We thank all the volunteers who gave their time and skills freely. We also thank the interpreters, technicians and staff of the Ecumenical Centre; and of course the generous donors whose logos appear below.

For Switzerland: City of Geneva, City of Plan-les-Ouates, City of Carouge, Geneva Industrial Services, Greenpeace Switzerland, Women for Peace, the Liberal Ecology Movement, Geneva Socialist Party, the Green Party-Geneva, Solidarity.

For France: Network Sortir du Nucléaire, Laval Biocoop.

IndependentWHO – Health and Nuclear Power is a grassroots movement, set up in 2006 by a collective of individuals and associations: Brut de Beton Production, ContrAtom Geneva, CRIIRAD, IPPNW Switzerland, Children of Chernobyl Belarus, Network SDN, SDN Loire et Vilaine, People's Health Movement. The group condemns the subordination of the World Health Organization (WHO) to the nuclear establishment and demands that WHO fulfil, independently, its mandate in the field of ionizing radiation.

To that end, IndependentWHO's Vigil has been demonstrating silently outside the WHO headquarters in Geneva, every working day, since April 26, 2007.

Among other actions carried out by the collective, a forum on radiation protection was held in Geneva in May 2012, with the participation of many scientists, elected officials and members of civil society. The proceedings of this forum are available on the IndependentWHO website.

With the continuing denial of biological damage caused by radioactive contamination, a second forum was held in November 2014, once again in Geneva, this time with the theme of the genetic effects of ionizing radiation. This publication is the full transcript of that forum and constitutes its Proceedings.

ISBN : 978-2-9552736-1-6