POSTER SESSION

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7.1 Periodic Table as a Powerful Tool for Radiation Education

放射線教育に対する周期表使用の有効性

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Abstract

The periodic tables ordinarily start with an element of atomic number 1, hydrogen. Hydrogen atoms, however, are derived from neutrons by way of β decay. Consequently, neutron should be located at a zero position of atomic number, which corresponds to the left side and above helium. A periodic table, especially with the zero position for neutron, is essential from present view of matter and serves as a powerful tool for radiation education.

要旨

周期表は原子番号１の水素から始まる。しかしながら、水素原子核（陽子）は中性子のβ崩壊によって生成される。したがって、中性子は原子番号０（陽電荷０、電子０）の位置に置かれるのが合理的である。そしてこの位置は当然水素の左側で且つヘリウムの上に対応する。このような中性子を０の位置に持つ周期表を使用すると、放射線教育、特に初心者に対する教育に極めて効果的であることが示され、物質に関する現代的知見から見ても本質的である。

なお、このような試みは、JCO における中性子臨界事故をきっかけになされたという経緯があるが、フランスでは 1946 年に武谷光男によって、それぞれ核化学および核物理学の教科書に掲載されていることが示された。

Introduction

Neutral particles in a nucleus have long remained unknown until Chadwick discovered a neutron (1932), although J.J. Thomson and Aston had suggested existence of anything neutral (1912) through recognizing light neon and heavy one by means of anode ray analysis, Rutherford and other scientists independently predicted that anything neutral (1920) should exist in the nucleus. What was a cause of the difficulty in the history of discovery of neutron ?

A neutron criticality accident happened at the Tokai facilities of JCO, a nuclear fuel maker, on Sept. 30, 1999, and was discussed in various contexts domestically, and in a severe tone, especially at abroad /1/. A background survey of the environmental neutrons has not been performed at any nuclear facilities concerning fission in the country. Neutron monitor which detected and recorded the neutrons from the JCO criticality accident was what had been equipped for fusion research facilities fairly distant from the JCO, but not for facilities of nuclear fuel treatment. Radiation education on neutron has not been made in both school and social education. In this country, textbooks of this field have been entirely unchanged these 100 years, "We have three kinds of radiations, α, β and γ rays". That is all. It is meant that description on neutron was not seen in the textbooks. From this reason, scientists in basic fields and science educationists also must be said to have been responsible

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for the neutron criticality accident through making light of fundamental aspects of radiation education and nuclear technology without revision of the old textbooks during 100 years.

Experimental (Social practice as Public Acceptance, hereafter PA, activities)

Just after the JCO accident, some lectures on properties of neutron were requested from the public in the vicinity of Rokkasho nuclear site in order to they may be become familiar with neutron and be free from anxiety on it. We, on demand, made lectures with a clear educational intention that an entire ignorance of neutron should be conquered for the public in the Peninsula Shimokita (Mutsu and Rokkasho), Chiba and Aomori. Focus is introduction of some explanation for understanding occurrence and properties of neutron. The explanation on properties of neutron was made as follows:

1) Neutrons come to the earth from the sun and stars, and are falling on us as rain or shower both day and night. This radiation which comes from the sky was called cosmic ray.
2) Secondary neutrons are derived from spallation (crashing into smaller parts) of nitrogen and oxygen atoms in the atmosphere due to the cosmic rays, spontaneous and induced fissions of uranium and transuranium elements, and neutron-producing nuclear reactions of light elements.
3) Neutron is beta-emitting nuclide with half-life of 10.6 min to decay into hydrogen, atomic number of which is one.
4) Neutron is a source matter of hydrogen in the universe.
5) Neutron should be regarded as an element with atomic number of zero.
6) Neutron is located before hydrogen in the table of isotopes as well as in the chart of nuclides.
7) Neutron should be listed up on the periodic table, and location of it should be before hydrogen, that is, left side of hydrogen, and above helium. The upper part of the left side of this newly arranged periodic table /2/ will serve for understanding as 'fusion corner'.

8) Neutron gives its kinetic energy to hydrogen in the maximum efficiency. From this reason, hydrogen-containing materials (as well as human body) serve as effective shields of neutron.
9) Neutron is neutral in charge, and is not affected by both positive and negative charges of atom, so easily goes into matter without resistance. In other words, it has a great penetrating power against matter.
10) Slow neutron easily gets close to nucleus and is caught by it. The nucleus which has caught it will act as beta-emitting nucleus in most cases. So neutron will make radioactive matter, that is, activate other matter.
11) We are not able to detect or count particles without charge such as neutron using electric or electronic devices.
12) We must convert neutron without charge to any charged particle for detecting and counting.
13) Neutron reacts with boron to give alpha particle with the highest probability. This nuclear reaction is employed for detecting and counting neutrons.
14) This same nuclear reaction is made use of protecting human body against neutrons with the highest probability as well. Boron converts neutron (with the longest range of naturally occurred radiations) into alpha particle (with the shortest range of them).

A Series of these explanations are arranged in a historical sequence and logically natural order. It will be helpful for basic understanding of dynamical aspect of atoms. It, however, does not mean that we always come to the last explanation. In one case we have stopped at the eighth explanation, and in other case we have stepped to the twelfth one. A principle for selection is faces of audiences. Faces of audiences serve as an indicator for selection of the proper steps to meet the situation.

Results

In Mutsu City, the meeting was organized by the Peninsula Shimokita Activation Society /3/. There are some fireman and head of fire department among the audience. In the accident of Tokai, the members of fire brigade were carelessly exposed to the neutrons in th criticality. So, they might have attended the meting of their own will for the purpose of understanding a radiation of neutron. The audiences in most cases understood the above-mentioned explanations, especially protection for human bodies using nuclear reaction with boron.

In Rokkasho Village, the Conference of Health Collaborators organized the meeting for understanding a shield against neutrons. They are responsible for helping medical doctors, nurses, and health nurses against the safety of the public. They wanted to understand how to protect human body against neutrons. Accordingly we proceeded to the last explanation in this case, and they learned about neutron enough. In the course of meeting, they showed a deep sympathy to the villagers of Tokai who were greatly disturbed by the accident.

In Chiba City, the members of the Society of Japanese Women Scientists organized the meeting at the Nati0nal Institute for Radiological Sciences. The targets were pupils of elementary schools, those of junior and senior high schools, and citizens containing house wives. This meeting was accompanied by a science experiment class for radiation measurements by audience themselves. Counters of alpha, beta and gamma rays were ready for measuring samples, and a course of self-made cloud chambers and measurements of environmental radiations using them were recommended. We, for the first time, mentioned the new periodic table containing zero position of atomic number for neutron. After finishing of the course of measurements, one of the middle-aged house wives came to us and told that the periodic table with zero position of atomic number for neutron was very nice for her to make clear the meaning of periodic table itself and to know relation between atoms and neutrons, and remembered her of the school days. This comment by a citizen was the most encouraging for us to employ it for explanation of understanding neutron.

In Aomori City, members of the Rotary Club organized the meetings, and members of Aoimori Science BBL /4/ organized meetings periodically twelve times during these two years. As a theme of the learning, topics of cosmic science were rather preferred to nuclear science. Universal occurrence of neutrons in the cosmos, their change into hydrogen and reverse change under gravitation in neutron stars and supernovae are reasonably understand using the periodic table containing neutron.

Discussion

1) Historical phase of the periodic table in relation with the discovery of radioactivity /Appendices 1/.

J.L. Meyer of Germany tried to classify elements using atomic weights obtained by S. Cannizzaro (1862, 1868). D.I. Mendelejeff announced his first periodic table of elements (1869). The next periodic table Mendelejeff proposed (1906) was a short period table similar as well as nowadays in use. On the other hand, Werner- Pfeiffer preferred along period table. There were some vacant positions for eka-elements that had not been discovered at that time. The word, eka, is a numeral of Sanskrit, one, and means an element that should contact in vertical direction in the table, or in a more concrete sense, an element that should locate just below in the table, because lighter elements were already known in most cases. In the case of neutron, it, however, was of a lighter case, or of the lightest case of unknown substances.

2) Possible effectivity for searching for any light particle.

When radioactive substances were discovered, they were recognized also to emit some light particles in addition to electromagnetic wave similar with X-ray, and first of all, a beta ray was recognized by Becqurel to be an electron with high velocity (1900), and an alpha ray by Rutherford to be positively charged helium with high velocity (1909). During This period /5-8/ , if any lighter material particles (apart from charge) than helium were supposed to be emitted in a phenomenon of the radioactivity and were searched consciously, a situation in relation to the discovery of neutron might have been so much different from the history. Before the discovery of neutron, a framework of human beings for observing and thinking natural phenomena was so deeply affected from negativity/positivity dualism /Appendices 2/ as a general principle that it seemed to be very difficult for human beings to think of a neutral particle, and it took much longer than thirty years for them to discover neutron after discovery electron. It may be possible for us to call a lighter particle (than helium) emitted from decay of radioactive substances or nuclear reactions as eka-helium /Appendices 3/, because it ought to exist in an atom and to compose atoms as well as helium nucleus (alpha particle).

3) Effectivity for understanding relation between neutron and matter.

In some stage of classifying various kinds of atoms, there was clear step where hydrogen was regarded as a component of atoms, because of atomic weight of each atom seemed to be integer times of that of hydrogen. This hunch was not to be entirely a mistake when neutron was not yet discovered, and was thought to rather contain implicitly possible existence of a particle with nearly equal atomic 'weight'. At this stage, the position with atomic weight of one and atomic number of one may regarded to be in degeneracy with atomic number of zero. The discovery of neutron splits the degeneracy into the different two states, neutron and proton, and the latter is written in atomic expression as hydrogen, but the former itself is neutral to be located at the zero position of atomic number.

The house wife among the audience of the meeting at Chiba City told that, though she learned atoms in the ordinary periodic table and neutron in her high school days, she was able to understand a total image of substance and relation between neutron and matter under a sweep of eyes by our explanation using the periodic table with zero position. This testimony given in the meeting for the public seemed to be very important as that from non-specialist of science, and gave us the first chance inspiring us so much that we employed with confidence the periodic table with zero position of atomic number.

4) Effectivity for understanding nuclear fusion reaction.

The upper part of the left side of the periodic table is effective for explanation of nuclear fusion reaction, which takes place from four hydrogen atoms to give one atom of helium (and two neutrinos) in the sun and stars, and from one deuterium atom and one tritium atom to gives one helium atom (and two neutrinos) and one neutron in a fusion reactor on the earth.

5) The periodic table with zero position in relation to TABLE OF ISOTOPES and CHART OF NUCLIDES.

We have various kinds of TABLE OF ISOTOPES /9/, in which the zero position of atomic number, of course, has been established for neutron. Isotopes are one-dimensionally arranged versus atomic number with internal order in mass number. If we make isotopes degenerate in mass number in the table of isotopes, and make element degenerate periodicity in the periodic table with zero position for neutron, resulting two one-dimensional series are entirely in agreement with each other. On the other hand, in various kinds of CHART OF NUCLIDES /10/ published, the zero position of atomic number for neutron is reasonably reserved rather as a starting point. Nuclides are expanded two-dimensionally versus atomic number and neutron number with equal mass line with 90 degree against a line on which atomic number is equal to neutron number. If we make the chart degenerate in neutron number, a resulting one-dimensional series as well become the same as above mentioned two one-dimensional series. The periodic table with zero position of atomic number for neutron, the table of isotopes, and the chart of nuclides, irrespective of difference in appearance, are entirely equivalent from viewpoint of a scientific recognition on matter.

Conclusions

It has been made clear through our practice in the public acceptance activities that the periodic table with zero position for neutron functions effective for radiation education to the public, especially to beginners. It promotes understanding of dynamical aspect of atoms, namely, change of radioactive elements with atomic number N (containing zero) emitting beta ray (electron) into elements adjacent to the rightside with atomic number N+1, relation between neutron and matter, for example, neutron capture (activation of matter by neutron), following decomposition (nuclear fission), and nuclear fusion reaction.

References

1. Nature, **401**, 513 , 1999.
2. M. Aratani, Forward to All-around Survey of Environmental Neutrons from Cosmic Ray Secondary Neutron Measurements, Proceedings of the Fisrst Workshop on Environmental Radioactivity, 65, KEK, Tsukuba, Japan, March 30-31, 2000.
3. M. Aratani, Safety in the National Policy for Atomic Energy , Proceedings of 11^{th} Intenational Conference of Women Engineers and Scientists, 413, Chiba, Japan, July 24-27, 1999.
4. Michiko Kudo, Tei Kamayachi, Kazuko Tsushima, Umiko Uchiumi, Michi Aratani, and Yuko Osanai, Science Education in Lifelong Education, Annual Report of the Sciety of Japanese Women Scientists, Vol. 4, 40-44, 2003.
5. M. Aratani, Messages Carried by "Life of Harriet Brooks, Mathew Effect and Women Scientists"/6-8/, KAGAKUSHI, The Journal of the Japanese Society for the History of Chemistry, 28, 2001.
6. Marelene F. Rayner-Canham and Geoffrey W. Rayner-Canham, HARRIET BROKKS, PIONEER NUCLEAR SCIENTIST, McGill-Queen's University Press, 1992.
7. S. Sasagawa and M. Aratani, LIFE OF HARRIET BROOKS, MATHEW EFFECT AND WOMEN SCIENTISTS, Tokyo, Maruzen Co. Ltd., 1998 (In Japanese).
8. M. Aratani, HARRIET BROOKS (1876-1933), A WOMAN SCIENTIST WHO OBSERVED DECAY SERIES AND RECOIL FOR THE FIRST TIME, Isotope News, No.2, 1999.
9. E.g., TABLE OF ISOTOPES, edited by C.M. Lederer and V.S. Shirley, Lawrence Berkeley Laboratory, University of California, Berkeley.
10. E.g., CHART OF THE NUCLIDE 2000, edited by Japanese Nuclear Data Committee and Nuclear Data Center, Japan Atomic Energy Research Institute, Tokai, Japan.

Appendix

Appendices1. Frôm atom to nucleus.

The word, atom, was originally introduced by ancient materialists as an ultimate particle of which the universe is composed. The word, atom means not to be divided into any parts. At beginning of the 19^{th} century this philosophical concept, however, has been changed by

Avogadro into a scientific concept that shows what is actually countable one by one. At the very short time from the end of the 19th century to the beginning of 20th century, it came to be thought that atom should have any internal structure according to a series of discoveries of X-ray, electron, radiations from uranium minerals, and polonium and radium as the first group of radioactive elements. At this stage, the definition that atom is what is not to be divided was no longer valid. Although atom has become something to be divided, it has remained yet unknown how atom should be divided. In other words, nucleus was not yet known, and consequently was not defined. It was in those days that the short period periodic table of elements was introduced by Medelejeff. Discovery of nucleus could not be earlier than recognition of alpha ray to be helium without electron (1909) by Rutherford group. And, nucleus, was ultimately discovered (1911) through experiment of alpha ray scattering with gold plate by Rutherford. Accordingly, about 10 years or more after J.J. Thomson discovered electron (1897) may be said to be a creative twilight through which the scientists roamed about a concept of nucleus /5-8/. At this stage, negativity/positivity dualism functioned still effective. At the next stage, however, the dualism did not work well, and twenty years passed till discovery of neutron (1932). Discovery of neutron may be said to liberation from the old framework of thinking like the negativity/poitivity dualism common to human beings irrespective east or west.

Appendices 2. The theory of negativity/positivity five elements (yin-yang wu xing theory) in ancient China.

Ancient Chinese philosophers developed the theory of negativity/positivity five elements. The theory is regarded to originate fro a shade/shine dualism. The terminology suggests that this theory of southern origin, because it may be possible only in the subtropical region that a shade protects living things from sunshine, and make them feel comfortable under shade of trees. In an early stage, theory of shade and shine, and theory of five elements were independently proposed, and the former was developed to more concrete negativity/positivity dualism, which combined with the latter to form one theory.

Here, five elements mean wood, fire, soil, metal, and water. The order of the five elements should be written in this way, because it has a meaning or an interpretation. Each of elements was composed from rarest gaseous material, qi. It seems to be similar to ether that was thought by ancient Greek philosophers to be the rarest and noblest element prevailing only in the universe above the moon and named the fifth elements in addition to four elements (fire, air, water, and soil) in the universe below the moon, namely on the earth. Both the qi and the ether were neutral in nature. The qi, however, later split into twi phases, negativity (yin) and positivity (yang). At this stage, wood was thought to be composed of less negativity and more positivity, fire was of positivity only (this is similar to phlogiston in alchemy), soil was of half negativity and half positivity, metal was of more negativity and less positivity, and water was of negativity only. This was a main pont of the theory of negativity/positivity five elements.

By the way, what does this order of the five elements mean? It seems to us curious logically. An ecological or historical viewpoint, however, leads us to an idea that order may be the sequence of materials or phenomena necessary for muman beings or recognized or encountered by them at early stage on the earth:

1) they lived in woods, or strictly speaking, they evolved from a higher kind of monkey in woods, found themselves to be in woods,
2) they learned or found making fire from wood,
3) they learned or found making ash as a kind of soil by burning wood,
4) they learned or found metal by digging soil, and
5) they learned or found water (lake, river, and sea) by going out of woods.

The stage 1) to 3) correspond to times of earthenware, the stage 4) corresponds to times of metalware, and the stage 5) corresponds to recognition of total environment as life-sphere.

The negativity/positivity five elements theory was applied widely for understanding and explaining the nature and the human phenomenon, and during a very long time functioned a framework of thinking. This theory was introduced to ancient Japan, and had a great influence on thinking, especially about human phenomenon here, which would be said to continue even nowadays, because you would find or the system to be alive in various kinds of antique style calendars, for example, the author is classified to be as wood in element and to be as green in color according to the year of the birth. It should be emphasized that negativity or positivity is a continuum in nature, but not a particle as well as an atom. They related to only quality of element, but not to quantity or size. From this reason the theory has not lead us to any internal structure of matter.

Appendices 3. Atomic science (scientist) and nuclear science (scientist).

The category of nuclear scientist is very new. A well-known nuclear physicist, Prof. Shin'ichiro Tomonaga, for example, told himself to be an atomic scientist, and his field of science was called atomic physics even at the times after the a world war II. At an early stage of research of this field, the word, radioactivity, was exclusively used among new sciences at the beginning of the 20th century. Nuclear science and scientists that come into existence in the latter half of the 20th century for the first time and reveal themselves suddenly in the presence of the public from the secret world of military research for development of atomic bombs in the desert of Los Alamos. Even nowadays, the word, atom, is used to the extent unreasonably expanded. Atomic bomb is a nuclear bomb in nature, and atomic energy is nuclear energy in nature. Nowadays, atomic physics or atomic science, however, is no longer nuclear physics or nuclear science. This kind of terminology might have any mental origin or basis. Apart from specialists, this kind of terminology will lead the public to ambiguity between atom and nucleus, and obscurity of scientific topics in general.

7.2 The reality of radioactive contamination in construction of Taiwan and the treatment concerned

台湾の建造物における放射能汚染の実情とその処理対策

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Abstract

It has been more than 50 years since Taiwan started the research on the peace application of radioactivity. During the first 20-30 years, it was found that the radioactive contaminated waste steel from atomic power plants was recycled together with general waste steel and was used to make other products including reinforcing bars. It was because the radiation resources ware not carefully controlled and managed. Since 1982, the radioactive contaminated reinforcing bars and buildings were gradually found, as the radiation dose rates were 5 μSv/h and 0.5 μSv/h, respectively. The radioactive nuclide was all Co-60. By August 2003, 1,626 households, 7,824 people's houses were founded to be radioactive contaminated. Furthermore, radiation dose rates higher than 5 μSv/h were measured from 264 of those householders. The government has stared to ameliorate this situation and 94.7% of the cases have become normal. The cancer death rate of these people is found to be 0.49% (89 patients in 7,824 people, 39 was dead), and it is 4 times higher than that for general people. In order to solute this pollution problem, the government has made the law to check the radioactivity of all reinforcing bars and to control and manage those radiation resources more carefully. Additionally, there are tax exemption, subsidy, and expropriation with compensation for the polluted buildings.

1．摘　要

台湾における放射能の平和利用に関する研究が開始されてからすでに半世紀が経過した。最初の20～30年間は、放射線源の管理が不十分であったため、原子力施設から回収された一般廃棄物のなかに放射能汚染された鋼鉄が混入し、再利用された可能性が示唆されている。1982年頃から放射能汚染された鋼鉄とその建造物が発見されるようになり、鋼鉄において5μSv／h、住宅建物では0.5μSv／hの放射線量率が測定された。核種は全てCo-60であった。2003年8月までに、1,626世帯、7,824人の住宅で汚染が発見され、そのうち、264世帯で5μSv/h以上の放射線量率が記録された。これらはすでに政府の協力で改善され、現在では94.7%が正常状態に回復

している。放射線を被曝した7,824人の内、89人がガンにかかり、すでに39人が死亡している。ガンによる死亡率は0.49%であり、これは一般人のガン罹患率の4倍に相当する。

政府はこの汚染問題を解決するために、1995年7月から、すべての鋼鉄に対しての放射能検査を法令で義務づけ、線源の管理と保管も厳しく規制し、また汚染住宅の税金免除や、補助金による支援、住宅の買収などの対策をおこなってきた。

2. 放射性物質の発見

1. 1982年9月　化学兵学校から、一個のCo-60 23.8Ci の線源が遺失した。
   1982年10月　放射性鉄筋が発見され、また多数のビル建造物からも放射能が検出された。鉄筋を製造した製煉所は化学兵学校から約10kmの距離。
2. 1983年3月　原子力施設から、放射能汚染された鋼鉄約30tが鉄筋の原料として回収され、再利用された。鉄筋から50μSv/h、ビルの建造物から5μSv/hの放射線量率が測定された。
3. 1985年　汚染されたビル中の歯科診療所の大気中で6.7 μSv/hの測定値を得た。

3. 調　査

1. TLD（熱蛍光線量計）を設置し、1ヶ月後に回収して、その期間の積算線量を測定する。
2. Detectorで現場測定、測定要点は：
   (1)電池のチェック
   (2)建造物から5m離れた場所の測定結果を背景値
   (3)建造物の平面図をかく
   (4)梁、柱、天井など多数の場所を測定する
   (5)壁の表面から0.5μSv/h以上、あるいは生活空間から0.4μSv/h以上の放射線量率が測定されると、この建造物は汚染されたと認定される。(Fig. 1)
3. 大規模な調査

2003年8月迄、1982ー1984年の建造物の放射能を調べることにより、1,626世帯、合わせて7,824人の住宅が汚染されていたことがわかった。その内の264世帯の住宅で5μSv/h以上の放射線量率が測定された。(Table 1)

4. ガンを引き起こす

1626世帯、7,824人の中、ガン患者が89人、すでに39人が死亡した。ガンによる死亡率は0.49%、一般人(0.11%)より4倍多い。(Table 2)

5. 考えうる放射性物質の出所
   (1) 製鋼所（廃鉄回収）
   (2) 船の解体
   (3) 原子力施設の放射性汚染鋼鉄
   (4) その他の放射線源

4．対　策

1. 鋼鉄汚染鑑定基準の設定

(1)　表面からのガンマ線量率が 0.5 μSv/h以上

(2)　バックグラウンド値の5倍以上

2. 汚染建造物の処理対策

(1992年12月16日現在)

(15μSv/h以上の住宅を対象に)

(1)　救済金(販売、居住の中止)

(2)　政府による買収

(3)　再建補助金

(4)　住宅税の全額免除

(5)　無料の健康診断

3. 民生ビルの賠償

(1) 1999年10月15日 台北地方裁判所　賠償金 38,450,000元*、上告

(2) 2002 年 3月25日 台北高等裁判所　賠償金 38,450,000元*、和解

＊1 元は約 3 円に相当

5．結　論

1.　過去20～30年以来、放射線源の管理が不十分であったために、放射能に汚染された鋼鉄が一般の廃棄物と一緒に回収、再利用された可能性が示唆されるようになった。1982年頃から放射能汚染された鋼鉄とその建造物が発見されるようになり、鉄筋では5μSv／h、住宅建造物では0.5μSv／hの放射線量率が測定された。その核種は全てCo-60であった。

