

Genetic effects of ionising radiation

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Mister Chairman

Ladies and gentlemen

Thank you for inviting me to this conference at the Waseda University of Tokyo.

Today, I would like to present to you some aspects of the issue of ionising radiation and genetics.

A brief history of the issue begins with the research of Professor Herman Muller. (Slide 2)

In nineteen twenty seven Muller published a paper named “ARTIFICIAL TRANSMUTATION OF THE GENE” in the Journal “Science”. (Slide 3)

Muller was the first to use x-rays to induce mutations in fruit flies. The importance of this work was recognized in nineteen forty-six with the Nobel Prize.

Later, Muller became a voice of concern about the consequences of genetic effects of ionising radiation to the health of human beings.

Let's turn to other examples of man-made radiation.

There have been many major and minor releases of radioactive elements to the biosphere, contaminating soil, air and water. The most recent major accident was the meltdown of the Fukushima Dai-ichi reactors, which released huge amounts of radioisotopes into the biosphere. (Slide 4)

Solid cancers and hematological malignancies, immunological diseases, cardiovascular diseases, effects on neurological and brain development and teratogenic effects have

been the short-term consequences of such accidents and in the long-term there have been hereditary consequences for the following generations.

Three examples of radiation exposure invite our attention. (Slide 5)

We begin at Chernobyl in nineteen eighty-six. The information relates to the breeding habits of a species of bird, the barn swallow, (*Hirundo rustica*). (Slide 6)

In nineteen ninety-seven Dr. Hans Ellegren and colleagues published an account of "Fitness loss and germline mutations in barn swallows breeding in Chernobyl" in the scientific journal "Nature".

Ellegren's research team reported an increased frequency of partial albinism, which is a morphological aberration associated with a loss of fitness among barn swallows breeding close to Chernobyl. (Slide 7)

Heritability estimates suggested that mutations causing albinism were, at least, partly of germline origin.

Furthermore, evidence of an increased germline mutation rate was obtained from the analysis at two hypervariable microsatellite loci, indicating, that mutations in barn swallows from Chernobyl were two-to-tenfold higher, than in birds from control areas in the Ukraine and Italy. (Slide (8)

Here, in this slide, you can see a DNA-fingerprint example. Arrows demonstrate mutant bands, bands stemming neither from the father nor from the mother.

The authors concluded, and I quote:

"Thus, both genetic and morphological data suggest that barn swallows, breeding in the Chernobyl area have experienced elevated levels of germline mutation rates at both, expressed yielding albinism and non-coding, microsatellite loci from the nineteen eighty-six release, of radioactive material, from the nuclear power plant. This seems to have led, to a loss of fitness among individuals in the breeding population, and may also be associated, with a significant decline in population size between nineteen eighty-six and nineteen ninety-six. We have no reason to believe that the barn swallow should be uniquely sensitive to radiation among animal species breeding close to Chernobyl or in other radioactively contaminated areas."

End of quote.

Here we see clear evidence of significant, quantifiable harm in a species of bird exposed to the nuclear contamination released at Chernobyl.

In two thousand and fourteen Dr. Timothy Mousseau and Dr. Andreas P. Møller published a paper concerning recent advances in genetic and ecological studies of wild animal populations in the Chernobyl and Fukushima areas. This paper described significant genetic, physiological, developmental, and fitness effects, stemming from exposure to radioactive contaminants. Barn swallows with aberrant, white feathers were first detected in Fukushima in two thousand and twelve and were observed in increasing frequencies during two thousand and thirteen and two thousand and fourteen. (Slide 10)

It may be that the fur of animals (for example, cattle in Fukushima), belong in the same category as partial albinism in barn swallows in Chernobyl and Fukushima.

Now, I want to turn to radiation issues directly related to human beings.

I begin with the fundamental question:

Is genetic damage transferred to following generations in human beings?

The answer, I think, is clear. It is.

The scene shifts now to England, and the nuclear reprocessing site, at Sellafield.

In nineteen eighty-three, Yorkshire Television company broadcast the film: "Windscale: the Nuclear Laundry", which, for the first time, highlighted a disturbingly high rate of childhood leukaemia near Sellafield in Cumbria. (Slide 11)

On the next slide you can see the geographical situation of the Sellafield reprocessing plant. (Slide 12)

In the official report, which came to be known as the Black report on Sellafield, it was confirmed that the incidence of leukemia was abnormally high in the region of Sellafield.

Later, Dr. Martin Gardner and colleagues found in a case control study in nineteen ninety, that, with regard to leukaemia, the relative risk for children of fathers working at Sellafield, and receiving a total preconception ionising radiation dose of 100 mSv or more, was 6.24. (Slide 13)

Normally, we would expect a non-radiation value of 1.0.

In a separate epidemiological study at Sellafield Dr. Louise Parker and colleagues found a significant risk correlation, of a baby being stillborn and the father's total exposure to external ionising radiation prior to conception.

Once again, transgenerational pathways were indicated

Returning to Chernobyl in nineteen ninety-six Dr. Youri Dubrova and colleagues published an examination of 79 families who remained living in the highly contaminated Mogilev region. The children were all born between February and September in nineteen ninety-four and were compared with one hundred and nine caucasian families from the United Kingdom. (Slide 14)

DNA-„fingerprints“ were obtained from all families using multilocus minisatellite probes.

In addition the parentage of the children analyzed was verified with additional probes. Mutants were defined as, novel DNA fragments present in the offspring, that could not be ascribed to either parent.