2.　1982年、化学兵学校のCo-60 23.8Ciが遺失した。また、同年原子力施設から排出された汚染鋼鉄類も廃鉄として回収、再利用された可能性がある。

3.　2003年8月までに、数万世帯の住宅を調査した結果から、1,626世帯7,824人の住宅が放射能汚染されていたことが明らかになった。そのうち、5μSv/hを超えた264世帯の住宅は政府の援助を受け、すでに94.7%が正常な状態へと改善されている。

4.　7824人のうち、89人がガンに罹患し、そのうちの39人が死亡したことから、ガンによる死亡率は0.49%であり、一般人の4倍であることがわかった。

5.　汚染鋼鉄と建造物の放射線量の測定法を設定した。同時にTLD(熱蛍光線量計)の設置や放射線検出器での測定を行った。壁の表面において0.5μSv/h以上、または生活空間中で0.4μSv/h以上の放射線量率が測定されると、この建造物は汚染されたと認定される。

6.　0.5μSv/h、またはバックグランドの5倍を超える放射線量率が測定された鋼鉄を汚染物に指定する。

7.　汚染建造物の処理方法として救済金の支払い、無料健康診断、住宅買収、住宅再建補助金の支払いなどの対策がある。

8.　2004年7月29日には、1,561世帯の放射能汚染住宅の放射線量率が1mSv／h以下になったことから、これらの住宅の特別管理を終了した。しかし、現在これらの住宅の売買に関して多く

のトラブルが発生している。

6. 参考文献

1. 王玉麟 輻射汚染白皮書第一冊、第二冊 1996, 2
2. 許思明（輻射安全促進会総幹事）私信
3. 張武修 陽明大学環境衛生研究所報告 2001.4

Fig. 1 壁面での放射線量率測定

Table 1 放射能汚染された住宅建物で測定された放射線量率

Radioactive (mSv/y)	No. of households
0	391
0-1	551
1-5	391
5-15	119
>15	145
Others	29
Total	1626

Table 2 放射能汚染と発がん性に関する統計 (1992-1997)

	In radioactive contaminated Buildings	In general buildinds
No. of buildings	182	--
No. of households	1609	--
No. of persons	7824	10 万人毎
No. of cancer patients	89	--
No. of persons dying of cancer	39	110
cancer death rate	0.49%	0.11%

7.3 Teaching material for radiation education using zircon sand

ジルコンサンドの教材化

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Abstract

放射能については学校などで学ぶ機会が少ないため、「よくわからないが危険なもの。極力排除すべきもの。」という曖昧で偏ったイメージしか持っていない人が多い。そこで本研究ではごく微量のウランを含むジルコンサンドが容易に入手できることに着目し、これを用いた実験教材・実験法を開発し、その有効性を高校地学の授業の中で確認した。授業実践では、含有放射能が既知であるジルコンサンドを利用して他の岩石や土中の含有放射能を測定するとともに、ジルコンには放射性核種を長期間安定に封じ込める性質があることに着目し、原発等の放射性廃棄物の固定化法についても説明した。また、花崗岩中のウラン系列の放射能を定量する際に必要となる、^{40}K から放出されるベータ線の測定については、高校化学の授業で食品中のカリウムの測定と関連付けて授業実践を行った。

1. Introduction

Many kinds of natural radioactivity exist in our environment and most of them can be found underground in soil and water. A small amount of natural radioactivity also exists in our daily necessaries such as potassic foods, and therefore in our body, too. Some of these types of radioactivity are used in dating techniques for academic research and some are used for industries such as nuclear power generation. This means that understanding radioactivity is becoming increasingly important today.

However, many people have an emotional attitude towards the usage of radioactivity and radiation, and they often say, "Although I do not understand it so well, it must be dangerous and must be refused". This is partly because they have obtained very negative impressions from the A-bombs in Hiroshima and Nagasaki, the Chernobyl nuclear power plant disaster, and recently, the criticality accident of JCO. Furthermore, they have had almost no opportunity for practical study of radioactivity and radiation in their school classes because the handling of radioactive isotopes is restricted by law and radiation measurement equipment is too expensive for school budgets.

However, the very small amount of natural radioactivity existing in our environment is not regulated by law and this radioactivity can be quantitatively measured by a beta (/gamma) ray detector called "Hakarukun2" (Fig.1-1), which

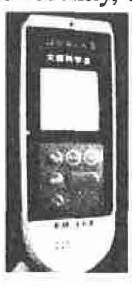


Fig.1-1 Hakarukun2

is lent to schools for free by the Ministry of Education, Culture, Sports, Science and Technology through the Institute of Radiation Measurements (IRM). In this paper, we introduce safe and inexpensive student experiments using zircon sand containing a uranium series, as well as a similar experiment using several chemicals and foods containing potassium 40.

2. Experiments using zircon sand for students

2-1 Zircon sand

Zircon is a zirconium silicate mineral with the composition of $ZrSiO_4$. It has high resistance to weathering because it is chemically and physically stable. Usually, several hundreds (or several thousands) ppm of uranium are contained in zircon as Zr^{4+} can be easily replaced with U^{4+} in the crystal structure [1-2]. Although zircon is contained in rocks, such as igneous rocks [3], it is not easy to collect a sufficient quantity for students' experiments from these sources because considerable time and complicated techniques are needed. Therefore, commercially available zircon sand was used in this work.

Two kinds of zircon sand were used in this research. One was the "Sand of Oceania" (Fig. 2-1), which is sold as a craft material at the Tokyu Hands craft materials store in Shibuya. The other one was zircon sand normally used to prevent the vibration of components of audio systems (Fig. 2-2). The former came from Bunbury in Australia and the latter from South Africa. As far as the results of XRD are concerned, these two kinds of zircon sand do not contain a high ratio of impurities because obtained peaks were in good coincidence with those of zircon and no other peaks were detected in either sample. The "Sand of Oceania" was subjected to radioactivation analysis to clarify the concentration of ^{238}U and their daughters it contained.

Fig.2-1 Sand of Oceania

Fig.2-2 Zircon Sand of South Africa

- Gamma spectroscopic analysis

87.2g of the sample was put into a film case, and gamma rays from it were measured for 72000s with the Ge semiconductor detector. The result indicated that the uranium in the "Sand of Oceania" was 1.66 Bq/g.

- Activation analysis

10mg of the sample was irradiated for one minute in thermal neutron flux ($2.57 \times 10^{13} cm^{-2} s^{-1}$) coming from PN-2 in Kyoto University Research Reactor Institute. After being irradiated for 43 minutes, the gamma rays emitted from ^{239}U were measured for 3760s with the Ge semiconductor detector, and ^{238}U contained in the "Sand of Oceania" was calculated to be 1.25 Bq/g.

Although the concentrations of ^{238}U in the "Sand of Oceania" were not rigorously coincident between the two analyzing methods, the difference itself was not so large and was unavoidable because the quantity of ^{238}U was very small and its distribution was not necessarily uniform in natural substances. In any case, the content radioactivity of the "Sand of Oceania" is between 1 and 2 Bq/g, which is far below the legal limit (74 Bq/g) in Japan. Therefore, it can be said that the "Sand of Oceania" is a suitable material for students' experiments at school.

2-2 Experimental procedures

Exp.1: Measurement of the radioactivity in ores

Since the radioactive content of the "Sand of Oceania" was identified as mentioned above, radioactivity of any sample can be determined by comparing it with the "Sand of Oceania" and considering the count rate of beta rays emitted from the same weight of samples. However, the sample must contain a uranium series and no other radioactivity, because the "Hakarukun2" cannot distinguish between beta rays emitted from a uranium series and those from other types of radioactivity.

The value of the radioactivity in the "Sand of Oceania" was treated as 1.5Bq/g based on the result of 2-1.

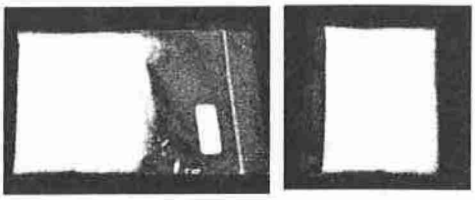


Fig.2-3 How to fold a plastic bag

- Materials and equipment

Two kinds of zircon sand (from Oceania and South Africa) and soil of Ningyoutouge (20g each), a beta survey meter "Hakarukun2", polyethylene bags (85mm × 60mm × 0.04mm)

-Methods and typical results

① Measurement of background (B.G). Put an empty bag under the measuring window of Hakarukun2 and keep measuring for 3 minutes. Then, take an average of count rates during these three minutes and assume the average to be B.G, which will be used to calculate the net count rate from the measured one in ②.

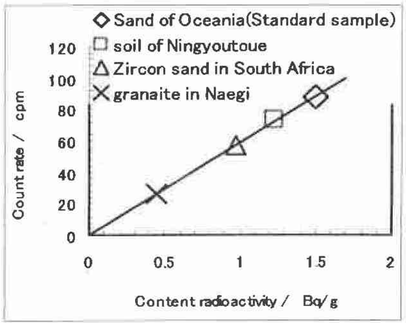


Fig.2-4 Radioactivity content of uranium series and Count rate of beta-rays

②Measurement of beta rays emitted from the standard sample (Sand of Oceania). First put the "Sand of Oceania" (20g) into a polyethylene bag and fold the bag in half as shown in Fig.2-3. Then, set this bag just under the measuring window of Hakarukun2 and keep measuring for 3 minutes to take an average. The net rate of the standard sample was 88.2cpm.

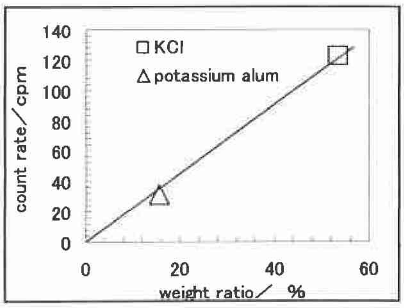


Fig.2-5 Weight rate of potassium and Count rate of beta-rays

Make a calibration curve using this value as shown in Fig.2-4, where the X-axis presents the radioactivity per 1g of the sample and the Y-axis presents the count rate of the sample.

③Measurement of beta rays emitted from zircon sand of South Africa and soil sample of Ningyoutouge. After measuring these samples in the same way as the standard sample, the concentration of radioactivity in each sample can be obtained from Fig.2-4. Since the value of the beta rays emitted from the South African sand and the Ningyoutouge soil was 57.6cpm and 72.6cpm, respectively, the radioactivity of the uranium series included in the zircon sand of South Africa was 0.98Bq/g, and that in the soil of Ningyoutouge was 1.23Bq/g.

- Applied Experiment

Measurement of radioactivity contained in granite. Although the radioactivity of a uranium series is also contained in granite, radioactivity other than a uranium series, such as potassium, is also contained. If the weight ratio of potassium is known from some database etc., the radioactivity of a uranium series can be estimated by the following procedure.

① Apply the weight ratio of potassium of granite to the calibration curve (Fig. 2-5) on which the relation between the weight ratio of potassium and the count rate of beta rays is presented. Then the count rate of the beta rays emitted from potassium can be estimated (Details of this calibration curve are described in the next chapter.)

②Put granite just under the measuring window of Hakarukun2. Then measure the beta rays emitted from granite for 3 minutes and take an average of the count rates.

③ Subtract the count rate of the beta rays emitted from potassium from the count rate of granite. This is the value of the beta rays emitted from nuclides of the uranium series in granite.

④ Apply the value calculated in ③ to the calibration curve of Fig.2-4. Then, the radioactivity of the uranium series in granite can be calculated.

- **Typical result;** results of granite from Naegi, Gifu

Since the weight ratio of potassium in this granite is 3.91% [(4)], according to the calibration curve of Fig.2-5, the beta rays emitted from ^{40}K are considered to be 8.4cpm. On the other hand, when the granite was measured, the average rate (net) was 26.1cpm. Thus, the count rate coming from the uranium series can be calculated as;

$$26.1\text{cpm} - 8.4\text{cpm} = 17.7\text{cpm} \qquad (1)$$

When this value is applied to Fig.2-4, the radioactivity of the uranium is considered to be 0.30Bq/g, which is correspondent to 25ppm. Although this value is not rigorously coincident with the value (11ppm) in the database [(4)], rigorous coincidence cannot be expected because the samples were natural, which means that the composition was not necessarily uniform in all samples, and other kinds of radioactivity, such as thorium, might be contained.

Exp.2 : Experiment to encourage thought about disposal of nuclear waste

Zircon is chemically very stable and is also resistant to weathering, as mentioned above. In addition, it has a property to enclose uranium and its daughter nuclides in crystal structures. This means zircon can be used as a model of a material to confine nuclear waste.

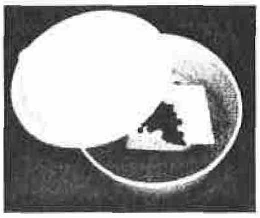


Fig.2-6 Activated charcoal with zircon sand

- **Preparation**

A beta survey meter "Hakarukun2", Zircon sand, soil of Ningyoutouge, two airtight containers (about 1100ml), activated charcoal 2g×2, and a tray for activated charcoal.

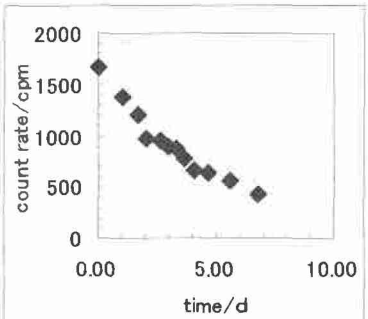


Fig.2-7 Decay of ^{222}Rn collected from soil of Ningyoutouge

- **Experiment method and example result**

① Put zircon sand in one airtight container and the soil of Ningyoutouge in the other.

② Put activated charcoal on the tray and set it on each sample carefully. Then, close the cap and leave it for one week. (See Fig.2-6)

③ After one week, take out the activated charcoal and put it in the polyethylene bag. Measure the beta rays with Hakarukun2. In our experiment the results were 1835cpm and 6.8cpm with respect to Ningyoutouge and zircon sand, respectively (See Table. 2-1.).

④ Confirm whether or not the radiation measured by ③ was emitted from ^{222}Rn.

A typical example of the results, the decrease of count rate, is shown in Fig. 2-7 and the observed half-life was close to that of ^{222}Rn (3.8 days).

Table.2-1 Results of beta-ray measurement

Sample	Beta-rays emitted from sand/soil	Beta-rays emitted from activated charcoal
Sand of Oceania	88.2 cpm	6.8 cpm
Soil of Ningyoutouge	72.6 cpm	1835 cpm

2-3 The trial lessons

2-3-1 Content of the trial lessons

We conducted trial lessons using the practical work described in 2-2 at some private senior high schools in Tokyo for 207 (4 classes of) twelfth grade students from June 7-18, 2004. The name of the subject was "Earth science 1A" and some of the cut scenes from the class are presented in Fig.2-8. The details are as follows:

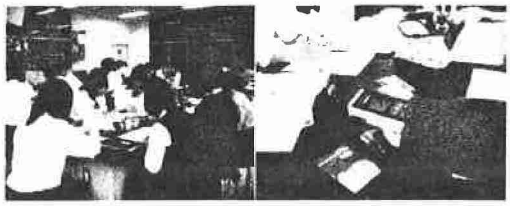


Fig.2-8 Cut scenes from the class

Table.2-2 Students' remarks in the second period

Positive comments of students
* I did not think that radiation came from seaweed. My image of it changed when I understood that it was also around us.
* Although it is considered only as a dangerous thing, if radiation is in a very small quantity, it does not seem to affect the human body.
* It was good to have an experience that was not easy. It was pleasant.
* I want to investigate how much radiation is needed to have an influence on the body.
Negative comments of students
* It was shocking that radiation comes from things we usually eat, such as seaweed.
* It turns out that there is also radiation around us. I feel this is somewhat frightening.
* Using the measuring instrument was difficult.

First Period: Basic knowledge about radiation and radioactivity (lecture)

To provide the minimum knowledge needed in subsequent experiments, we gave a lecture; the difference between radioactivity and radiation, natural radioactivity in our immediate environment (^{40}K was mentioned as the example), kinds of radiation, half-life and etc.

Second Period: Measurements of radiation emitted from familiar things (experiment using potassium 40)

Since there were many students who mentioned atomic bombs and nuclear power generation when describing their images of "radioactivity and radiation", an experiment was conducted to show that radioactivity was also contained in familiar things in the form of natural radioactivity. Several samples were prepared (potassium chloride, a potassic fertilizer, seaweed, edible brown algae, cut and dried Japanese radish etc.) , all of which contain ^{40}K. The students measured the beta rays emitted from these samples using Hakarukun2. Since they were able to recognize that potassium was contained in all the samples mentioned above, it was not difficult for them to find that radiation was emitted from potassium. The purpose of this experiment was to put emphasis on the following three points rather than just to perform simple calculations.

① To understand that radiation is also emitted from many familiar things around us.

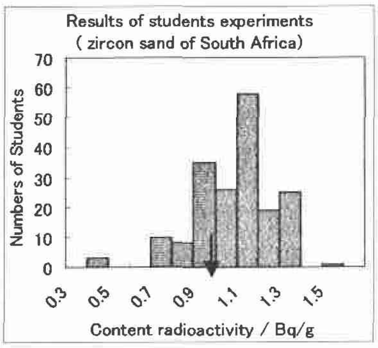
②To learn how to use Hakarukun2 (especially the memory call function etc.)

③ To understand the meaning of operational procedures, such as measuring a background

Students' comments written on their work sheets are summarized in Table.2-2. It seems that for the students who mentioned atomic bombs and nuclear power generation as their images of "radiation or radioactivity", it was a great surprise to find that radiation also comes from familiar things such as seaweed. There were some students who modified their image although there was also a student whose comments revealed that the previous "dangerous" image remained firmly fixed. Anyway, this was a lesson that aroused great surprise in students.

Table.2-3 Students' remarks about the third period

Positive comments of students
1. It turns out that radiation comes from various things.
2. I was worried about it until I investigated it, since granite is used for the walls and doors of houses, but afterwards I was reassured.
3. I mastered how to use the Hakarukun2 to measure.
4. I want to measure concrete etc.
Negative comments of students
1. Although I thought that radiation was not related to myself and had a vague image of it, I was surprised to find it in sand. It was a little frightening.
2. The usage of calibration curves was difficult.



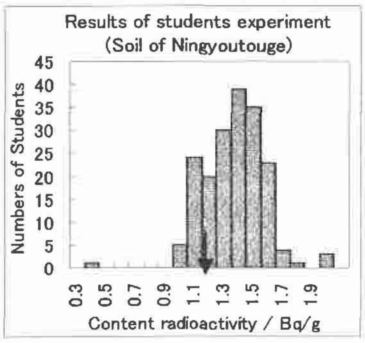


Fig.2-9 Results of students' experiments

Third Period: Measurement of the radioactivity in a uranium series (experiment)

The exp.1 and applied experiment in 2-2 were conducted. As for the applied experiment, the calibration curve and the weight ratio of potassium in the granite were given beforehand, and the students used this information to solve the problem.

The values of radioactivity which students acquired from their experiment are summarized in Fig.2-9, and comments are summarized in table 2-3. The mark ↓ in Fig 2-9 shows the correct value of the preliminary. Many students obtained the radioactivity content of each sample correctly. Since this was the first time many students had used the calibration curves, many of them were a little confused in the calculation in exp.1. However, they were able to calculate the radioactivity content with no problem after some repeated explanations from the teacher.

As for the calculation problem of the application experiment, the number of students who solved this by themselves was very small but they seemed to understand after further explanation.

Fourth Period: Summary

The exp.2 in 2-2 was demonstrated first. The students were able to identify the radioactivity on the activated charcoal as being radon, based on the decay rate (half–life) of the count rate. Then they learned how various types of radioactivity, such as uranium and potassium, were confined in granite and that heat generated by the decay of radioactive nuclides becomes a part of the geothermal energy of the earth. We also explained that it was possible to confine radioactive species such as fission products from nuclear power plants for a very long time if the confining materials were chosen properly.

After some explanation on health physics was given to students, the cloud chamber was shown to them using video teaching materials so that they could confirm visually that radiation was being emitted from radioactive substances.

3. Students Experiments Using ^{40}K

3-1 Experiments

In the applied experiment of the exp.1 in 2-2, the calibration curve between the weight ratio of potassium and the count rate of beta rays was used. This curve is easy to build using Hakarukun2 and some chemicals in which potassium content was known as presented in our previous work (Kamata, Fukagawa et al.) [5-6]. Since this building procedure is expected to be useful in senior high school chemistry classes, we tested it in two senior high schools.

3-1-1 Preparation

Instrument: "Hakarukun2", several polyethylene bags (85mm×60mm×0.04mm),

Samples (chemicals): potassium chloride, potassium alum (each sample is about 10 g)

Samples (foods, commodities): seaweed, edible brown algae, instant coffee, and potassic fertilizer.

3-1-2 The experiment method

① Measure BG as explained in the exp.1 of 2-2.

② Fold a polyethylene bag in half with the sample (10g of potassium chloride and/or potassium alum) and put it just under the measuring window of Hakarukun-2. Then, measure it for 3 minutes.

③ Subtract B.G. obtained in ① from the results of ②, plot "the count rate of the beta rays emitted from ^{40}K" to the weight ratio of potassium contained in the sample, and make a calibration curve.

④ Measure food in which potassium is contained in the same way as ②.

⑤ Subtract B.G. from the results of ④. Then, calculate the weight ratio of potassium in the food using the calibration curve of ③. Compare the result with the data in the food ingredient table[7)].

3-2 The trial lessons

3-2-1 Content of the trial lessons

We conducted trial lessons using the experiment described in 3-1 at the following two senior high schools B and C for nineteen 11th grade students on June 25, 2004 in the subject of

Chemistry I, and for forty-two 12th grade students on June 9, 12 and 13, 2004 in the Chemical Experiment Course.

Senior high school B: A standard private senior high school in Kanagawa prefecture

Senior high school C: Senior High school attached to Tokyo Gakugei University

We gave these students a questionnaire (pre-test) before the experiment in order to check their ability to recognize radiation and radioactivity. After the experiment, in order to judge whether the contents of the experiment were suitable for high school students, we gave another questionnaire (post-test)

3-2-2.The results of the questionnaire

①The results of the question "which of the following are considered to emit radiation?" are presented in Fig.3-1. Since seaweed, chemical fertilizer and alum were used in the experiment, changes in the answers before and after the experiment were very large as expected. Furthermore the right answers regarding "Your body" also increased after the experiment although we did not discuss clearly anything about radioactivity in the human body. This means that there were students who understood that ^{40}K was also taken into the body with non- radioactive potassium contained in food.

As for "air", the reason for the increase in the number of right answers might be the background radiation the students measured.

② Figure 3-2 presents the answers to the questions that examined students' concepts before and after the experiment. In all items, the number of correct answers increased after the experiments. Especially, we can see a big deference in c."Damage to health when a very small amount of 'Radioactivity' is taken in". It was thought that their recognition changed through the experimental activities such as measuring the radioactivity of seaweed they usually eat.