Firstly mutation frequency was found to be twice as high in the exposed Belorus families as in the UK control group. The estimated exposure of the families, was up to 5 mSv per year in the Mogilev area. (Slide 15)

Secondly Dubrova and colleagues were able to establish a correlation between degree of soil contaminated by ¹³⁷Cesium and mutation rate. (Slide 16)

As a final example of genetic consequences of ionising radiation I want now to present to you the story of the pale grass blue butterfly, Yamato shijimi. (17)

Two months after the Dai-ichi accident scientists from the Ryukyus university collected 144 first voltine butterfly adults from 10 localities.

At the time of the accident the populations of this species were hibernating as larvae and were exposed to external man-made radiation. It is also possible, that they ate contaminated leaves during the spring and were thus exposed to some internal radiation. (Slide 18)

Captured butterflies were transferred, to the Ryukyus university at Okinawa, where the following experiments were performed in a radioactively non-contaminated environment.

Eggs from P-females were reared and the adults were mated for each locality. The overall abnormality-rate was evaluated and, for the inheritance of abnormalities by the F2 generation, abnormal F1-females from different sample locations were crossed with normal F1-males from Tsukuba, which is the furthest city from the NPP Dai-ichi zone where the sampled irradiated butterflies had been collected.

The results, of the laboratory experiments, showed both physiological and genetic damage. The parental generation, or P-generation, did not have as many abnormalities as subsequent filial ones, but there were some, and they were physiological. The experiment showed more overall abnormalities in F2-generations and the researchers

found inherited traits from the F1-generation. Therefore, the researchers concluded that germline must be involved. (Slide 19)

In this slide you can see some strains of butterflies. (Malformed antennae, palpi, eyes, eclosion failure, and different wing abnormalities) (Slide 20)

Similar abnormalities induced by external and internal low-dose exposures, were experimentally reproduced in individuals taken from a non-contaminated area, from Okinawa.

I quote:

“To evaluate the effects of internal exposure caused by ingested food, we fed host plant leaves collected from the Fukushima and other areas (i.e., Fukushima, litate montane region, litate flatland, Hirono, and Ube; see Fig. 1; Supplementary Table 8) to Okinawa larvae, which had never been exposed to artificial radionuclides. We confirmed that these leaves indeed contained high activities of ^{134}Cs and ^{137}Cs Almost all individuals that consumed leaves from the non-contaminated locality (i.e., Ube) survived, whereas many individuals that consumed leaves from the contaminated localities could not survive well.° End of quote.

The abnormality rate of the experiment is shown in the slide 19.

Ziizeria maha is monophagous and eats exclusively leaves from *Oxalis corniculata*, a plant reaching maximal 10 cm over ground of soil.

The host plant leaves were collected from the Fukushima and other areas (Fukushima, litate montane region, litate flatland, Hirono, and Ube): see slide 18.

External radiation was applied with ^{137}Cs from a CsCl radiation source.

It seemed clear to the researchers, that the butterfly was measurably affected by radioactive pollution of the environment caused by the reactor accident at Fukushima. The butterflies experienced both physiological effects and genetic hereditary damage.

I want to take a moment to congratulate the Ryukyus group and emphasise that their research is of immense significance in the field of low-dose radiation.

I believe that work of this kind, must be continued, and expanded into a full DNA-analysis of this butterfly species.

Let me now draw together what I believe these case studies show us. (Slide 21)

- We must accept, that both, the dose-effect relationship and the exact mechanism of the mutagenic process in human beings are at this time not fully understood.

But:

- Ionising radiation is mutagenic - this fact has been known since Muller's pioneer publication in 1927
- Secondly - Human beings are genetically affected by the process of radiation-induced mutagenesis, as are all living organisms
- Thirdly - Childhood leukemia may have resulted from pre conception irradiation of the spermatogonia of Sellafield workers
- Fourth - Risk of stillbirths to mothers, who conceived a child with fathers working at Sellafield, who had been exposed to radiation prior to conception correlated with paternal radiation exposure. The link was clear: the higher the dose, the higher the risk
- Fifth – The families living in the Mogilev area, who had been irradiated with a dose of up to 5 mSv per year, from 1986 on and whose children were born in 1994, experienced a two-fold increase in minisatellite-mutations, compared with a control group from the UK
- Sixth - The butterfly study demonstrated huge abnormalities, in both germline, and physiological or somatic damage following the Fukushima accident. Some traits have been passed from the F1 to the F2 generation.
- Finally - Barn swallows breeding in Chernobyl experienced partial albinism and fitness loss. Their population diminished in numbers, and a decline in life expectancy was observed and an elevation of microsatellite mutation rate was found. In addition, many other species living in the wild, also experienced an observed decline in population size.

Confronted with these facts and problems, I believe, that we have an obligation, to try to answer some important questions about the possible genetic consequences of the Fukushima disaster and discuss the possible problems of resettlement in contaminated areas, which might result in radiation doses, of up to 20 mSv per year.

In the light of what we do know, I would respectfully ask the following questions:

(Slide 22)

Firstly, is it reasonable and ethical to resettle children, young, fertile, or pregnant women in such contaminated areas? Or, at all, that humans live in such contaminated area?

Secondly, are there population groups other than children, pregnant women and their fetuses, who are more sensitive to ionising radiation than the general population? If there are, how can we locate and identify such hypersensitive groups?

Finally, should Japan not respect the precept widely recognized as the precautionary principle?

As a general guideline, where there are threats of serious or irreversible damage to human life, lack of full scientific certainty should not be used to weaken ethical standards.

This raises a serious question about resettlement to areas, which might expose people, to dosages of up to 20 mSv per year.

For the long term good of humanity, I am personally convinced that this precautionary principle should be applied in Japan.

I believe that there is no better rule of thumb than that contained in the proverb "Better safe than sorry". (Slide 23)

Thank you for your attention