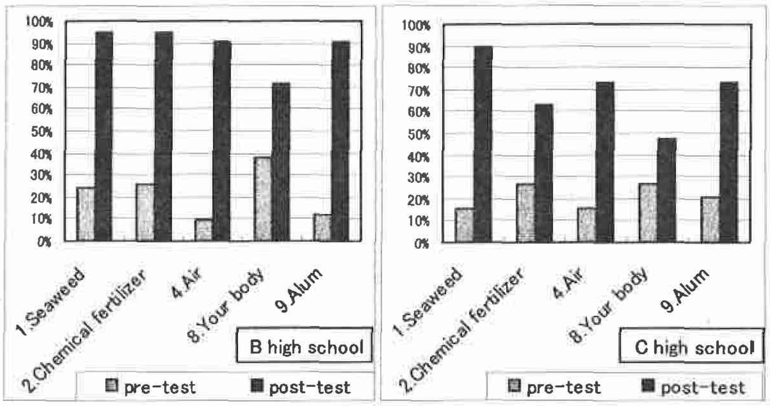


Fig3-1 What do you think emits radiation? (pre-test and post-test)

③In order to investigate the accuracy of students' measurements, the potassium ratios in the seaweed measured by students were compared as shown in Fig. 3-3. The value reported in a food ingredient table is 7.1%[7], and half the students acquired the value of 6.0 - 7.9%. From students, there were comments such as, "I did not think that a correct result would come out in such an easy method" and "I was glad that the exact value came out."

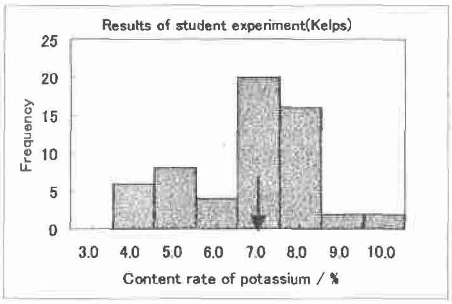


Fig.3-3 Results of students' experiments

④As for the contents of the experiment, 85% of students of both schools answered, "It was very easy" and "It was easy".

As for the question on whether students had become interested in radioactivity through this experiment, 87% of students of both schools answered, "I became very interested in it." and "I became interested in it." Although the students who answered that they wanted to learn more about radioactivity and radiation remained at 33% of the whole, many students wrote the comment "pleasant", or "easy".

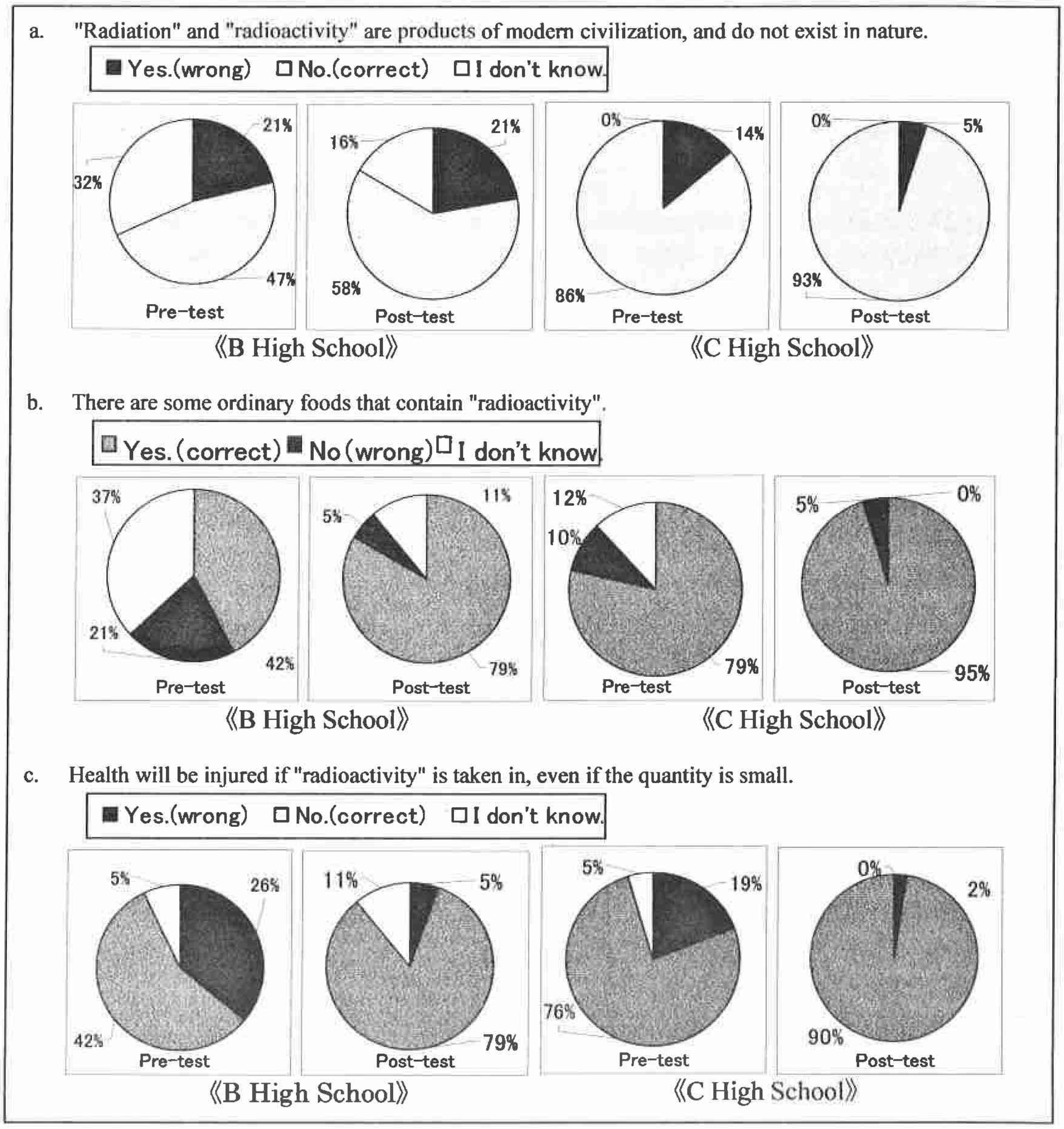


Fig3-2 Some opinions concerning radiation (pre-test and post-test)

4. Conclusion

This paper reported several experiments for radiation education that can be easily done by high school students using natural radioactivity. Practice research showed that many students obtained new knowledge and changed their understanding of radioactivity and radiation during their activity.

In practice, our experiments were confirmed to be available in classes of Chemistry and/or Earth

Science. It should be noted here that they are also expected to be useful in many places other than senior high school because they do not need any dangerous chemicals or special techniques, and can make younger students more interested in radioactivity in their environment.

[References]

1) Trocellier, P. ; Delmas, R., Nuclear Instruments and Methods in Physics Research B181 (2001)408-412
2) Lomenech, C.; Simoni, E.; Drot, R.; Ehrhardt, J.; Mielczarski J., Journal of Colloid and Interface Science 261 (2003) 221–232
3) Nakata, K.; Komuro, K., The Earth Monthly, Vol.26 (2004) 486-492
4) GSJ Geochemical Reference samples Database, http://www.aist.go.jp/RIODB/geostand/welcomej.html
5) Kamata, M.; Fukagawa, S., Chemistry and Education (in Japanese), 48 (2001) 736-737
6) Kamata, M.; Fukagawa, S., Chemistry and Education (in Japanese), 49 (2001) 582-584
7) Japan Science and Technology Agency, Food composition Database, http://food.tokyo.jst.go.jp/

7.4 THE PRINCIPLES, TERMS AND RESPONSIBILITIES CONTAINED IN THE ROMANIAN LEGISLATION RELATED TO COVERAGE OF RISK IN NUCLEAR ACTIVITIES DEVELOPED BY SOCIETATEA NATIONALA NUCLEARELCTRICA SA

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Abstract:

Societatea Nationala "NUCLEARELECTRICA" (SNN) SA, a Romanian state owned stock company, established in July 1998, following the restructuring of RENEL, the former centralized Romanian Utility is the Owner of the Cernavoda Nuclear Power Plant and has three main branches:

- "CNE Prod", operating Unit 1 Cernavoda NPP;
- "CNE Invest", including Units# 2 to 5, actually in charge with the completion of Unit 2;
- "FCN - Pitesti", the nuclear fuel factory

Cernavoda NPP project is based on technology transfer process from Canada, Italy and United States for CANDU 6 reactor type. The transfer of technology covers mainly nuclear island, secondary cycle and turbo – generator

- Romania has a well developed nuclear infrastructure
    - Heavy water plant (ROMAG)
    - Fuel fabrication facility (FCN)
    - Technically qualified CANDU experienced staff
    - Nuclear R&D program

This places Romania in an excellent position to optimize their resources and nuclear infrastructure with the construction and the operation of Cernavoda 2 and 3.

- Romania is part of Non Proliferation Treaty, Third Part Liability Convention, Nuclear Safety Convention, etc.. The Romanian nuclear regulations are in line with the European Community legislation
- In accordance with general international practices of Nuclear Operators and with the International and National specific Legislation regulating the nuclear activities in Romania, Nuclear All Risk – Material Damage and Nuclear Liability insurance policies are placed by SOCIETATEA NATIONALA NUCLEARELECTRICA to the international nuclear "pools" from February 1995.
- Regarding the environmental protection, each unit of Cernavoda NPP can accommodate spent fuel for ten years of full operation. Furthermore, Romania is developing radioactive waste management programs and adopting concepts recognized worldwide (interim dry storage, near surface repository for low and medium level waste). The final repository of the nuclear spent fuel is subject to future decision.

- Based on the experience of decommissioning of older CANDU nuclear plants, decommissioning process of Cernavoda Project have been evaluated.
- Cernavoda site complies with the requirements of international standards concerning nuclear plants
- The nuclear safety standards applicable to Cernavoda NPP Units 1&2 site construction and operation comply with all safety principles included in IAEA guideline and regulations.

A variety of public and private insurance tools may be used to transfer risk resulting from extreme weather events associated with climate change. The most prominent of these regimes have developed in connection with risks from nuclear damage, oil spills, transportation of dangerous and hazardous goods, and the pollution of watercourses through industrial accidents.
The paper will introduce how insurance tools are used within these existing regimes to transfer and share risk and losses and present the tiered compensation systems currently used in these regimes to redistribute risk. This is done to allow consideration of how similar concepts might be used to address transboundary damage resulting from climate change.
Finally, the nuclear third party liability regime in Romania shall be described and the way Societatea Nationala "Nuclearelectrica" S.A. – the key player and promoter of Romanian nuclear industry development –

Main text:

Briefing history of the Romanian Nuclear Program

The Romanian nuclear power program starts with VVER 440 implementation study and analysis in early '70s. The program took shape in '80s with site selection of **the first Romanian Nuclear Power Plant at Cernavoda**, in Dobrogea region on the right side of the Danube River, about 160 km east of Bucharest. Cernavoda NPP was designed with five units of 700 MWe each.

In December 1978 the license contract with AECL was concluded, as well as other contracts for engineering and technical assistance services, equipment and materials procurement, for the nuclear part of the Unit 1. The services, engineering and procurement contracts were extended for Unit 2, in 1981. In February 1981 was signed the contract for the conventional part of the Unit 1 and 2 (turbogenerator set, electric generator and auxiliaries) with General Electric (USA) and ANSALDO (Italy).

The construction of the Unit 1 started in 1979, under Romanian management, and in 1991 the completion was about 45%.

After 1990, this program was reconsidered and based on IAEA recommendations, RENEL signed in 1991 a Project Management Contract (PMC) with AECL - ANSALDO Consortium (AAC), stipulating that he consortium will take over the project management activities, including the completion and commissioning of Unit 1. The Consortium provided also the initial operation of the plant, and on-the-job training of the Romanian personnel. A group of Romanian specialists worked in the Project

Management Team (PMT), under the direction of the Canadian and Italian managers, in order to acquire the necessary management skills.

The Project Management Contract (PMC) between RENEL and AAC was the first significant co-operation action of western organizations and a utility of Central and Eastern Europe for the completion of a Nuclear Project. Cernavoda NPP is the sole nuclear facility in Eastern Europe effectively relying on Western technology and on internationally recognized safety criteria.

It is a general rule of international law that States have the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or to areas beyond the limits of their national jurisdiction. This rule is reaffirmed in Principle 21 of the Stockholm Declaration, and Principle 2 of the Rio Declaration. It is also repeated in the preamble to the UNFCCC.
It is a further principle of international law that every international wrongful act entails international responsibility. In the context of transboundary environmental damage, this principle has two parts: first, a State has a responsibility to take measures to prevent the occurrence of transboundary environmental harm; and second, a State has a responsibility to redress damage if transboundary harm occurs.

International liability and compensation regimes typically impose civil liability on third party private and public actors responsible for the damage caused by environmental disasters. In so doing, these civil liability regimes, which are negotiated among States, and address State-regulated industries, further Rio principles. They deter mined transboundary environmental harm from domestic industries, by creating cross border financial repercussions for economic activities that may have significant cross-border impacts.
They also serve a reparative function, by identifying or creating funding sources to compensate for transboundary damage caused by domestic industries. In this way, civil liability and compensation regimes implement the polluter-pays principle by shifting the costs of transboundary environmental harm that might otherwise be borne by society at large, through government disaster relief and collective loss, sharing mechanisms at the first instance, directly to the person or entity most responsible for the activity causing damage. If operator liability proves insufficient to ensure redress, these regimes fall back upon agreed state and global collective loss sharing arrangements to address uncompensated damage.

These civil liability regimes are instructive for addressing the role of insurance in combating climate change-related risks, because each has considered how to allocate the risk of transboundary damage among individuals, the private sector and governments, and each has employed insurance and collective loss sharing strategies to minimize the financial impact of man-made disasters, and assist in prompt response.

. Liability and compensation schemes as insurance

Liability and compensation regimes commonly channel liability for damage resulting from a dangerous activity to the entity undertaking that activity. Liability is strict –

meaning that liability is tied to the conduct of the dangerous activity giving rise to damage, rather than to the actual fault of the operator. Liability is also generally limited to a fixed amount, based on the risk posed by an operator's specific activities. In exchange for the benefit of limited liability, operators are required to secure and maintain insurance, or other forms of financial guarantees, corresponding to their liability.

The existence of agreed financial limitations on what could otherwise be unlimited liability, as well as limitations on the time within which claims may be brought, and upon the types of damage for which recovery may be had, all serve to render the economic risk from undertaking dangerous activities estimable, and therefore *insurable.* Mandatory insurance requirements then make certain that these risks are in fact insured by the operator. Above these limits, the structure of supplemental layers of compensation are agreed to address excess loss.

Insurance Related Actions

International liability and compensation regimes are themselves a form of pre-disaster risk hedging instrument, purchased by participating State governments (and their taxpayers) through international negotiations. The State's cost is the expense of negotiating a civil liability text with other State Parties, and the expense of constructing a domestic legal and institutional framework to implement the agreed international framework. In developing countries, this cost is often subsidized through financial assistance for negotiation and implementation.

With a third party liability regime in place, governments that might otherwise have been compelled to tap their own disaster funds (or resort to donor funds) to address response costs and damage for the transboundary impacts of a major oil spill, a major nuclear disaster, or the toxic contamination of a major water supply, can shift post-disaster response costs directly to a strictly liable private or public entity (or its insurer), eliminating the transactions costs involved in proving fault and collecting damages.

n some situations, governments may also be able to shift a portion of their response costs to other governments, through collective loss sharing arrangements. Where regimes create mechanisms for the handling of individual claims for compensation, resource-constrained states are relieved of a portion of this burden as well.

Participation in these regimes reduces uncertainty (risk) for States, who might otherwise be cast in the role of unwilling insurers of their own and their citizens' losses. This can occur when adequate compensation cannot be obtained from responsible parties, either because operator liabilities have caused bankruptcy, causation cannot be determined, the responsible party cannot be located, or domestic laws are inadequate to guarantee recovery. These regimes also reduce uncertainty (risk) for potential victims, by ensuring the availability of a certain minimum level of compensation, and elaborating procedures for the presentation of a defined category of claims.

Finally, these regimes reduce risk for investors in business operations engaged in high-risk activities, by defining limits of liability. This in turn helps to ensure that exposure to liability does not deter economic activities that are viewed as in the public interest, despite their associated risks.

Potential victims and States do nonetheless retain certain risks: the cost of pursuing compensation or reimbursement claims under the scheme (in effect, payment of a deductible); and the risk that damage will exceed limits of liability and not be recoverable (in effect, exceed policy coverage). However, liability and compensation regimes may further reduce these risks through the provision of supplemental cover.

Role of insurance and collective loss approaches within compensation and liability regimes

International civil liability and compensation regimes typically require the private or public operator of a dangerous or hazardous activity to maintain sufficient insurance or financial

security to cover claims up to an established liability limit. This compulsory insurance requirement ensures that a reliable amount of funding will be readily available to compensate victims in the event of a disaster.
Over the years, tiered compensation systems have evolved to provide supplemental coverage for those situations in which claims exceed the limits of the operator's limited liability and therefore the operator's compulsory insurance coverage. These tiered systems have many similarities with commercial reinsurance. They have been created where: (1) the potential damage from a particular risk is so great that it cannot be insured by the private market alone; (2) the limits of liability established in international treaties have proven to be too low (potential economic losses from accidents involving hazardous mitts operator liability cannot be easily amended; (3) a public policy decision has been made to share uncompensated losses collectively, at the state or global level; or (4) a public policy decision has been made to direct "overflow" losses to a class of actors other than operators, who are nonetheless causally linked to the creation of the regulated risk.
Not surprisingly, the most elaborate tearing systems have developed around the activities that pose the greatest threat of massive transboundary damage and consequently the spectre of the greatest potential liability and costs of redress. In these situations, tiering has served to spread the risks of damage beyond individual operators, to operator industries as a whole, to public funds and/or to international solidarity funds, much in the way that reinsurance is used to backstop insurance and in the way that governments or the World Bank backstop national insurance systems. This evolution is most readily seen in the oil spill regime, which presently uses a two-tiered system of compensation, and the nuclear damage regime, which uses a three-tiered compensation system.

The nuclear conventions create a three-tiered system of compensation. The 1960 Paris Convention, as amended by the 1963 Brussels Supplementary Convention, and the 1963 Vienna Convention, which are linked by a 1988 Joint Protocol, together address risks from the peaceful use of nuclear energy.
These regimes combine operator liability and insurance obligations in a first tier, backstopped with installation state public funds in a second tier, further backstopped by a global collective loss sharing mechanism in a third tier. This tiering recognizes that given the almost incalculable extent of possible damage from nuclear incidents, it is not possible to internalize the costs of potential damage as a risk management strategy.

At the first level, these conventions hold operators of "nuclear installations" (primarily facilities used to generate nuclear energy) strictly liable for damage resulting from nuclear incidents. State Parties are required to establish by national legislation a *minimum* operator liability of US$5 million SDRs for damage resulting from any one nuclear incident under the Vienna Convention, though States may allow for higher limits. The Paris Convention establishes a maximum limit of 15 million SDRs, though States may agree to greater or lesser amounts, though no less than US$5 million. The operator's minimum liability is to be guaranteed by insurance or another form of financial security (***operator insurance***). ***At the second level,*** if the operator's financial security is insufficient to cover the limit of liability established by the State, under the Vienna Convention the State must make up the difference, up to the operator's limit of liability. Above the established operator's limit of liability, supplementary public funds are required to be made available up to a total of *175 million SDRs* by the State Party in whose territory the nuclear installation that caused damage is located (***installation State public funds***). ***At the third level,*** if damage exceeds the 175 million SDRs provided through the second level, *a further sum of 125 million SDRs* (bringing the total available from all sources up to 300 million SDRs) is to be provided from public funds contributed jointly by all Convention Parties, on the basis of a predetermined formula, based on each Party's installed nuclear capacity and UN rate of assessment ***(international collective loss sharing).*** Under the 1963 Brussels Supplementary Convention, contributions are based 50% on the ratio between the GNP of each Party and the total of the GNPs of all Parties for the year preceding the nuclear incident, and 50% on the basis of the ratio between the thermal power of the reactors situated in the territory of each Party and the total thermal power of the reactors sited in all Parties (again emphasizing the polluter-pays principle).

As with the oil spill regime, the liability imposed under the nuclear conventions has effectively resulted in layers of insurance pools. Because the capacity for individual insurers to cover nuclear risk is limited, national insurance pools have been organized to allow a number of insurance companies to each contribute to cover a small part of the third party liability of an operator. (Vanden Borre, 2002). As a result, Dutch operators are restricted to buying third party liability insurance with the Dutch pool, Belgian operators restricted to the Belgian pool. Vanden Borre explains that pool members (i.e. insurance companies) declare each year how much coverage they are willing or able to provide, so that the capacity of the pool is equal to the contributions of its members. This allows insurers to insure a greater nuclear risk, because the amount of exposure is known. Reinsurance of nuclear risk occurs also directly among national pools, without the intervention of third parties, which minimizes the cost of reinsurance, as only a portion of costs are charged, rather than reinsurance commissions (7.5% on average, versus 30%, according to Vanden Borre). Above the operator insurance limit, excess claims are covered by installation state public funds, and then by another insurance pool, assembled with joint State funds.

It should be noted that a ***1997 Protocol to Amend the Vienna Convention***, which has been adopted but not yet ratified, sets a new possible limit of the operator's liability at not less than 300 million SDRs (approx. US$400 million). The ***1997 Convention on Supplementary Compensation***, which has yet to enter into force, offers the possibility of a global nuclear regime, because it could be ratified by countries that are not presently parties to existing nuclear treaties, including the United States. The Convention presents a new formula for contingent retrospective joint state contributions that builds upon the 1963 Brussels Supplementary Convention formula. Parties to the 1960 Paris Convention and 1963 Brussels Supplementary Convention have also negotiated new limits on liability. It is expected that when they come into force they will be the following: Operator, up to €700 million; Installation State (public funds), up to €500 million; and Joint State contributions up to 300 million, for a total of €1500 million (OECD NEA 2003). New shares have also been negotiated for the basis of joint State contributions: 65% upon installed nuclear generating capacity and 35% upon an "economy factor" based on GDP. The negotiated Protocol with new limits is expected to be ratified after parties have enacted relevant legislation (OECD NEA 2003).

Insurance and collective loss sharing tools offered by existing Conventions

As seen above, existing civil liability and compensation schemes use both pre-disaster and post-disaster insurance-related tools to redistribute risk from disasters and ensure a means for adequate compensation:

- strict operator liability (regardless of fault), with compulsory private insurance or financial security
- strict State liability with self-insurance (1972 Space Convention)

Convention on Third Party Liability in the Field of Nuclear Energy, adopted 29 July 1960, entered into force on April 1, 1968 (1960 Paris Convention), amended by the Brussels Supplementary Convention on Third Party Liability in the Field of Nuclear Energy, adopted 31 January 1963, entered into force on 4 December 1979 (1963 Brussels Supplementary Convention), and amended by the Protocols of 1964 and1982.

Vienna Convention on Civil Liability for Nuclear Damage, adopted 21 May 1963, entered into force on November 12, 1977 (1963 Vienna Convention).

1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (Vienna); adopted 21 September 1988, entered into force April 27, 1992 (1988 Joint

Protocol) 1997 Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage, adopted 12 September 1997, not yet in force.
1997 Convention on Supplementary Compensation for Nuclear Damage, adopted 12 September

1. Tritium, a problem for radiation protection

With the introduction of nuclear energy, an additional consideration outside the existing radiation protection framework has appeared i.e. the need to assess the radioecological and radiobiological impact of radionuclides of long half life existing in the environment for longer duration. Tritium, a radioactive by-product of power reactors also, is one of the such major radionuclides of concern. In fact, this radionuclide besides having longer life disperse more rapidly and represents a significant risk to the population exposed.

There is now the growing emphasis on tritium in radiation protection as the challenge of **nuclear fusion** comes nearer. From many varied reports from different laboratories, it appears that projected levels for fusion reactors may produce deleterious and detectable effects. The degree of concern over tritium problem is evidenced by a rapid increase in publications on the health implications of environmental tritium during the eighties. Keeping many such considerations in view, this monograph has been prepared which reviews the work on the behaviour of tritium in its various forms in the environment with an emphasis on the release from various sources, its world inventories and present levels, its transfer in the various compartments of ecosystems. Besides this, its metabolism in the biosystem and the possible implications of low doses of tritium in present and future generations have also been discussed. In this report the question of tritium releases and pathways to man have also been covered with the view of modelling.

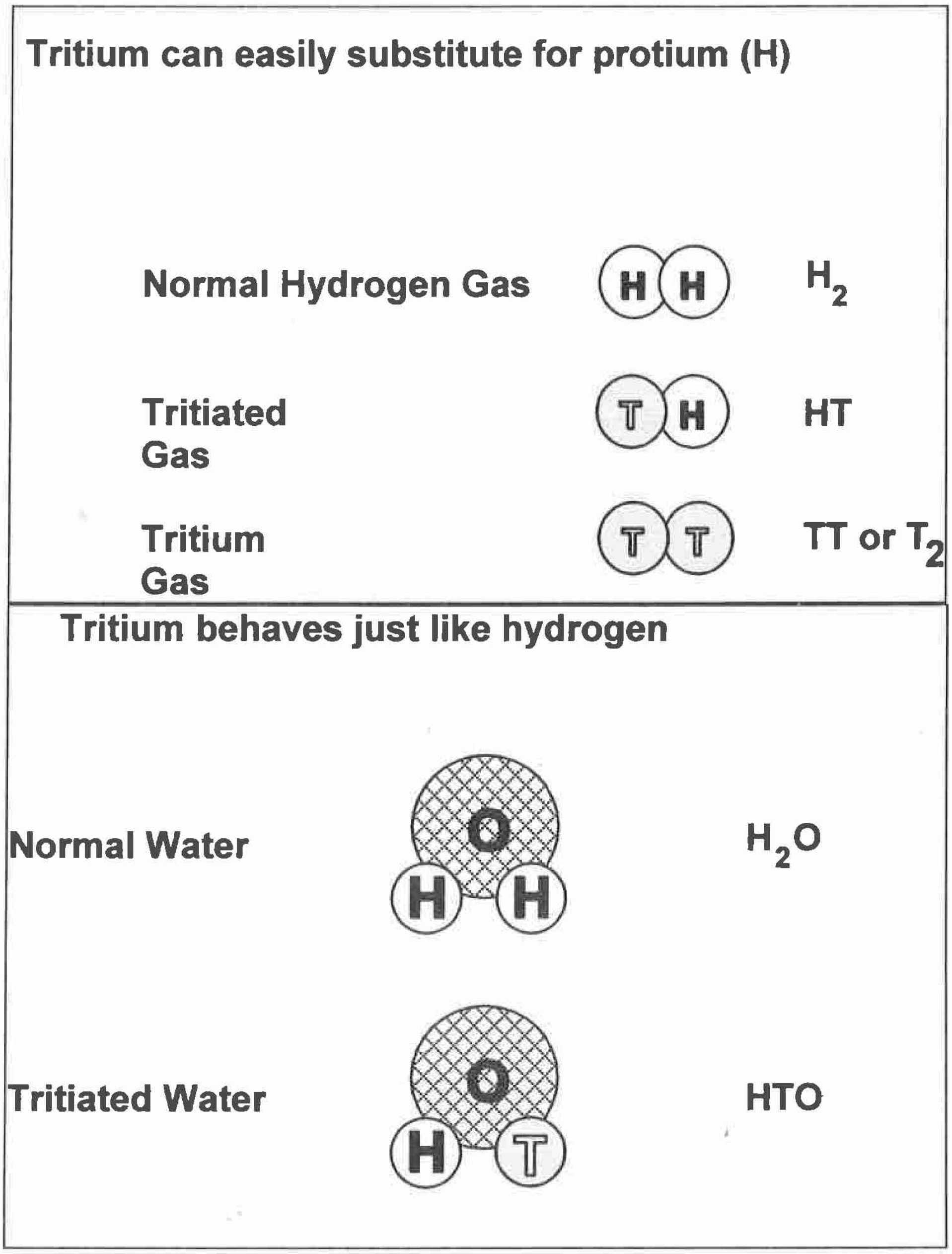
2 Properties

In order to examine the various perspectives of impacts of tritium in the environment, it is necessary to take a detailed look at a number of endpoints such as the physical characteristics of tritium, its natural and artificial sources, world inventory, distribution routes from the environment to man, metabolism, and several other related factors. This would enable one to evaluate whether or not tritium in the environment is a potential hazard, now or in the future. Besides a detailed analysis of the many papers relating to the tritium research a reference has also been made to some those papers which appear indirectly but pertinent to the specific aspects of the tritium question. Hopefully the present document will help the committees charged with the responsibilities of setting the standards permissible dose limits and determining an acceptable level of exposure from such radionuclides, particularly considering accidental situation which involves a release of large inventories of radioactivity.

3 Behaviour in the environment

The chemical form in which tritium is released determines greatly its radioecological behaviour. Tritiated water, becomes rapidly distributed in a given environment and is diluted as light water. Tritium incorporated in organic material behaves differently and may be accumulated in biological system.

3.1 Speciation of Tritium: Tritium has appeared as an occupational hazard mainly as tritiated water of high specific activity or as tritium gas. The speciation of tritium in the environment is another focal area of interest. Most tritium is released into the environment as HTO, elementary HT or, rarely and as a small fraction, tritiated methane gas. Certain liquid effluents containing tritiated compounds may constitute a peculiar risk due to their preferential incorporation by living organisms.



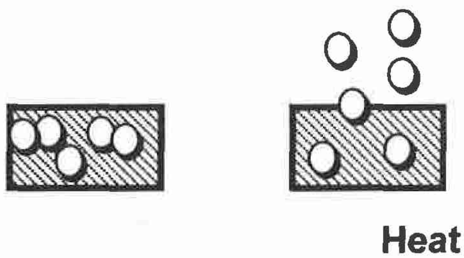
Several mechanisms intervene in the **conversion** of HTO or HT to organic tritium like exchange with organic hydrogen, metabolic reduction, photosynthesis etc. The surprisingly high T/H ratio in atmospheric methane raises questions as to its origin and its fate. At least 80% of this methane is of biological origin; it can also be a by-product of laboratory or industrial processes where tritiated organic matter is present. A particular problem in that respect may be the shallow burial of low level tritiated organic material. Tritium might initially be absorbed at sites capable of absorbing hydrogen at the surface of plants.

Tritium can form organic compounds

$$C_6H_{12} + T_2 \text{ "Benzene" } \rightarrow C_6H_{11}T + HT \text{ or}$$

$$CH_4 + T_2 \text{ "Methane" } \rightarrow CH_3T + HT$$

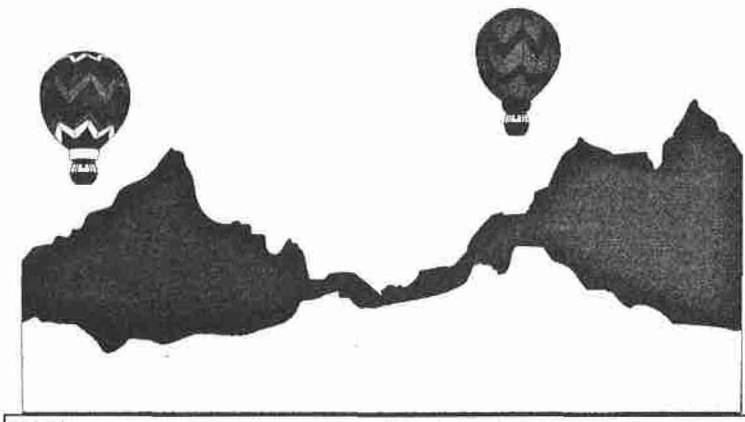
Tritium can be captured in metallic compounds called "Hydrides" and then released by heating

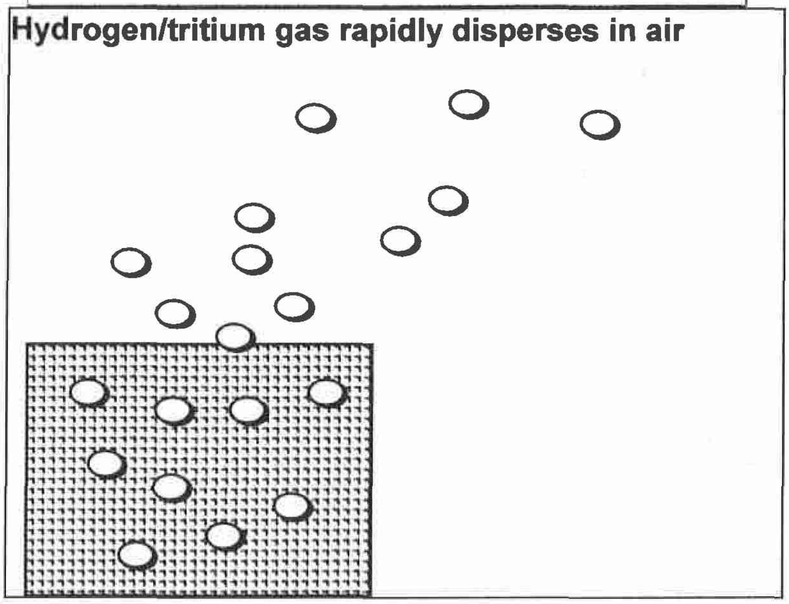


3.2 Factors affecting Metabolism : Tritium as a gas or as tritiated water can reach the body tissues of animals and man through several routes. However, the absorption time and passage time of tritium from various compounds in and through various tissues to blood depend on the various factor as studied in different animals and human, viz., basal metabolic rate of the animal, habitat, physiological status, season etc, which are yet to be investigated fully. Tritium can be absorbed in either form by way of the skin or the lungs, or it can be ingested in the form of food as organically bound tritium or as drinking water. Organically bound tritium (OBT) has the form of tritium bound to one or more constituents of food which is consumed.

3.3 Fixation: Tritium gets fixed in skin and transmitted to body fluids when intact skin is brought into contact with surfaces that have been exposed to tritiated H gas (HT or T_2). There have indications that the hazards associated with the route of tritium uptake are probably small in laboratories handling small quantities of T_2 but could be significant when large quantities are being processed, particularly during repair or maintenance of process of equipment. The significance of T_2 contaminated surfaces in terms of dose to skin and to body tissues showed that the significant uptakes of HTO and OBT could also occur from skin contact with T_2 concentrations.

Hydrogen/tritium gas is lighter than air





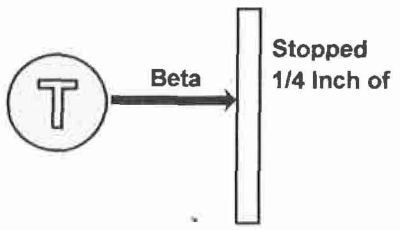
3.4 Organically bound tritium: OBT is formed in microorganisms, plants or animals; the relative contribution of these pathways to the dose to man depends on site and food habits. Considerable information on transfer of HTO and OBT to milk and meat and on that to the growing organism have been obtained. A few data are available on transfer of tritium from soil organic matter to plants showing that tritiated water as well as organic matter from tritiated organic compost is incorporated into various parts of plants. Tritium in liquid effluents released in aquatic environments can come from several sources and occur in different physico-chemical forms. Certain organic compounds may constitute a particular risk due to their preferential absorption by aquatic microorganisms. This fraction was however small (<1%) in the case of effluents from a radiochemical laboratory and for OBT of high specific activity formed in purification resins in the primary loop of PWR.

OBT could exist in exchangeable and nonexchangeable forms and the presence of minute traces of residual HTO in soil after its apparent removal may falsify the results. The need for standardising procedures for measuring

OBT should be stressed. Enrichment of tritium in organic material compared with water should be viewed with suspicion if the source of the tritium exposure and details of the exposure conditions. As an example, enrichment could be caused by discontinuous release. Thus one must verify that equilibrium conditions have been attained since enrichment may have been simulated by the different metabolic behaviour of various compartments under conditions of discontinuous exposure.

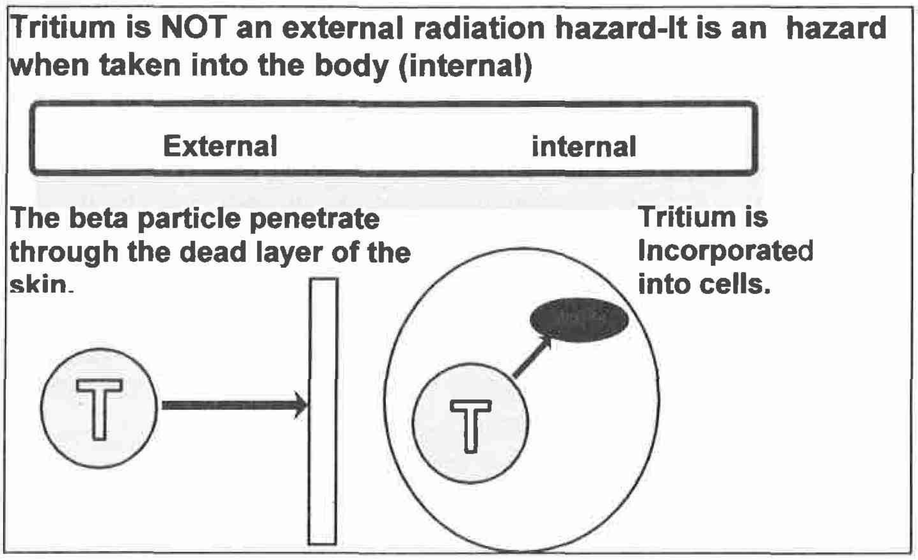
As long as OBT is exchangeable with water, its behaviour may be unpredictable and the simulation with the way tritium will behave in different metabolic pathways face difficulty. Although it is pointed out that in tissue and cell preparations, all exchangeable tritium can be removed easily. It was generally agreed that non-exchangeable tritium should be equated with OBT. The importance of reversible reactions in living organisms should also be underlined. Some studies are also necessary to determine whether catalytic oxidation of HT could occur in air.

Tritium decays by emitting a weak beta particle



Environmental tritium from atmospheric testing will be at natural levels by about 2030

The world inventory of tritium from atmospheric testing is approximately 400 million curies (approximately 41 kg).



3.5 Waste Management: The waste management of tritium needed to be addressed before undertaking a massive tritium production programme for fusion.

Tritium containment is necessary in the first few years because of its high mobility in the biosphere if buried. Most tritium waste could be adequately managed but it should be kept in mind that tritium-contaminated aqueous effluents from reprocessing plants which could not be disposed of in rivers or the sea; and the high temperature treatment processes where tritium could be released.

3.6 Modelling: A need for improved model development now mainly relates to accidental releases. Improved data on environmental behaviour are needed for the development of such models and a great with establishing a programme of reliability testing. The data available are still too fragmentary on the models which could predict distribution from source data. For the realistic models are to be realistic, their parameters need to be tested experimentally and it also demands a continuous feed-back must exist between experimentalists and modeler. Hitherto known worked out models are relatively insensitive to changing activity concentrations and accidental situations. They are more likely to overestimate dose to people, particularly if HT was present. As per Linsley's remark* in the specific activity model, to predict the consequences of atmospheric releases of tritium, the specific activity of tritiated water taken in by man has been equal to that in atmospheric water at the location of interest. However this situation is rarely achieved in practice.

3.7 Doses: Doses to the localised critical group resulting from routine releases of tritium are usually a very small fraction of the dose limit; in such situations, the conservative approach of the specific activity method is acceptable. When estimating collective doses for use in optimisation studies, a more realistic assessment is required in principle. However, these doses are generally low when considering tritium dispersion on a regional scale. Thus the specific approach may be adequate at such levels. More sophisticated models are however required to predict the consequences of accidental releases, where equilibrium conditions are not anticipated, for example after a pulsed release. Such models are needed to analyse safety aspects at the design stage and in planning the likely scale of events on an exposed population. Under these circumstances, information is required about the spatial distribution of the tritium deposit and the time dependent behaviour of the nuclide in the environment. The model must take into account factors such as the interaction between tritium in the atmosphere and soil, HT to HTO conversion, evaporation and subsequent dispersion; and finally transfer through a food chain to man and the consequences of intakes of OBT. The problem arises in testing the validity of these models against actual environmental measurements.

4 Metabolism and Radiotoxicity

Though tritium exposure in the form of HTO has been considering not very toxic, yet the metabolism of tritium in mammals and man needs a careful evaluation when all forms of tritium had to be taken into account in terms of effects. Information on elementary tritium is limited but for the other forms the incorporation into various molecules of the cell need to be looked into. For long-term effects metabolic incorporation into cellular macromolecules is most important, and prime among these is DNA and associated proteins. In fact, the short range of the tritium beta particles label in the cell nucleus is decisive for the biological effects. Tritium activity can also be very high in lipids, whereas it is relatively low in carbohydrates which mostly have a rapid turnover and thereby can release their label into tritium water.

A better information on tritium localisation inside the cell is required. The studies performed on many proliferating and renewal tissues have given some indications, but most of them have a relatively rapid turnover of its OBT and it appears that large variations in turnover of OBT can occur. A better information on turnover in different tissues and in different molecules is thus needed. It may not be enough to study molecular species such as lipids or proteins, to have a comprehensive picture, an information on specific molecules would be needed. For example, the turnover of histones differs from that of proteins in the cytoplasm and that of proteins in muscle or skin is much slower than that in liver or intestine. All this information would be quite useful to obtain better metabolic models.

For a one-generation study the course of tritium incorporation and its turnover becomes of importance , however, it is of less consequences in the case of multigenerational studies when the animals are chronically (continuously) exposed to HTO. In such a situation the maximum activity in the organism should remain constant. Organically bound hydrogen in an animal may arise from an incorporation from the hydrogen of body water during the metabolic synthesis of the compounds in tissues. Tritium content of the tissues thus indicates the extent to which hydrogen has been derived from each of the two available sources. The organically bound hydrogen pool consists of many compartments, the hydrogen of which will not usually equilibrate with each other.

4.1 RBE: A consideration on the radiosensitivity of the tissues involved and the RBE need to be looked into. The RBE seem to differ from 1 to 3 compared to X-rays. This must be better defined for radiation protection purposes. The mechanisms of action in order to judge better the RBE in different systems needs to be studied. There has been also the question whether we can extrapolate from animals to man. We can certainly do this for the same defined effect such as myeloid leukaemia but one cannot in general, extrapolate from one effect to another, for example, from the RBE of leukaemia to that of another cancer. One cannot extrapolate quantitatively from animals to man except on general principles (Streffer*).

4.2 Radiotoxicity: The toxic effects of tritium administered in various forms, especially as water and labelled thymidine have been adequately demonstrated at various levels of biological organization. The radiotoxic effects of tritium on embryos and fetuses seem consistent and apparently higher than those expected from an equivalent absorbed dose from external X- or gamma-irradiation. However, there have been a few other studies where no such difference is evident. It appears to be dependent on many factors *viz.* the organ or cellular system studied, doses and dose rates etc.

4.3 Human studies: About 20 years ago Silini et al (1973) in the *EUR 5033 e* report on radiotoxicity of tritium in mammals stated that *`the data available are of little use for public health protection because the effects measured are not of immediate practical application. For example systemic studies of the lethal action of tritium in vitro and in vivo which are probably the most significant, even on a practical level, have only been conducted fragmentarily and without practical objectives.'* Since then the situation has changed a lot and several new studies with prime aim on the dose dependent response, on human tissue has made and appeared in the literature. In this context the contribution from Japanese researchers on the *in vitro* studies on the human tissues and delayed effects studies by Brookhaven National Laboratory are worth drawing attention, besides from several fragmentary but specific reports.

4.4 Carcinogenesis: With emerging new reports the "stochastic effects", those for which the probability, rather than the severity of an effect from HTO occurring is a function of dose also can not be ruled out. Biotoxicity of tritium in the form of induction of cancer, hereditary effects, teratogenesis and life shortening really need an exhaustive investigation and warrant careful evaluation. Though the situation need not be alarming with tritium, the studies on radiation damage on various parameters have given evidence of two compartments of radiation damage; the reparable or potentially lethal and the irreparable or lethal. However, a positive trend of acclimatization to HTO-exposure is always there along with the presence of radiation-induced repair mechanism.

Several reports from the literature indicate that tritiated thymidine may be potentially carcinogenic depending on the amounts of tritium incorporated into the cell nuclei and on the time of life at which the tritium was introduced into the cells. In this context the effect of organically bound tritium needs yet to be explored which may be quite different in magnitude than those of HTO.

The aspects of carcinogenic actions of tritiated water merit careful attention in view of the data showing the incorporation of tritium from tritiated water (HTO) into DNA and other macromolecules, and the significance of nuclear fraction of tritiated water. The potential carcinogenic effects at low doses of tritium remain a controversial subject. Further studies involving the effects of tritiated water on different processes in cultured cells under controlled laboratory conditions can provide much useful basic information.

5 Future Research Needs

Four main areas of tritium research can be envisaged for a careful evaluation.

(1) the chemical form of tritium in environmental samples and their fate after interaction/dissociation from microorganisms

(2) the organically bound tritium (OBT) in the food chain and its possible biological consequences

(3) Development of specific models and their the validity and suitability to predict environmental transfer of released tritium
in an accidental situation as well in commercial use of tritium.

(4) The studies on effects at low doses and low dose rates on the validity of extrapolating not only between species but between specific strains in one species.

Gerber* rightly remarked that the need for continuing collaboration between scientists in Europe, Canada, USA and Japan should be stressed. European scientists had concentrated their efforts in ecology; the North American scientists on large scale animal experiments; and Japanese scientists on molecular and cellular studies.

*: Panel discussion: Workshop on Environmental and Human Risks of Tritium, Karlsruhe, (FRG), 17-19 Feb., 1986, Radiat. Prot. Dosim., G. Gerber, C. Myttenaere, H. Smith (eds.) vol 16, No.1-2 (1986)

7.6 Radiation education using local environment

－Educational experiment using Misasa spring water－

地域の自然を利用した放射線教育－三朝温泉の泉水を使った実験

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Abstract

我々の身の回りには、種々の天然の放射能が存在しているにもかかわらず、一般には放射線や放射能というと何か特別なもので怖いものというイメージを持っている人がほとんどである。そこで我々は、ラジウム温泉として有名な三朝温泉（鳥取県）の泉水を利用して放射線教育を行えば彼らのイメージも変わると考え、危険な薬品を使わず操作も簡単な実験法を開発してきた。本論文で紹介する実験法は、泉水中のラドン 222 を水相から気相に追い出し、これを活性炭に吸着させ、そこで生まれた娘核種を測定しようとするもので、放射化学的手法（共沈法）を用いて分離する方法に比べ、危険な試薬や取り扱いの複雑な機器が不要なため、一般教室などで実施することも可能である。なお、本論文では小学校や地域の科学教室で小中学生を対象として行った授業実践の結果についても合わせて報告する。

1.Introduction

Many people misunderstand radiation and radioactivity, believing them to be special and artificial. However, many kinds of natural radioactivity exist around us. Therefore, if we use these forms of radioactivity as teaching materials for radiation education, learners can easily understand that radiation/radioactivity exists in nature and is part of the environment in which we live. From this viewpoint, we developed several kinds of safe and inexpensive experiment for education using the natural radioactivity existing in our immediate environment, and reported them to date[1-4].

Misasa hot spring is located in Tottori prefecture and is very famous in Japan as a radioactive hot spring. Although a local festival called the "Curie Festival" is held every year in Misasa town to praise Marie Curie's great work in physics, this does not mean that many citizens are fully acquainted with (or even interested in) radiation and radioactivity. So we decided to develop a very simple experiment for elementary and junior high school students to stimulate their interest in radiation and radioactivity.

In this paper, we will report the details of the experimental procedure to observe the radioactive equilibrium between ^{222}Rn released from Misasa spring water and its daughters as well as the decay after isolation from ^{222}Rn. We will also present the practical results of our experiments held in elementary school and in an open science class conducted for children at Tottori University. It should be noted here that our experiment does not need any hazardous chemicals or Bunsen burners, which means we can put it into practice even in normal classrooms without any special facilities.

2.Experiment

Figure 1 shows the radioactivity in Misasa spring water. Since radon is the only gas in this series as shown in Fig.1, ^{222}Rn can be released from spring water into air when the spring water is mechanically stirred or heated. After that, the released ^{222}Rn can be trapped on activated charcoal and produce its daughters there. Since ^{214}Pb and ^{214}Bi emit relatively high energy beta-rays, they can be measured easily using a handy survey meter, the "Hakaru-kun II".

After radiochemical equilibrium is established on the charcoal, it is heated in a microwave for a minute to remove the ^{222}Rn it holds. Then the decay of ^{214}Pb and ^{214}Bi can be observed. The details are as follows;

	Half-life	Decay mode
^{222}Rn	3.82 d	α
⇩		
^{218}Po	3.11 m	α
⇩		
^{214}Pb	27 m	β
⇩		
^{214}Bi	19.9 m	β
⇩		
^{214}Po	164 μs	α
⇩		

Fig.1 Radioactivity contained in Misasa spring water

2-1 Apparatus to collect ^{222}Rn from Misasa spring water.

First, the nozzle of a washing bottle (500mL) is cut short as shown in Fig.2. A bag with a width of 3cm is made from a polyethylene sheet with a thickness of 0.07mm, and a partition is made as shown in Fig. 3. Then, a piece of absorbent cotton and activated charcoal (0.4g) are hot-sealed in the tube and the mouth of the bag is sealed up.

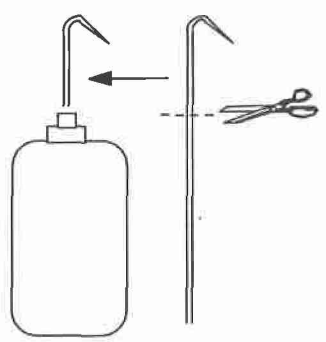


Fig.2 How to make the washing bottle

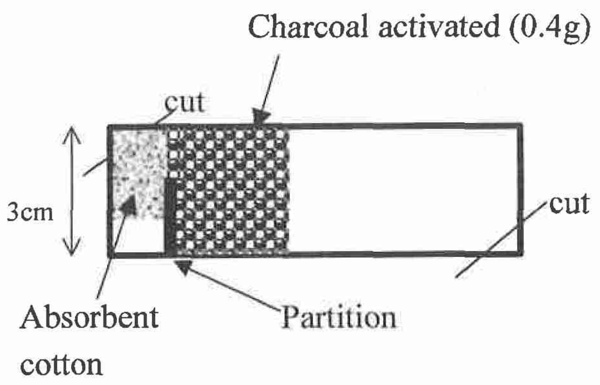


Fig.3 Package of activated charcoal to collect ^{222}Rn

2-2 Observation of radioactive equilibrium between ^{222}Rn and its daughters

As shown in Fig. 4, 400mL of Misasa spring water is put into the washing bottle and the bottle is shaken 30 times with its mouth closed so that ^{222}Rn is released into the air in the bottle. Then the air in the bottle is slowly sprayed on the activated charcoal in the polyethylene bag described above as shown in photo.1 (Two corners of the bag are cut off just before this procedure to let the air flow through it). After repeating this procedure three times, the polyethylene bag is put just under the measuring window of the beta survey meter "Hakaru-kun II", as shown in photo.2, and measurement is started.

Put 400ml of spring water in Washing bottle.

⇩

Close the mouth of a washing bottle by a palm and shake strongly 30 times.

⇩

Attach a nozzle to the washing bottle and spray the air in the bottle on activated carbon (photo.1).

repeat 3 times

⇩

Put it under HAKARU-KUN II to measure the β -ray from $^{214}Bi(+^{214}Pb)$.

Fig.4 The sequence of the educational experiment

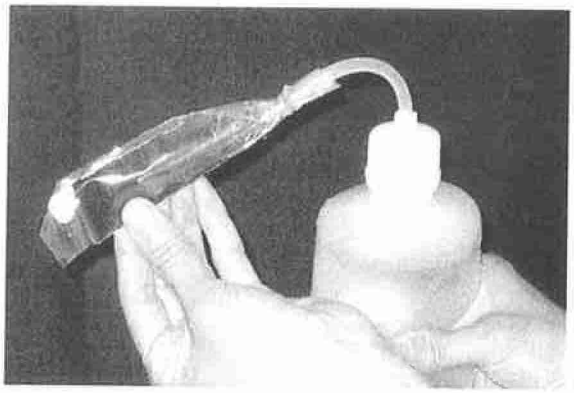


Photo.1 How to collect ^{222}Rn with activated charcoal

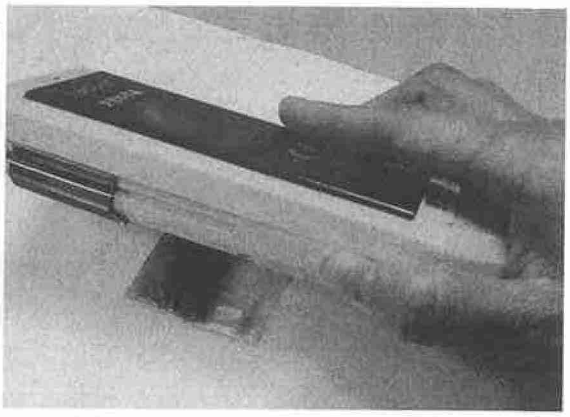


Photo.2 How to measure activated charcoal in the bag

2-3 Observation of the decay of ^{214}Pb and ^{214}Bi.

After radioactive equilibrium is established, the activated charcoal is taken out of the polyethylene tube and put in a small Pyrex dish. Then the dish is heated in a microwave (500W) for 20secs, three times. In this way ^{222}Rn on the charcoal is released into the air and its daughters such as ^{214}Pb and ^{214}Bi remain on the charcoal. The charcoal is packed in a new polyethylene bag and beta rays are measured with the same survey meter, the "Hakaru-kun II", for a few hours.

3. Typical example of experimental results.

A typical example of the results is presented in Fig 5. This presents the relation between time and the count rate of beta particles coming from ^{214}Pb and ^{214}Bi being produced on the activated charcoal.

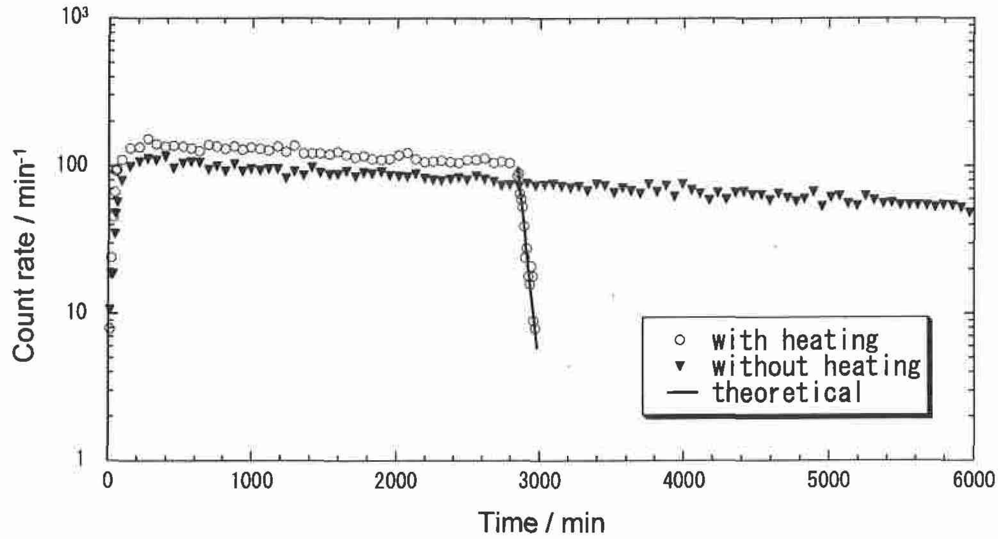


Fig.5 Typical example of experimental results

Solid symbols denote the data of the experiment without heating and the open symbols denote those with heating in a microwave oven at t=2800.

The solid line was $\varepsilon(\lambda_1 N_1 + \lambda_2 N_2)$ calculated from the following equations;

$$N_1 = N_{10}\exp(-\lambda_1 t) \quad (1)$$

$$N_2 = \{\lambda_1/(\lambda_2 - \lambda_1)\}N_{10}\{\exp(-\lambda_1 t) - \exp(-\lambda_2 t)\} + (\lambda_1/\lambda_2)N_{10}\exp(-\lambda_2 t) \quad (2)$$

where ε is the count efficiency of the beta particles coming from ^{214}Pb and ^{214}Bi.

Equations (1) and (2) were derived from the following equations;

$$dN_1/dt = \lambda_1 N_1 \quad (3)$$

$$dN_2/dt = \lambda_1 N_1 - \lambda_2 N_2 \quad (4)$$

with initial conditions as;

$$N_1 = N_{10}$$
$$\lambda_1 N_1 = \lambda_2 N_2 \quad \text{at} \quad t=0 \qquad (5),$$

where λ_1 and λ_2 denote decay constants (s^{-1}) of ^{214}Pb and ^{214}Bi, respectively.

4. Practical Research

4-1 Practice study in elementary school.

The experiment to measure beta rays coming from ^{214}Pb and ^{214}Bi as mentioned above was put into practice together with another experiment using a cloud chamber at Misasa Nishi elementary school in Misasa, Tottori Prefecture on September 19th, 2003. The experiment was conducted with forty-nine 6th grade (11 or 12 years old) students and was 90 minutes long. Since the students were scheduled to visit Hiroshima as their school excursion and had studied about the A-bomb, most of them seemed to be interested in radiation/radioactivity. The sequence of the experiment is as follows and some of the cut scenes from the class are presented in photo.3.

- Basic explanations on radiation and radioactivity. (20 minutes)
- First experiment; observation of radioactive equilibrium (cf. Fig.4). (20 minutes)
- Second experiment; observation of the tracks of alpha particles with a hand-made cloud chamber. (40 minutes)

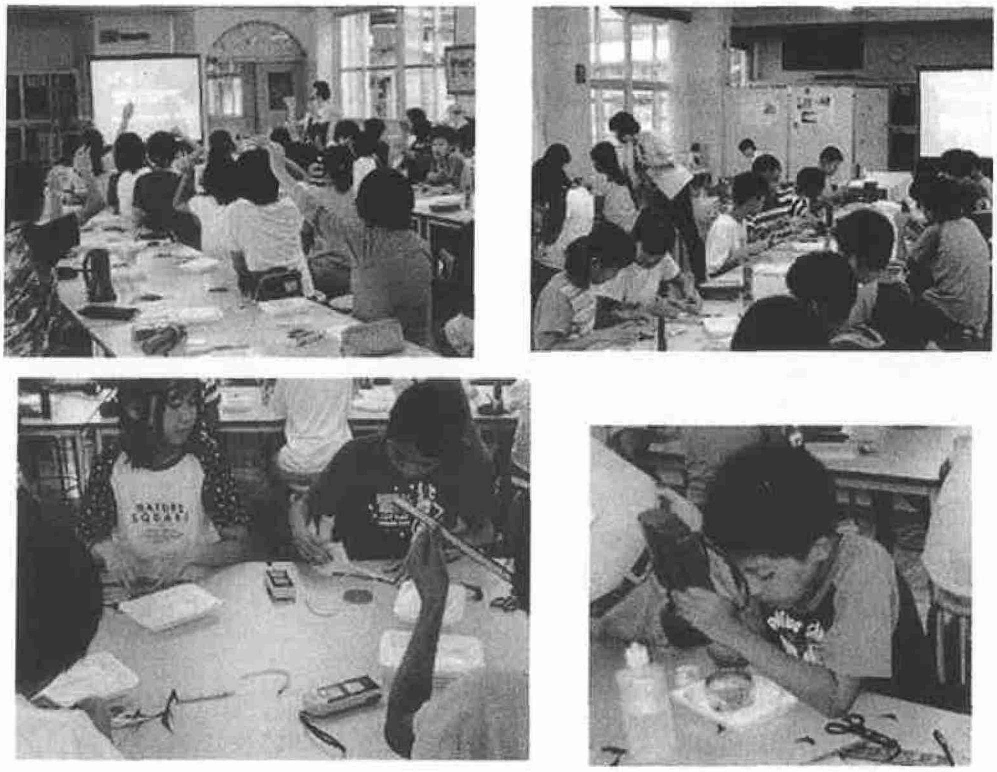


Photo.3 Cut scenes from the class

After the class, the students were asked to complete some simple questionnaires. Obtained results are presented in Fig.6.

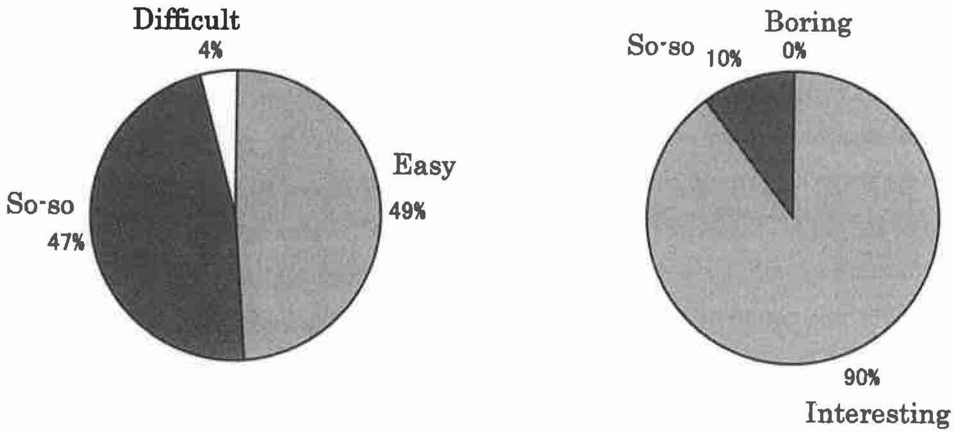


Fig.6 Results of questionnaires
(Left: Was the first experiment easy for you?
Right: Was the first experiment interesting for you?)

4-2 Practical study in science school at Tottori University.

An open science class is conducted 5 or 6 times a year for elementary school and junior high school students at Tottori University. In this class, on July 10th, 2004, we had students take part in the activity presented in 4-1 and investigated the responses from participants using a simple questionnaire paper. The participants of this class were nine students (from the 4th to 7th grade) and some of the cut scenes from the open class are presented in photo.4.

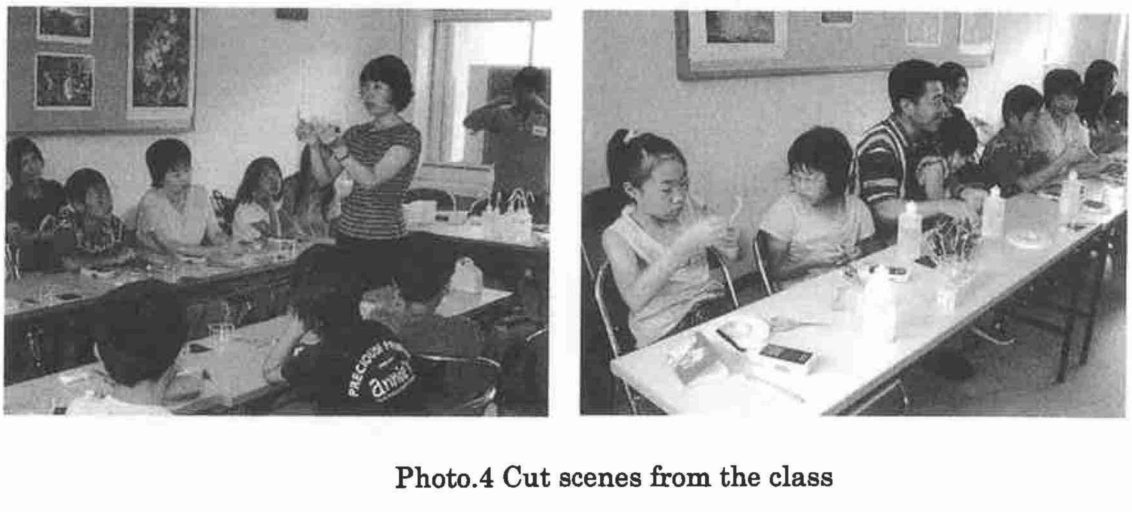
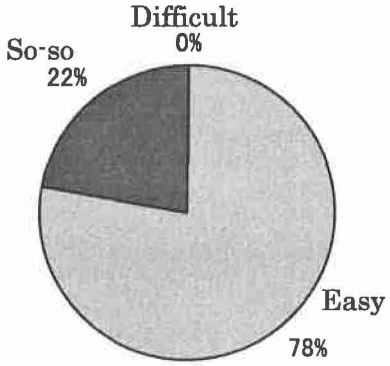


Photo.4 Cut scenes from the class

The result of the questionnaire is presented in Fig. 7. Although the number of samples was not large enough, it is probably safe to say that most students enjoyed our experiment.



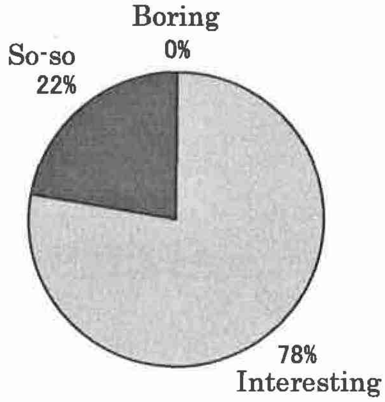


Fig.7 Results of questionnaires
(Left: Was the first experiment easy for you?
Right: Was the first experiment interesting for you?)

5.Conclusion.

Since our new experiment does not need any dangerous chemicals or complicated techniques, even elementary school students were able to conduct it without any technical difficulty.

Although there were quite a few students who experienced difficulty in understanding the theory of this educational experiment, most of them seemed to be interested in radiation/radioactivity and enjoyed measuring the radioactivity in the spring water – a substance that was familiar to them. It can be expected that this educational experiment will also be very useful for senior high school and university students because it covers many useful basics of radiation/radioactivity.

Acknowledgement

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References

1.M.Kamata, M.Nakamura and T.Esaka, "Radiochemical Experiment with Natural Radioisotope(I) Radiochemical Analysis of ^{214}Bi in Mineral Spring Water", Chemistry and Education (in Japanese), **42**, 286-291(1994).

2. M.Kamata, M.Nakamura, T.Esaka, "Educational Experiment for Students using Natural Radioactivity. I (Radiochemical Analysis of ^{214}Bi in ENA and IKEDA Mineral Spring water)", Proceedings of International Symposium on Radiation Education (ISRE 98), 238-244(1999).

3. M.Nakamura, M.Kamata, T.Esaka, "Educational Experiment for Students using Natural Radioactivity. II (Practical Example of Radiochemical Experiment Conducted at Tottori University)", Proceedings of International Symposium on Radiation Education (ISRE 98), 245-251(1999).

4.M.Nakamura, T.Esaka, "Practice of Educational Experiment for Schoolchildren to Measure Radiation Using Hot Spring Water of MISASA", Chemistry and Education (in Japanese), **48**, 538-539(2000).

7.7 Radiation studied on the Internet
— on-line radiation teaching materials –

インターネットで学ぶ放射線　－オンライン放射線教材－

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Abstract
In order to facilitate scientific understanding of radiation in Japan where social understanding has been already progressed, we developed Internet radiation teaching materials that can be utilized as off-school teaching materials or supplementary materials. The teaching materials of "atomic structure and radiation" and "medical treatment and radiation" were tried for 160 high school students and 59 junior high school students, respectively. More than 70 % of the student answered that these teaching materials were effective when they understand radiation.

1．緒言

情報社会が成熟しつつある現在、小、中および高校生には多種多様な情報がもたらされ、社会から与えられる知識量はここ 10 数年ほどで 2 倍にも達したとの報告もある。そのような中で、本来、科学的理解を基礎として、社会的理解が為されることが望ましいにもかかわらず、社会的理解のみが先行している事例が幾つか存在する。「放射線」もそのような事例の一つである。「放射線」に関しては原子爆弾や原発事故を通して、早くから社会的理解は深められているものの、その科学的理解は高等学校の理科総合あるいは物理の履修を待たねばならない。本研究では、時間軸ならびに視野、視座（視点）を定めることを要点とし、既に社会的理解が進んでいる放射線関連事例を科学的理解につなぐインターネット教材、特に、オフスクール教材あるいは副教材となりうる教材の開発を行なうことを目的とした。また、本教材の開発においては、社会的・科学的情報の獲得方法を身に付ける力ならびに科学的事実に基づいて討議する力を併せて培えるよう心掛けた（図 1）。

なお、本教材の作成にあたっては、合理的な思考だけでなく、国民の社会的認識としての安心、平和、そして原子爆弾による国民の痛みを認め、互いに思いやる心を作成基準とした。

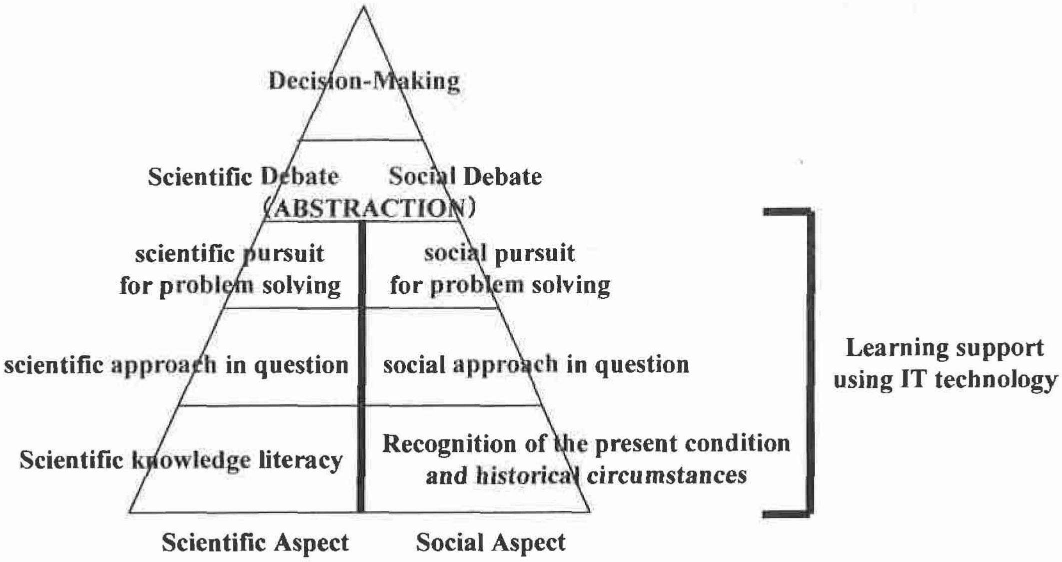

Figure 1. The scientific aspect and the social aspect of radiation education

２．事前調査

放射線教育の前提として、現行学習指導要領における放射線・原子力の扱いに関して調査を行い、更に、教育現場における放射線教育の実際および教諭が放射線・原子力に関して、望ましいと考える学習内容の調査を、62 名の小・中・高等学校教諭と集団あるいは個人討論を行なうことによって調査した。その結果、現在、各課程において学習されている放射線・原子力関連の事項と、教諭が望む事項（付けたい力）は以下のように整理された。

【小学校】

学年	現行の取扱内容			望まれる学習内容（付けたい力）
	理科	社会	その他	
６年	環境汚染		放射線の利用	環境汚染，酸性雨，ｵｿﾞﾝ層の破壊，ｼﾞｬｶﾞｲﾓの発芽抑制，殺菌，X 線撮影，原子炉，発電にかかるｺｽﾄ，熱機関，電池，資源ｴﾈﾙｷﾞｰ，温度と熱運動
５年	資源とｴﾈﾙｷﾞｰ	原子力発電		

【中学校】

学年	現行の取扱内容			望まれる学習内容（付けたい力）
	理科	公民	その他	
３年	原子の構造	核燃料	放射線と放射能	地球温暖化，京都議定書，CO_2 と温室効果，自然ｴﾈﾙｷﾞ／風力発電，太陽電池，ﾄﾚｰｻｰ，年代測定，厚さ測定，非破壊検査，核実験，核拡散防止条約，体外被ばく・体内被ばく，ﾗｼﾞｵ

２年		原子力施設の事故	放射線の利用	ｱｲｿﾄｰﾌﾟ（放射性同位元素），α崩壊，β崩壊，基底状態・励起状態，崩壊曲線と半減期（GM計数管），核分裂，核力，結合ｴﾈﾙｷﾞｰ，質量欠損，JCO臨界事故，もんじゅ２次系ﾅﾄﾘｳﾑ漏洩事故，高速増殖炉，被ばく線量，ｼｰﾍﾞﾙﾄ

【高等学校】

学年	現行の取扱内容					望まれる学習内容（付けたい力）
	物理	化学	地理・歴史	公民	工業	
３年	原子と原子核		核実験	核実験	厚さの測定、非破壊検査	原子核・電子，陽子・中性子，がん治療，害虫駆除，核燃料，ﾌﾟﾙｻｰﾏﾙ，核廃棄物（使用済み核燃料・高ﾚﾍﾞﾙ廃棄物），ﾊﾞｯｸｸﾞﾗｳﾝﾄﾞ，放射線／放射能，紫外線・X線・γ線，透過力，電離作用，霧箱，ﾁｪﾙﾉﾌﾞｲﾘ事故，ｽﾘｰﾏｲﾙ島事故
２年	運動とｴﾈﾙｷﾞｰ		自然とｴﾈﾙｷﾞｰ	原子力関連の事故	ﾄﾚｰｻｰ	
１年	理科総合A	理科総合B		地球温暖化		
	核分裂、結合ｴﾈﾙｷﾞｰ、ﾗｼﾞｵｱｲｿﾄｰﾌﾟ（RI）	人間の活動と地球環境の変化				

３．教材内容

上記３の事前調査において、各課程において付けたい力（学習目標）としての放射線・原子力関連学習内容を検討した結果、小学校・中学校では、「環境問題と原子力」あるいは「医療と放射線」、そして高等学校では、「原子構造と放射線」という結びつきで学習を展開することが最も望まれていることが明らかとなった。よって、本研究においては、小学生向け教材として、総合学習等の時間に担当教諭が、学習教材の一つとして利用できるように、単体コンテンツの集合体としてまとめた「環境問題と原子力」（現在、製作中）、中学生向け教材として、中学生個人が教養学習として使用できるように、また、その学習対象者を広く一般に拡げることが可能な生涯学習型教材「医療と放射線」、そして、高校生向け教材として、物理学履修者を対象に、個人でも集団でも用いることができる副教材「原子核と放射線」を開発した。なお、「医療と放射線」の場合には、「放射線、医療、病変部位探索、ＣＴ」をキーワードとして、「原子核と放射線」の場合には、「原子構造、崩壊、半減期、確率」をキーワードとして作成した。

教育課程	教材テーマ	想定履修対象
高等学校	原子核と放射線	物理学履修者全般（副教材的取扱）
中学校	医療と放射線	個人の教養知識（生涯教育教材）
小学校	環境問題と原子力	総合学習教材

教材内容は、「医療と放射線」では、原子の構造などを含む放射線放出機序をぶら下がりコ

ンテンツとし、興味の有無によって学習できるように工夫されており、最も単純なスクロールでは、放射線の性質や作用などを省略して、放射線の医療における利用と今後の展開についてのみ学習可能とした。更に、図２のように放射線医療診断機材を用いて作製したビデオ教材を多用することによって、インターネット独自の動的視覚に訴える学習支援を試行した。また、「原子核と放射線」では、物理学履修者が対象であることから、当初より、原子の構造は既知として、放射線の種類、性質、放射線の単位、放射線の作用、放射線の利用、そして、放射線を利用して確かめることができる一般的な物理学定理などを理解できるように工夫した。特に、インターネットにおける学習の特性を生かすため、Java Scriptを使用した教材を揃えて、学習者が能動的に学習参加できるように工夫した。図３は、Java Script で作製した物理学的半減期学習の試行画面である。

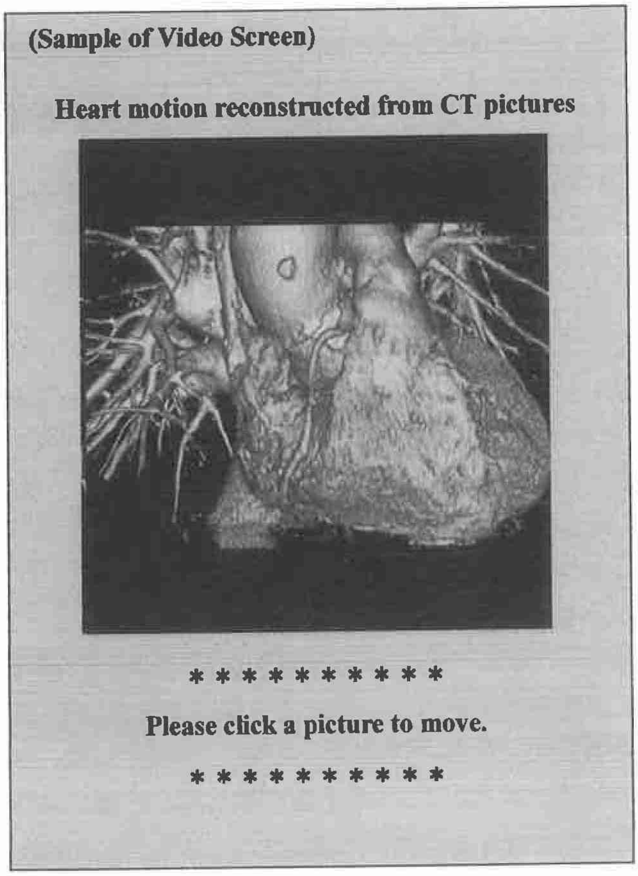

Figure 2. On-line Teaching Materials "Medical Treatment and Radiation"

This teaching materials are devised so that students can simply study the radiations applied in medical treatment by explaining the difficult terms including atomic structure, the characteristics of radiation, biological action mechanism, etc. as hanging contents. This composition enables study united with a student's skill level.Furthermore, the learning support original with the Internet study is performed by using abundantly the video teaching materials produced by the radiation medical equipments as follows.

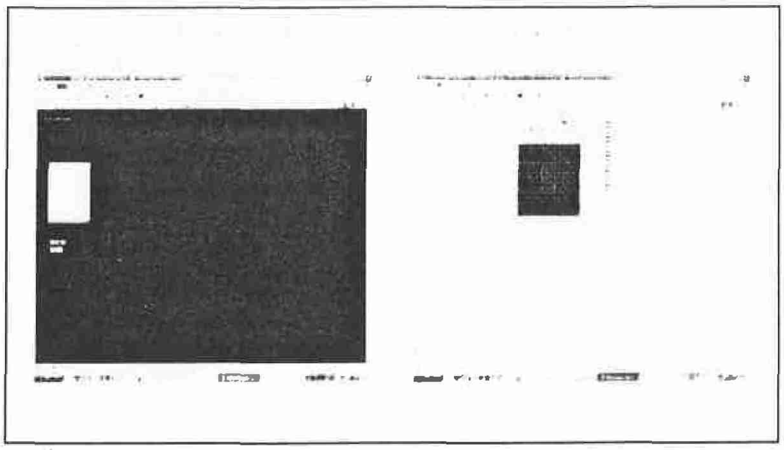

Figure 3. On-line Teaching Materials "Nucleus and Radiation"

Since the physics completion persons understand the atomic structure, in the teaching materials, we devise so that students can understand the kind of radiation, character, the unit of radiation, the action of radiation, use of radiation, and the general physics theorem that can be confirmed using radiation through a stage.
Especially, in order to employ the characteristic of the study using the Internet, the teaching materials which used Java Script were prepared, and it devised so that the study participation of the student could be carried out actively.
Following screens are trial screens of the physical half-life produced by Java Script.

４．教材評価ならびにその効果

上記試作教材に関して、高大連携学習として高校生 160 名に、そして、オフスクール学習として、夏休みに、中学生 59 名を募って、オンライン放射線教材を利用した授業を行ない、教材評価を試みた [1-3]。その結果、学習後のアンケート調査では、放射線を理解する上で、オンライン放射線教材が大いに役に立った、あるいは役に立ったと感じた生徒は、70％以上にも上り、役に立たなかったと感じた 11％の生徒よりも圧倒的に多かった（図４）。また、オフスクール学習として開催した放射線教育活動に参加した中学生５９名に関しては、学習後のアンケートに保護者からも回答いただいた。その結果、91.5％の参加者が、家庭に帰って、保護者に対して、放射線について話をしたと回答しており、一般に放射線に関する関心は高く、理解し易い放射線教育教材は、世代を超えた拡がりを持つ可能性がある。

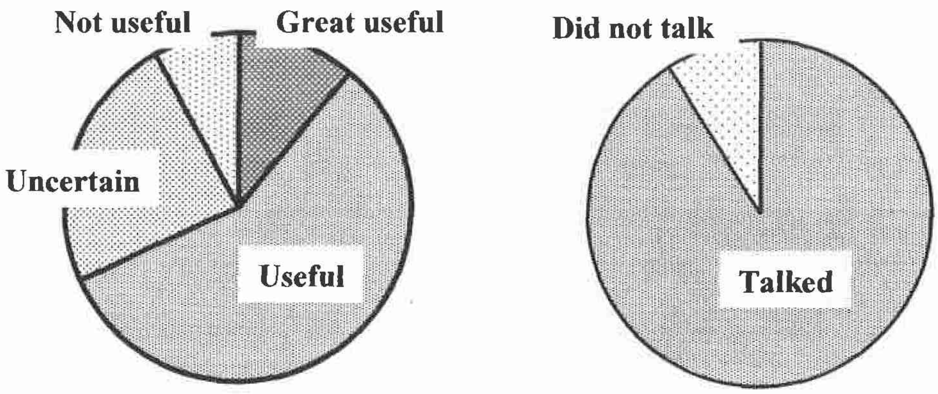

Figure 4. The questionnaire after self-study with on-line teaching-materials

(Objects: 219 persons of junior high school and high school students)

Were these teaching materials helpful when you understood radiation?

５．考察

オンライン放射線教材の活用によって、従来にはない教育形態を提供することが可能となる。その教育の特徴を以下にまとめる。

（１） 教科・科目を超えた問題提示型学習活動の支援
（２） 個人あるいは少人数単位で学べる学習環境の創造
（３） タブーを作らない学習項目の提示
（４） ディベート機会の創造
（５） 価値対立的な問題に対する合意形成能力の育成

１に関しては、現在、試行されている総合的な学習の時間と対応するものであり、オンライン放射線教材が、オンスクールにて利用されうる土壌となる。実際に、数は少ないが、小学校・中学校において放射線・原子力を取り上げておられる先生方は総合的な学習の時間を利用されており、本教材の今後の改訂にあたっては、これらの先生方の意見を十分に吸い上げることが重要となる。２に関しては、オフスクールの場としてのインターネット学習環境を本教材は創造し得る。価値観が多様化し、学校教育における授業時間数が減少している現在、オフスクールの果たす役割は今後とも大きなものとなり得る。また、生涯学習の意味からも活用が期待される。３に関しては、オンライン放射線教材は学校教育における指導要領を超えた内容について教材を提示できる。指導要領にないから、あるいは価値対立的なテーマであるからという理由で、学習対象となりえなかった放射線・原子力に関して科学的な知識を導く、一助となり得る。４に関しては、インターネットを利用した学習教材の利点である。空間的あるいは時間的に隔たりのある者同士が、同一教材を用いて学習した内容について意見を述べ合うことが可能である。ただ、実際には、インターネットを利用した討論では匿名性も手伝って、制御が効かない場合が多い。従って、経験的に、実際の学習においては、指導者が指揮・監督可能な閉鎖討議系において利用することを推奨する。我々は、これまで、40 人学級における掲示板機能によるディベートを試み

たが、それまで面接型ディベートでは 10 人程度が限度であったものを、40 人にまで拡大することができるようになった。さらに、将来的には、WiKi を利用した討議形態も研究を重ねていく予定である。５に関しては、オンライン放射線教材が科学的知識を基盤にして構成されていることから、価値を科学的事実に立脚して、評価・検討できる能力を育成し得る。

以上のように、オンライン放射線教材は、IT 環境の整備、あるいは学習フォローアップの問題など、克服すべき課題を有するものの、従来型の学校教育を支援し、また、オフスクール学習の場を提供する可能性を持つ新しい放射線教育ツールとなり得る。

６．謝辞

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７．参考文献

1) 井上浩義,　甲斐原梢；中学生を対象とした科学技術体験活動「放射線を知っていますか？」. Isotope News 5, 16-18, 2002.
2) 井上浩義；科学技術体験活動「放射線を知っていますか？」. Isotope News 12, 14-17, 2003.
3) 井上浩義；“放射線を知っていますか？”商標登録第 4766054 号, 指定商品又は指定役務並びに商品及び役務の区分：第 16 類（印刷物, 放射線に関する印刷物）および第 41 類（知識の教授, セミナーの企画・運営又は開催, 電子出版物の提供など）

7.8 Education Effects on Awareness of Irradiated Food in Japan

放射線照射食品認知における教育効果

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要旨
日本における放射線照射食品の認知に関して、次世代の消費中心となる理系学部に通う大学生597名にアンケート調査した。その結果、対象者の35.1%が放射線照射食品を受容したが、その受容は、放射線に関する教育を受けた者、あるいは過去に放射線照射食品について情報を得ていた者は、そうでない者に比して有意に高い割合を示した（$P<0.01$）。このことから、放射線照射食品の認知には、教育が重要であることが明らかとなった。

Introduction

It has been said that food irradiation was an emerging technology with many consumer advantages including reduction of disease caused from organisms, safe transport of produce from insect quarantine areas, partial replacement of less safe chemical fumigants, extended food shelf life, and potential to ease world hunger through reduction of spoilage and waste[1,2]. One important requirement, however, for successful adoption of this technology is consumer acceptance. In many researches for the irradiated food, it was reported that consumers were not likely to demand food irradiation because of the distrust of anything even remotely related to nuclear energy[3].

In Japan, the application of irradiation to food has been investigated about the nutrition, chronic toxicology, genetic influence, etc. under supporting by Atomic Energy Commission from 1967. The irradiation only toward potato under specified conditions has been approved by the Ministry of Agriculture, Forestry and Fisheries (MAFF). The consumers in Japan, where has received the atomic bombs, trend to be oversubtle and be in awe of "radiation" and the applications thereof. On the other hand, a lot of researchers have found a need for consumer education, which includes the elementary information of the radiation, to arouse the concern toward food irradiation[4,5].

In this study, the importance of the knowledge of radiation to understand the irradiated food was investigated in Japanese young students.

Subjects and Methods

The response to the food irradiation for young students, which will born new consumer generation in future, has been studied in July to August 2003. Students aged 20±2.7 years who attended four colleges in Japan were included in this study. The subjects major in the medical, the engineering, or the environmental science in each college. The questionnaire was administered to total sample of 597 persons, of whom 281 were male and 316 were female (Table 1). 49.4 % of subjects have completed both the physics and the chemistry in school and the remainders have done the chemistry, the physics, and biology in greater order.

Table 1. Subject Characteristics

	Male	Female	Total
Subject Number	281	316	597
Age	21±2.4	20±1.4	20±2.7

A questionnaire concerning the education of the radiation and the acceptance of irradiated food was administered in unregistered and non-interviewed form. The question relating to the education of the radiation was divided into three parts and included the following inquiries: what have you completed in science course?, Have you ever learned the radiation?, and Do you think which the radiation is artificially produced, exists in nature, or is the two? The last inquiry was instituted to confirm the accuracy of the knowledge to the radiation. The question relating to the acceptance of irradiation food was divided into four parts and included the following inquiries: Have you ever heard of food irradiation?, Are irradiated foods contaminated by radionuclides?, Do you think the irradiated food should be manifested of the treatment with the radiation in store?, and Which will you purchase the normal food, the irradiated food, or decide either of them by considering the food price? In last question, irradiation benefits were previously presented.

The significance of responses was analyzed by cross tabulation (SPSS). Values of $P<0.05$ were considered significant.

Results

Table 2 shows the summary of basic acquaintances with the radiation and the acceptance of food irradiation in this study. The responder, which could ratify that they have learned the radiation, were relatively fewer, 41.3 %, and there was not the difference between responders in male and those in female. Nevertheless of such a result, 76.1 % of subjects had a correct information for the radiation. Young student awareness of irradiated food was 24.8 %, who answered that they have ever heard the food treated with radiation. This awareness for the subjects who have learned the radiation trended to be more than that for subjects which have not been learned or were uncertain of the education for the radiation as shown in Figure 1. With regard to the food contaminated by radionuclides when irradiated, 85.3% of young students could not distinguish apparently it from irradiated food.

Table 2. Perception toward the radiation and food irradiation

Inquiries		Total Responses (%)	Sex (%)	
			Male (n=278)	Female (n=258)
1) Have you ever learned the radiation?	Yes	41.3	45.7	36.6
	No	31.3	25.9	37.2
	Uncertain	27.3	28.4	26.2
2) Do you think which the radiation is artificially produced, exists in nature ,or is the two?	Artificial	10.6	11.2	9.9
	Natural	13.3	12.4	14.3
	The two	76.1	76.4	75.9
3) Have you ever heard of food irradiation?	Yes	24.8	25.7	23.7
	No	75.2	74.2	76.4
4) Are irradiated foods contaminated by radionuclides?	Yes	39.0	38.5	39.5
	No	14.7	22.7	6.2
	Uncertain	46.3	38.8	54.3*
5) Should it be manifested in store about that the irradiated foods were treated with the radiation?	Yes	84.0	84.2	83.7
	No	7.5	6.5	8.5
	No Concern	8.5	9.3	7.8
6) Which will you purchase the normal food or the irradiated food?	Irradiated	3.7	4.3	3.1
	Normal	62.7	61.2	64.3
	Consideration of price	33.6	34.5	32.6

* $P < 0.05$ vs. another sex

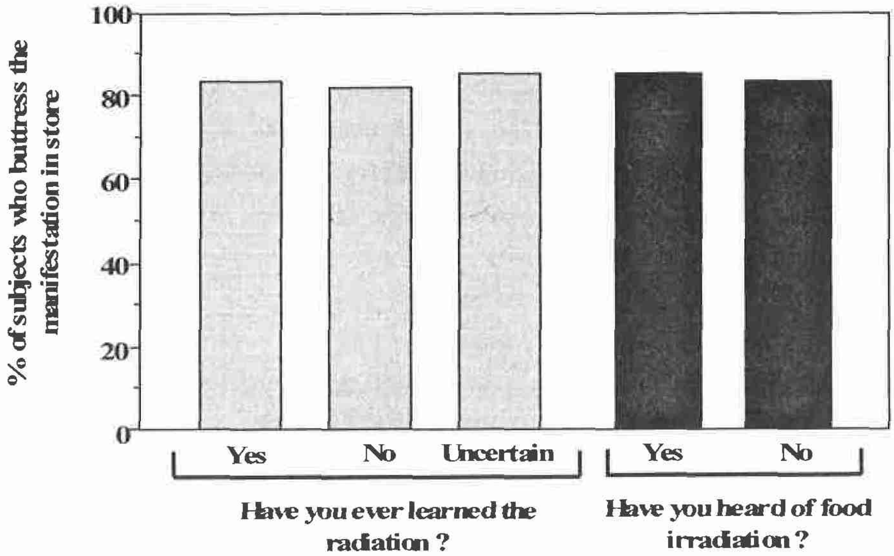

Figure 1. Rate of subjects who answered that they think that the irradiated food should be manifested of the treatment with the radiation in store in 'Yes', 'No', or 'Uncertain' group responded to the learning question and in 'Yes' or 'No' group responded to the knowledge question

The manifestation, which indicates that the food sold in store was treated with the ionizing radiation, is required by the majority of young students (84.0%). This requirement was widely recommended not relating to sex, learning, and knowledge of the irradiation food (Table 2 and Figure 1).

On purchasing irradiated foods, which was introduced to be authorized for human consumption by the government and World Health Organization, though the information of the irradiation benefits, sterilization and conservation, was presented prior to this question, minority of responders, 3.7%, convincely indicated they would buy irradiated produce. The acceptors in a broad sense, however, may involve the subjects that they would decide either the non-irradiated or the irradiated food by considering the price in store. Therefore, 37.3% of subjects might be regarded as persons who understood the irradiated food. In such a treatment, the irradiated food could be accepted by the subjects who have ever learned the radiation and have known the irradiated food significantly more than those who have not learned and have not known ($P<0.01$), respectively, as shown in Figure 2.

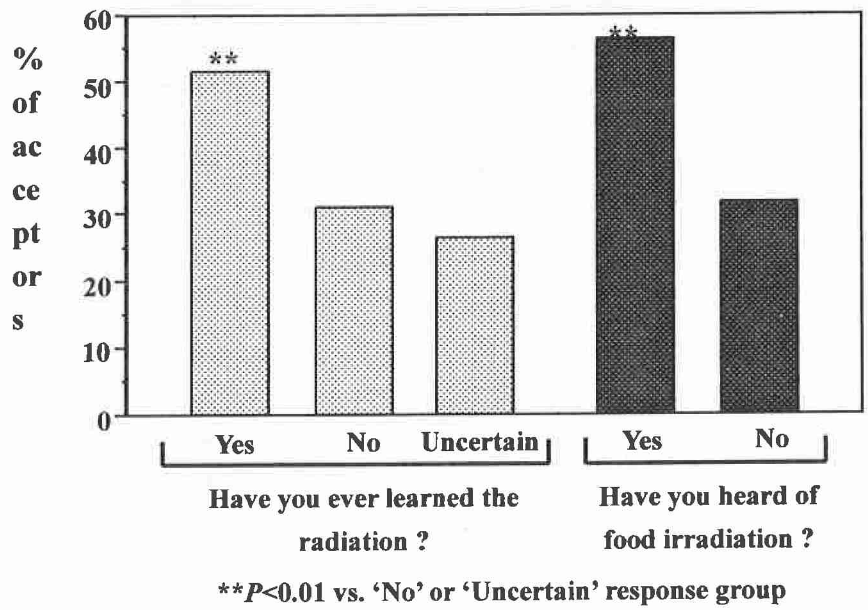

Figure 2. Rate of the acceptors in 'Yes', 'No', or 'Uncertain' group responded to the learning question and in 'Yes' or 'No' group responded to the knowledge question.

Discussion

Consumers generally do not understand the food safety benefits of most food preservation technologies including pasteurization, canning and freezing[6]. The majority of young consumers who attended this study were also unsure in their knowledge and understanding of the irradiation technology. Only 24.8 % of the subjects have ever heard about the irradiated food (Table 2). This awareness in the present study was extremely less than that in U.S.A. (approximately 73 %)[5] and that in Korea (approximately 82 %)[7] though the subjects in other countries were general consumers as shown in Figure 3. It is necessary in Japan to disseminate the existence of the irradiated food before the consumer acceptance.

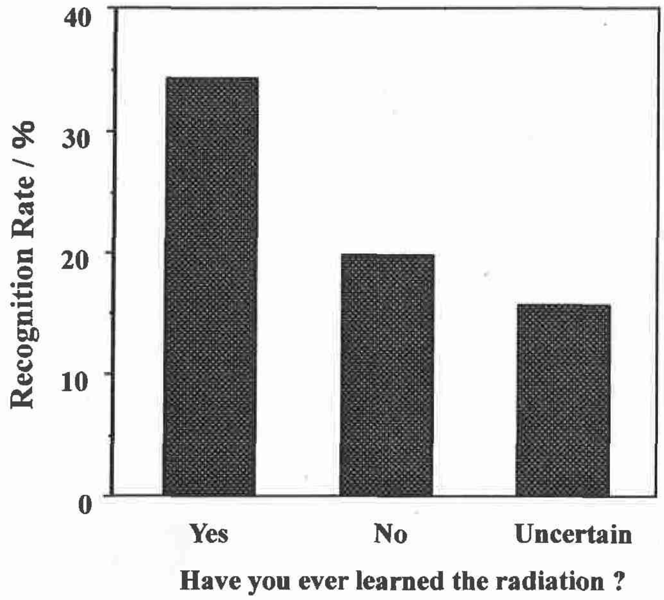

Figure 3. Rate of subjects who answered that they have heard of food irradiation in 'Yes', 'No', or 'Uncertain' group responded to the learning question

The majority of the subjects considered that the irradiated food should be plainly manifested in store (Table 2). In addition, in order to be acceptable, the irradiation must offer to the consumer an advantage which could be higher quality, greater safety, longer shelf life, wide product availability, or lower cost. As one of the successful studies in which both the manifestation and the information of irradiated food to consumers were established, Schutz, et al have reported that it was very important to indicate the label statement on the perception of quality, safety, and willingness to buy[8)].

The consumer needs to be educated and informed. Information may not reduce consumer concern, but it allows choice to be based on fact, rather than suspicion. This study confirms that the more young students, new-aged consumers, know about the radiation, the more likely they are to accept it for purchasing (Figure 2). Therefore, the education is the key as being denoted in the International Atomic Energy Agency (IAEA) report[9)]. Proponents of food irradiation firmly believe these food will be accepted when offered for sale.

Acknowledgments

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References

1) Diehl, J. F., "Food Irradiation", In Developments in Food Preservation -2, (Thorne, S. ed.), p.1984, Applied Science Publishers, New York (1983)

2) Bruhn, C. M., Sommer, R. and Schutz, H. G., EFFECT OF AN EDUCATIONAL PAMPHLET AND POSTERS ON ATTITUDE TOWARD FOOD IRRADIATION, *Journal of Industrial Irradiation Technology*, 4(1), 1-20 (1986)

3) Conley, S. T., What do consumers think about irradiated food, *FSIS Food Safety Review* (Fall), 11-15 (1992)

4) Bruhn, C. M. and Noell, J. W., Consumer In-Store Response to Irradiated Papayas, *Food Technology*, 41, 83 - 85 (1987)

5) Clarke, S. and Riley, J., The more consumers learn about irradiation, the more they want it. American Meat Institute (1993)

6) Bruhn, C. M. and Schutz, H. G., Consumer awareness and outlook for acceptance of food irradiation, *Food Technology*, 43 (7), 93 - 94 (1989)

7) Kwon, J-H., Byun, M-W. and Cho, H-O., Development of Food Irradiation Technology and Consumer Attitude toward Irradiated Food in Korea, *RADIOISOTOPES*, 41, 654-662 (1992)

8) Schutz, H. G., Bruhn, C. M. and Diaz-Knauf, K. U., Consumer attitudes toward irradiated foods: Effects of labeling and benefits information, Paper No. 84., *Annual Meeting of Int. Food Technologists*, June 25-29, Chicago, TL (1989)

9) Young, M., Defesche, F., Van Asperen de Boer, Urbain, R. H., and Webb, C. P. N., Marketing and Consumer Acceptance of Irradiated Foods, *IAE-TECDOC-290*, International Atomic Energy Agency, Vienna (1983)

7.9 Research and Analysis on the Knowledge of Radiation Possessed by Students in Upper-secondary School

高校生が保有する放射線の知識に関する調査と分析

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Investigation into the knowledge of radiation will give us information about teaching contents to be utilized in upper-secondary schools. Furthermore these results will be explored for teaching points on radiation education, which aims to promote the exact understanding of radiation.

1. はじめに

平成１５年の年の瀬が押し迫った12月24日～26日に国立オリンピック記念青少年総合センターで、原子力体験セミナー〔専門（授業実践研究）コースⅢ〕が開催された。その２年前の12月には兵庫でワークショップ形式の研修をする機会を得たが、それ以来の参加であった。

この専門コースのねらいは、過去にこのセミナーに参加した受講者によってその成果を活かす授業の実際をデザインすることにあるように思われる。その背景には、今まで多大な費用と時間をかけて取り組んできた放射線・原子エネルギーに関する教師教育が余り成果をあげていないという現状認識を読み取ることができる。

今回私が参加した「理工系グループ」「高校分科会」では、各指導項目を生徒の発達段階の座標軸と教科・科目の座標軸からなる２次元のマトリックスに配置する作業と、生徒の放射線に関する「思い違い」を把握するために授業に先立って実施するミスコンセプション調査項目を検討する作業に取り組んだ。「原子力に関する新聞記事を読み、適切な判断ができる市民を育てるために」を目標として、４つの柱を立てた。「自然放射線の存在」「放射線の人体への影響」「原子力発電の仕組みと危険性」「エネルギー確保と環境問題」を柱として「教育課程作り」と「思い違いの原子力Ｑ＆Ａ」作りの２グループに分かれて作業を展開した。

この度の発表はその作業の成果として作成することができたＱ ＆ Ａを、今年４月に入学してきた１年生の３クラスを対象にして実施したものである。

2. 調査方法

(1) 調査時期　平成１６年4月２２日（木）・２３日（金）

(2) 調査対象　平成１６年度札幌清田高校1学年３クラス１２０名
（男子：６７名、女子：５３名）

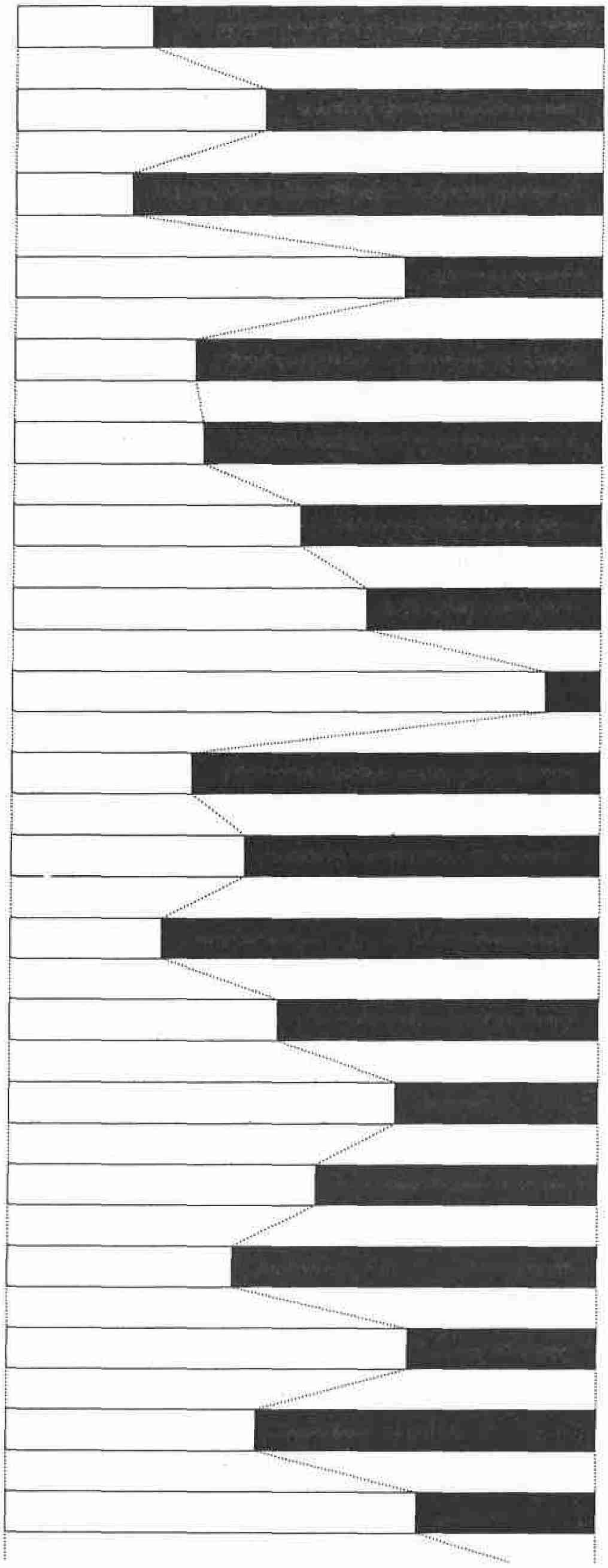
(3) 調査内容

次の３０項目の質問について　①　Ｙｅｓ　or　②　Ｎｏ　で回答する質問用紙を用意し、マークカードに生徒が記入したデータをマークカードリーダーで読み取り集計した。

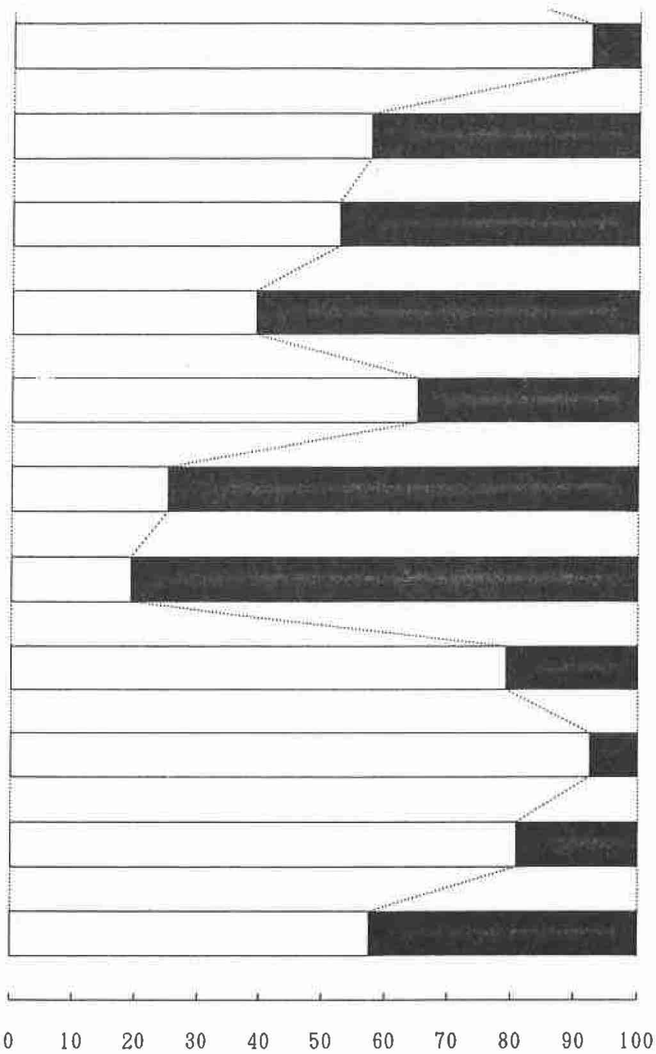
1. 放射線と放射能は同じものである。
2. 川や湖の上では放射線量は他よりも少なくなる。
3. オゾン層は放射線によって破壊される。
4. 宇宙からも高エネルギーの放射線が地球に届いている。
5. ジェット旅客機が通常飛行する１万m上空では放射線量は地上の約1/10に減少する。
6. 食べ物の中に放射線を出す物がある。
7. トンネルの中での放射線量は他よりも少なくなっている。
8. 胃の検診で飲むバリウムには放射性物質が含まれている。
9. ガンの治療に放射線が使われている。
10. 放射線を浴びると、必ず放射能を持つため危険である。
11. 放射線を照射した食品を摂取することは、どんな場合でも危険である。
12. 私たちの体内には放射線を出す物質がある。
13. ラジウム温泉に入り過ぎると、放射線障害を引き起こす。
14. 中性子は電荷を持たないが、高速で物質に当てると危険である。
15. 締め切った分厚いコンクリート製の部屋の中にいても放射線を受ける。
16. 微量の粉塵程度や水に溶け込んだ放射性物質なら体内に入っても危険ではない。
17. 原子力発電はウランと空気の反応で熱を発生させ、電力を生み出す。
18. 原子力発電所を稼働させると多量の二酸化炭素を発生する。
19. 出力百万キロワットの原子炉を１年間運転させると、原子炉に蓄積される放射性物質の量は広島型原爆で生じた量と同じ位になる。
20. 原子力発電のエネルギー源として、ウランの核分裂が使われている。
21. 原子炉では核分裂を制御棒で安全に制御できる。
22. 原子力発電の基本的仕組みは、火力発電と同じように高温高圧蒸気タービンを回転させて電力を得る。
23. 原子力発電で発生する熱エネルギーの内で電気エネルギーに変換できる割合は、おおよそ１／３である。
24. 原子力発電で最も恐ろしいことは、操作を誤ると広島型原爆よりもはるかに大きな核爆発を起こすことである。
25. 日本の全発電量の８０％以上を原子力発電以外の発電によってまかなっている。
26. 核燃料の埋蔵量は、あと1000年以上使えるだけある。
27. 放射線を使って害虫を駆除することができる。
28. 核関連施設で使用された物は環境を汚染する可能性があるので、処理が必要である。
29. 医療器具は全て熱湯・高温または薬品によって殺菌される。
30. 放射性物質の中には、絶対年代の測定に使われる物がある。

3. 調査結果

1. Ｙ：２８件、Ｎ：９２件
(23.3%)、(76.7%)
2. Ｙ：５１件、Ｎ：６８件
(42.9%)、(57.1%)
3. Ｙ：２４件、Ｎ：９６件
(20.0%)、(80.0%)
4. Ｙ：８０件、Ｎ：４０件
(66.7%)、(33.3%)
5. Ｙ：３７件、Ｎ：８２件
(31.1%)、(68.9%)
6. Ｙ：３８件、Ｎ：７９件
(32.5%)、(67.5%)
7. Ｙ：５９件、Ｎ：６１件
(49.2%)、(50.8%)
8. Ｙ：７２件、Ｎ：４７件
(60.5%)、(39.5%)
9. Ｙ：109件、Ｎ：１１件
(90.8%)、(9.2%)
10. Ｙ：３７件、Ｎ：８３件
(30.8%)、(69.2%)
11. Ｙ：４８件、Ｎ：７２件
(40.0%)、(60.0%)
12. Ｙ：３１件、Ｎ：８９件
(25.8%)、(74.2%)
13. Ｙ：５５件、Ｎ：６５件
(45.8%)、(54.2%)
14. Ｙ：７９件、Ｎ：４１件
(65.8%)、(34.2%)
15. Ｙ：６３件、Ｎ：５７件
(52.5%)、(47.5%)
16. Ｙ：４６件、Ｎ：７４件
(38.3%)、(61.7%)
17. Ｙ：８１件、Ｎ：３８件
(68.1%)、(31.9%)
18. Ｙ：５１件、Ｎ：６９件
(42.5%)、(57.5%)
19. Ｙ：８３件、Ｎ：３６件
(69.7%)、(30.3%)



20. Y： 110件、N： 9件
(92.4%)、(7.6%)
21. Y：６９件、N：５１件
(57.5%)、(42.5%)
22. Y：６３件、N：５７件
(52.5%)、(47.5%)
23. Y：４７件、N：７３件
(39.2%)、(60.8%)
24. Y：７８件、N：４２件
(65.0%)、(35.0%)
25. Y：３０件、N：９０件
(25.0%)、(75.0%)
26. Y：２３件、N：９７件
(19.2%)、(80.8%)
27. Y：９５件、N：２５件
(79.2%)、(20.8%)
28. Y： 110件、N： 9件
(92.4%)、(7.6%)
29. Y：９７件、N：２３件
(80.8%)、(19.2%)
30. Y：６９件、N：５１件
(57.5%)、(42.5%)



4. 結果の分析

(1) 高い正答率を示した項目

①「原子力発電のエネルギー源として、ウランの核分裂が使われている。」	92.4%
①「核関連施設で使用された物は環境を汚染する可能性があるので、処理が必要である。」	92.4%
③「ガンの治療に放射線が使われている。」	90.8%
④「核燃料の埋蔵量は、あと1000年以上使えるだけある。」	80.8%
⑤「オゾン層は放射線によって破壊される。」	80.0%
⑥「放射線を使って害虫を駆除することができる。」	79.2%
⑦「放射線と放射能は同じものである。」	76.7%
⑧「日本の全発電量の８０%以上を原子力発電以外の発電によってまかなっている。」	75.0%
⑨「放射線を浴びると、必ず放射能を持つため危険である。	69.2%
⑩「ジェット旅客機が通常飛行する１万m上空では放射線量は地上の約1/10に減少する。」	68.9%

(2) 低い正答率を示した項目

①「医療器具は全て熱湯・高温または薬品によって殺菌される。」　19.2%

②「私たちの体内には放射線を出す物質がある。」　25.8%

③「出力百万キロワットの原子炉を１年間運転させると、原子炉に蓄積される放射性物質の量は広島型原爆で生じた量と同じ位になる。」　30.3%

④「原子力発電はウランと空気の反応で熱を発生させ、電力を生み出す。」　31.9%

⑤「食べ物の中に放射線を出す物がある。」　32.5%

⑥「原子力発電で最も恐ろしいことは、操作を誤ると広島型原爆よりもはるかに大きな核爆発を起こすことである。　35.0%

⑦「原子力発電で発生する熱エネルギーの内で電気エネルギーに変換できる割合は、おおよそ１／３である。　39.2%

⑧「胃の検診で飲むバリウムには放射性物質が含まれている。」　39.5%

⑨「放射線を照射した食品を摂取することは、どんな場合でも危険である。」　40.0%

⑩「川や湖の上では放射線量は他よりも少なくなる。」　42.9%

(3) 性差が顕著に見られる項目

「トンネルの中での放射線量は他よりも少なくなっている。」

男　Y：46.3%　N：53.7%、　女　Y：52.8%　N：47.2%

「ラジウム温泉に入り過ぎると、放射線障害を引き起こす。」

男　Y：37.3%　N：62.7%、　女　Y：56.6%　N：43.4%

「締め切った分厚いコンクリート製の部屋の中にいても放射線を受ける。」

男　Y：56.7%　N：43.3%、　女　Y：47.2%　N：52.8%

「原子力発電所を稼働させると多量の二酸化炭素を発生する。」

男　Y：35.8%　N：64.2%、　女　Y：50.9%　N：49.1%

「原子力発電の基本的仕組みは、火力発電と同じように高温高圧蒸気タービンを回転さて電力を得る。」

男　Y：59.7%　N：40.3%、　女　Y：43.4%　N：56.6%

5. まとめ

昨年１２月に行われた調査項目を検討する作業部会では、もっと放射線の利用に関す項目を増やした方が良かったという声が検討メンバーから出ていたが、実際にこの調査項目を使ってみると、同様の感想を持つ。放射線の危険性を正確に指導することと同時に、放射線の利用によって恩恵を受けている側面も大切な指導事項であると思われる。

此の度の調査によって、入学直後に高校生が保有する放射線の知識の実状の一端を知ることができた。将来的なエネルギーの確保と環境保全の問題に取り組む上で避けて通ることが出来ない「放射線」について、その理解を促す取り組みにこの調査結果を活かしていきたい。

《参　考　文　献》

1. 日本原子力学会，「原子力がひらく世紀」，2002.
2. 松浦辰雄・飯利雄一，「放射線・原子力と教科書」，研成社，1992.
3. (財)放射線利用振興協会，「原子力・放射線用語集」，2003.

7.10 Development of Innovative Classroom Instructional Material for Enhancing Creative Teaching and Learning Nuclear Topics: A Proposal

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The role of education all over the world is becoming more and more significant and requires an in depth study since the life of the people is advanced, expanded and complicated. Educators are once again asked to address problems which have arisen within their own society. Thus, the search for ways to improve quality of education is global especially in line with nuclear science and technology. One area of focus is that managing and promoting learning inside the classroom, how teachers' utilized instructional materials were such an issue. Indeed, qualifications and resources are not the only factors that influence teachers' effectiveness, equally important are teachers' motivation, commitment, resourcefulness, innovativeness and creativeness in dealing with instructional materials. Lack of these things will produce poor attendance and unprofessional attitudes towards students. This paper aims to present a proposal on the use of innovative teaching device from the sample photographs as a result of the experiment taken at Kyoto University Research Reactor Institute (KURRI) where samples were treated with gamma rays from a radioactive source ^{60}Co and lately exposed to photographic films giving rise to understanding of photons emitted by radioactive material in a form of electromagnetic waves and later converted into visible light in a more authentic and simplified manners. As a consequent, this proposal was made to enhance teaching and encourage science teachers to exert great effort to develop instructional materials specifically in this area that requires the concretization of concepts which could not be detected by human senses.

1. INTRODUCTION

Teachers are considered as researchers and scholars of their own classrooms. Classroom life if full of habits and routines that often passed unnoticed. They often remain invisible until they are viewed from different angles or landscapes. Most children come to school ready and willing to learn. How can schools foster and strengthen this predisposition and ensure that they leave the school with the capacity to continue learning through life? How well do school systems perform in providing young people with a solid foundation of knowledge and skills about nuclear topics and in preparing them for life and learning beyond school [1]? These are some of the questions in which young people who run the education system needs to know. Many education systems monitor students learning in order to provide some answers to these questions. Science teachers are faced with enormous challenge. A large range of students' backgrounds and abilities exists in science classrooms. Many students are reading far below grade level. Often a significant percentage of students with poor speaking, writing and understanding skills are present. Some students may have weak science backgrounds especially in line with nuclear science. With many of these students, in order to make a point to demonstrate an idea related to science process or nature of science, examples that relate to the environment must be used (e.g., desktops, rulers, cars and candies) as a context for explaining science process. This everyday context of concrete objects maybe necessary when introducing a scientific skill or process before using it to learn science course subject matter [2].

However, learning nuclear concepts in school is quiet difficult to understand. One method of teaching is trying to have the students learned by experiments. Most schools cannot afford a laboratory for a fundamental experiment on nature of radiation. Lacking knowledge for handling of radioactive materials and cost of nuclear instruments made impossible in implementing such laboratory in ordinary schools [3]. Students need effective approaches to learning both to succeed to school and to meet their learning needs later in life. In particular, they need to regulate the learning process, taking responsibility for reaching particular goals. These types of outcomes are not pursued as a specific part of the curriculum, yet they can be strongly influenced by students' experiences at school and play a crucial part in their future [1].

1.1 Background of the Study

With the advancement of science and technology, physics plays a significant role in life and progress of mankind. Certain developments within the field of nuclear science have encouraged man to think, work and live differently from the past. For through the application of laws and principles of physics, man is thereby enabled to produce and enjoy modern convenience and comforts. It is quiet evident that physics have contributed increasingly to the progress of mankind and thus, offers greater opportunities for a life of prosperity and fulfillment.

In the field of education, among the different subject areas offered in science has taken the lead in the development of various curricula perhaps in many other countries, Chemistry and Physics have been given emphasis to provide students with basic knowledge of scientific concepts and principles so as to become scientifically literate and more effective citizens. Since Physics dominates the science curriculum, it becomes necessary for teachers teaching nuclear science and technology to provide the students with the necessary skills, knowledge and abilities as well as their interest in this field [6].

How to impart nuclear concepts effectively and efficiently is important to study because this will play a vital role in providing students who will be science conscious which will provide avenues for a life- career or profession. One can be an engineer, an architect, a mechanic, a doctor, a teacher or a scientist if he studies nuclear science well. It is therefore, necessary to focus instructions towards awakening the students' awareness and interest in nuclear science and to foster his appreciation on the importance of the subject. Hence, it is imperative that teachers should look into effective means of imparting nuclear knowledge to students and this will largely depend on the initiative of the teacher to make appropriate instructional materials that will serve as a key components influencing and enhancing creative teaching and learning abstract concepts [4]. Ultimately, it will be a starting point in opening the doorway to nuclear science.

1.2 Rationale of the Study

For much of the last century, the content of school science curricula has been dominated by the need to provide the foundation for the professional training of small number of scientists, mathematicians and engineers. Today, however, literacy in science is important for all to understand medical, economic, environmental and other issues that shape modern societies, which rely heavily on technological and scientific advances [1].

Science teachers emphasize that the teaching in science to be effective, must deal more with students' activities in the classroom. Teaching strategies are becoming increasingly oriented toward students' cognitive development [5]. The use of instructional materials in the classroom like poster becomes imperative. Many researchers or even educators have exerted effort in developing instructional materials for several reasons to wit;

Bacay 1984 believed that the instructional materials prepared by the teacher are much better than those found in the textbooks since they are prepared and written for specific groups of students. Furthermore, she stressed that the choice of structure, pattern, practical applications and skills development exercises are definitely adapted to the needs and abilities of a particular group of students [6].

Alturas 1978 recommended that the teachers and instructors should be encouraged to develop instructional materials specifically focusing on topics which are somewhat abstract that contain practical application of concepts and principles [7].

Peterson 2003 suggested that getting students to relate to scientific concepts is often difficult. Good models, especially those used to describe processes on the atomic or astronomical levels not tangible to students are essential. The simple and authentic the instructional materials, coupled with its everyday occurrences in the lives of the students, make them a perfect candidate to help explain the relative sense of the topics in various disciplines from ecosystems and species niches to gravity and motion [8].

A good theme to follow in the effort to meet needs of diverse learners in science education is "Teaching with purpose," which was crafted by National Science Teachers Association (NSTA) President John Penick. According to him, "Teaching with purpose means having a personal guiding framework for our teaching practices - a framework based on what research says works best in teaching and learning science [9]."

This proposal, therefore, can be used to examine the goals of nuclear science teaching and learning with care to identify optimal activities and experiences from all modes of instruction that will best facilitate these goals. While relevant variables are interrelated and complex, there is a real need to pursue rigorous research on learning through instructional materials to capitalize on the uniqueness of this mode of instruction for certain learning outcomes. With more precise information on these deficiencies, more comprehensive teaching materials can be designed to incorporate information about goals and the nature of nuclear topics; teachers became more effective in facilitating student learning and development. Furthermore, this study will serve as another attempt to develop teaching materials that will assist reduces students' deficiencies in Physics, specifically giving stress on nuclear topics [4]. It is then towards these perspectives that this proposal was made.

1.3 Objectives of the Study

Based from the aforementioned realities, the following objectives are then formulated;

a. Enhance creative teaching and learning nuclear topics inside the classroom giving rise to students' cognitive development.
b. Help captive students' interest and appreciation to natural and nuclear phenomena through understanding the fundamental facts, concepts, principles, laws and theories.
c. Provide useful experiences in sharpening students' abilities to observe, infer, design experiments, conduct investigations and organize data.
d. Facilitate teaching abstract nuclear topics specifically the emission of visible light from a material exposed to or irradiated by gamma ray in an authentic manner.
e. Measure student capacity to use scientific knowledge, recognize scientific questions, and identify what is involved in the scientific investigations and to relate scientific data to arrive at certain conclusion.
f. Stimulate the interest of science teachers to conduct and design scientific investigations and communicating scientific procedures and explanations in written and oral form.

1.4 Significance of the Study

To teach effectively, science teachers need to be competent in selecting and preparing the instructional materials and strategies in teaching, as well as motivating the interest of the students in the subject matter.

This proposal can give ideas to physics teachers on how to remedy their difficulties encountered in teaching nuclear topics and stimulate their interests to develop more instructional materials and other necessary measures for the improvement of science instruction.

This study can also help solve the problems confronting most public schools teachers in the different parts of the country today, such as lack of science textbooks and other reference materials to locate nuclear topics, insufficient teaching device to teach these concepts which could not be seen and recognized by human senses and though equipped with gamma ray facility where irradiation of sample materials can be done and a dark room where experiment on natural emission of light from a radioactive samples be performed but knowledge is not sufficient enough to perform the tasks, this study can suffice the purpose.

It can as well enhance the teaching-learning situation since the students will be exposed to this kind of teaching device for them to learn at their own pace [4]. Moreover, it can help them acquire more science skills, processes, knowledge and abilities in understanding nuclear topics and phenomena particularly giving rise to radiation, excited photon, gamma ray, thermoluminescence, electromagnetic spectrum and the like with less effort on the part of the teacher [10].

This proposal can specifically help elevate the present status of radiation or nuclear science education in all countries in the annual evaluation of teacher and student performance and increase the rank into a satisfactory level as has been doing by the Program for International Student Assessment (PISA) where the objectives are to measure the three forms of literacy; reading, mathematical and scientific and focus on how well the students apply knowledge and skills to tasks that are relevant to their future life, rather than on the memorization of subject matter knowledge [1].

2. METHODOLOGY

2.1 Materials

The materials utilized in the conduct of the experiment were depicted in Figs. 1 to 9, except for ASA films (400) which were not included in the line up but can be seen in Figs.10and 12under Experimental Set Up (2.3).

Gamma Room and Dark Room Experiments
(Artificial Source)

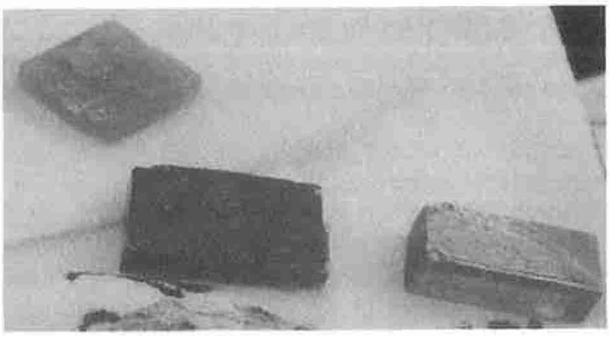

Fig.1: Sample materials used in the study (from top left- Sodium Chloride Crystal, middle- Potassium Bromide and right below- Potassium Chloride).

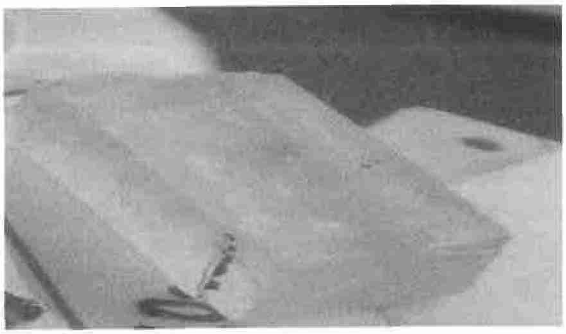

Fig.2: Sample material (Calcite).

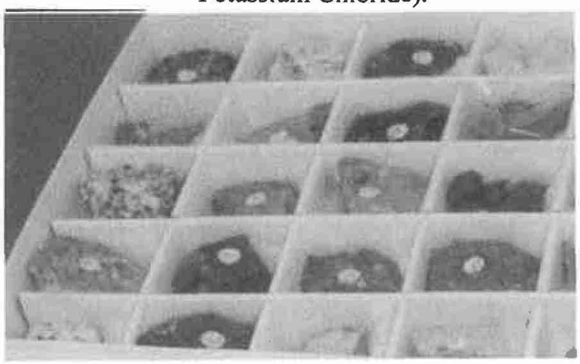

Fig.3: Sample rock material (rock no. 2- second from left bottom- Two mica-granite).

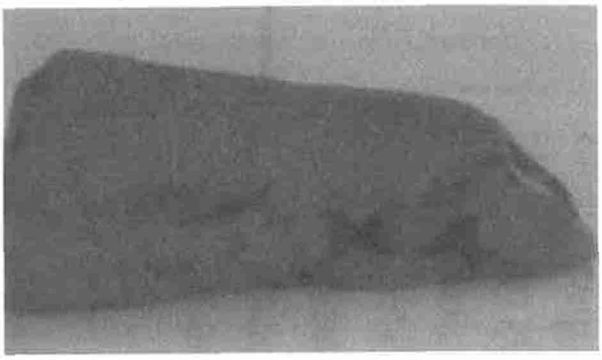

Fig. 4 Sample rock material from Kochi (Sandstone).

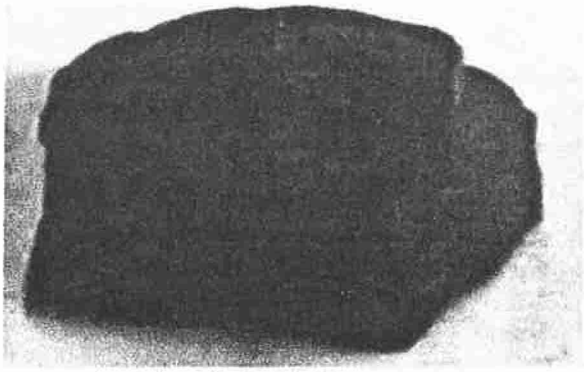

Fig.5: Sample rock material from Russia (Chert).

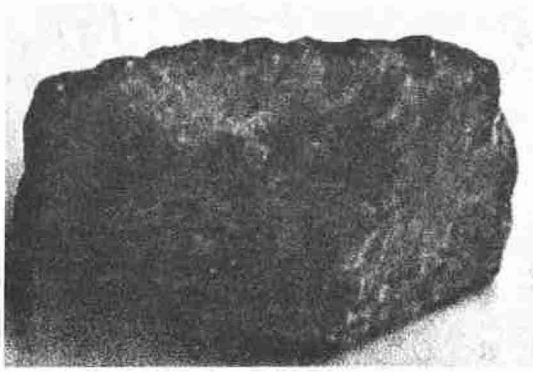

Fig. 6: Sample rock material from Japan (Red granite).

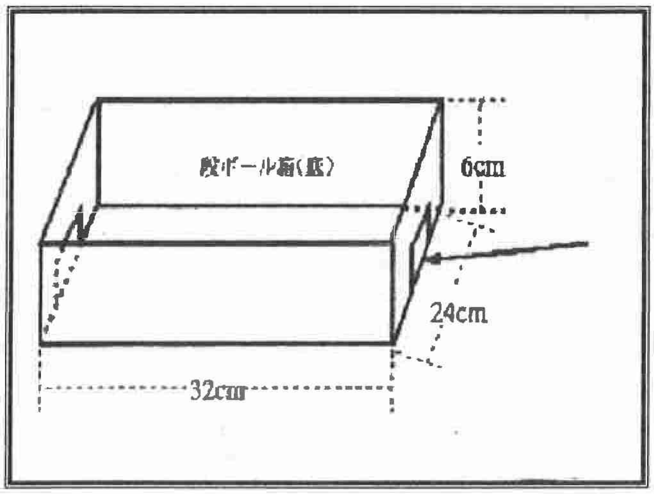

Fig.7: Sample rectangular black box whose dimension is shown. Big arrow is pointing to the hole for the film to pass through..

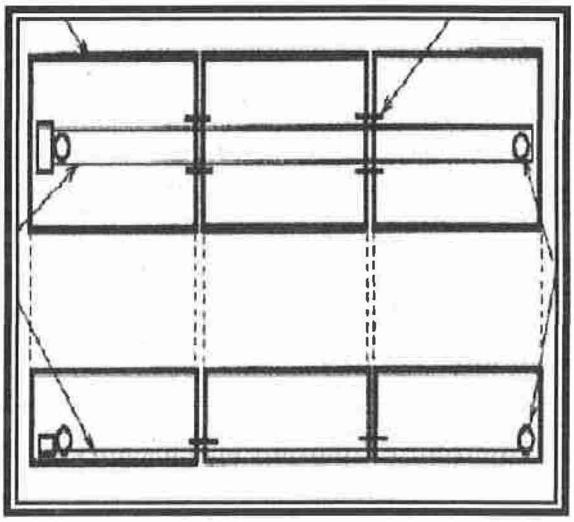

Fig. 8: Three rectangular boxes combined. Holes be made in both sides of the box to obtain two rows of samples.

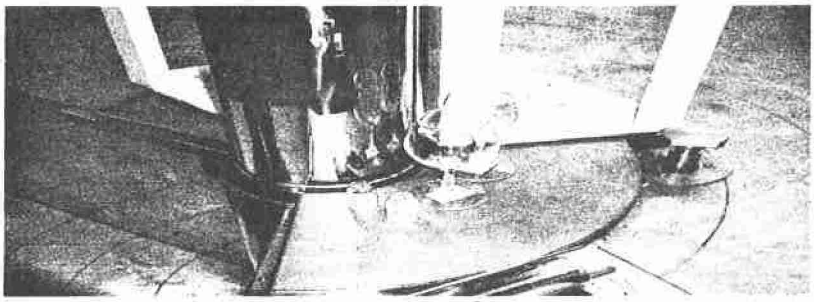

Fig.9: Kyoto University Research Reactor Institute (KURRI) Gamma Radiation Room where sample Materials were directly exposed to ^{60}Co before photographic film exposure.

2.2 Experimental Procedures

This part of the study consisted of two phases; experiment conducted in Gamma Room where steps considered were indicated below (1-6) whereas, (7-16) determine the steps taken inside the Dark Room and from (17-20) the extension as to the result of the experiment.

A- Gamma Room Experiment

1. Gather and prepare all the materials required in the experiment.
2. Check the Gamma Room facility to ensure safety.
3. Set up the area in which the samples will be irradiated (Fig.9).
4. Decide for irradiation time considering the nature of materials to be irradiated.
5. Once the time is decided, arrange and expose the samples directly and manipulate the facility as safety as possible all throughout the experiment as shown in (Fig.10).
6. Decide for photographic exposure time of the samples and take into consideration the irradiation time.

B- Dark Room Experiment

7. Prepare the black rectangular box as shown in the given set up (Figs. 11 and 12) and some other materials needed right after samples have been exposed to radiation
8. Darken the room, bring the irradiated materials inside, set the film in two rows as in Fig. 10 as no stream of light can be accommodated, place the samples one at a time on the film as carefully as possible and cover each sample with a small piece of black cloth.
9. Once finished, carefully cover the box and ultimately with wide black cloth on top.
10. Set the timer to a decided time of exposure.
11. Wait until such time samples will be ready for removal from the film.
12. Remove the black cloth including the cover of box, remove the samples, re - rolled the films and place them in canisters that are properly labeled as to the position of the samples in the box for clarity of sample identification.
13. Switch on the light and be ready for another set of experiment by following the same procedure but take into account the irradiation and exposure time as variations can be made.
14. Develop the films and make the necessary action as to the results of the photographs.
15. The irradiated samples that have been decided to include as components in the teaching material will then be subjected to analysis using the Gamma Ray Digital Spectrum Analyzer System Model DSA-1000 for measuring the peak area spectrum which entails possible spectroscopic interpretation measurement in terms of energy and intensity of the incident radiation.
16. For effective manipulation of the system, follow the procedures as indicated in the Operations Manual especially for beginners.

17. Collect the selected photographs make a tentative design and layout of an Explanatory Panel as a teaching material which will serve the purpose of instruction.
18. Study the Sequential Model as shown by Figs. 18 and 19 to arrive at the determination of the teaching and concept models.
19. Lesson can be changed, reinforced and enriched based from the applicability of the teaching material and nature of learners.
20. Planning for the next lesson can be done in sequential manner without going beyond the limitation of the teaching device.

2.3 Experimental Set Ups

Figs. 10 and 12 show the Experimental Set Ups in Gamma and Dark Rooms respectively.

A- Gamma Room Experimental Set Up

Fig.10: Sample insulated objects were arranged and directly exposed to radiation source.

B- Dark Room Experimental Set Up

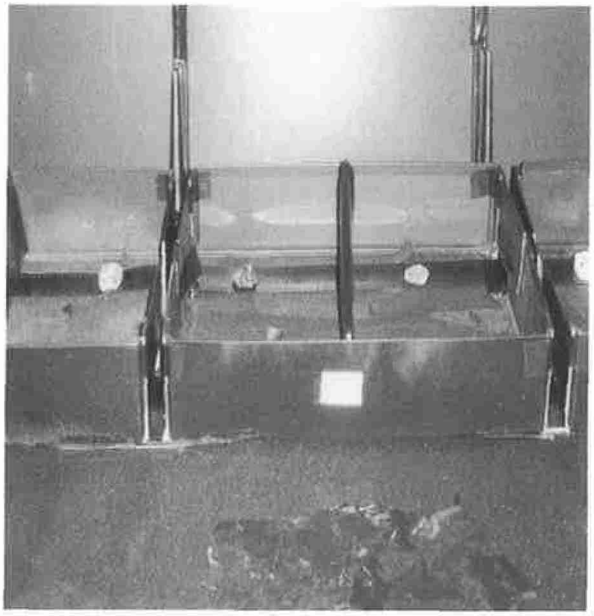

Fig.11: Sample materials required in the Dark room experiment

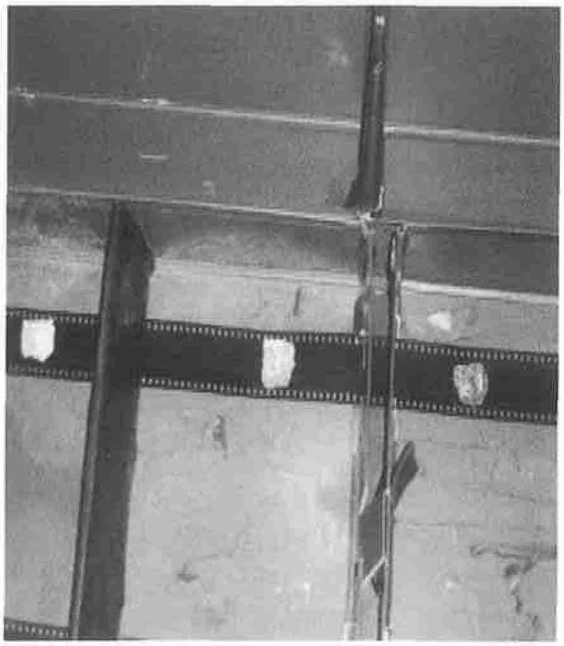

Fig. 12: The samples on the photographic films in two rows inside the rectangular black box.

2.4 Experimental Photographs

Figures 13-19 were the photographs of samples developed and chosen based from the results of the experiment.

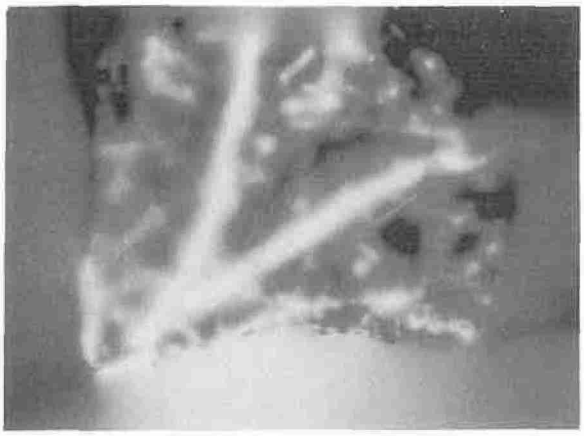

Fig.13: Rock from Russia [Chert].

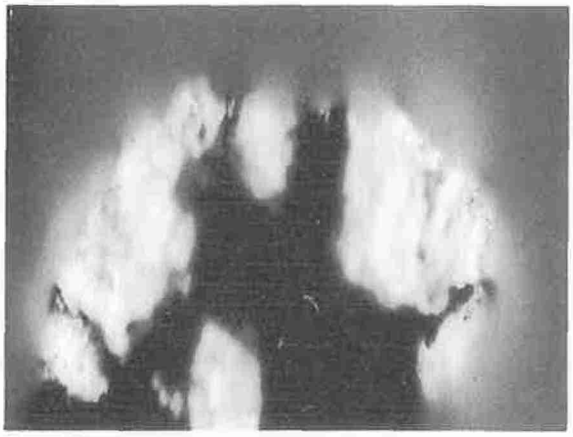

Fig.14: Rock from Japan [Red Granite].

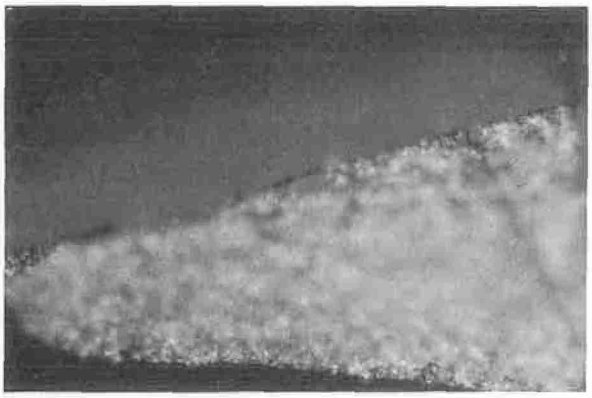

Fig. 15: Rock from Kochi, Japan [Sandstone].

Fig. 16: Rock [Two Mica Granite].

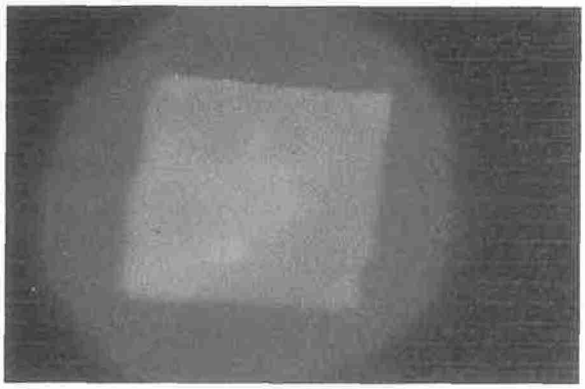

Fig.17: Sodium Chloride Crystal [NaCl].

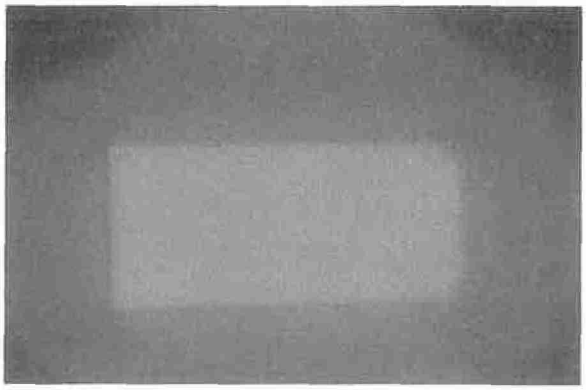

Fig.18: Potassium Chloride [KCl].

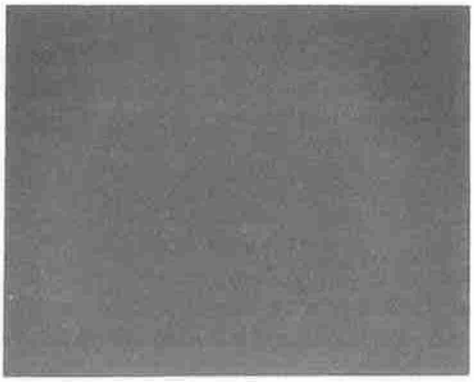

Fig.19: Potassium Bromide [KBr].

2.5 Sequential Models of the Study

A- Construction of the Explanatory Panel (fixed or movable).
B- Design and layout the experimental photographs in the constructed panel.
C- Preparation of the "Day's SMART (Specific, Measurable, Attainable, Reliable and Time Bounded) lesson plan" based from one of the component areas of the applicability of the teaching material as indicated in Fig.19 below.
D- Execution of the day's lesson using the concept model and teaching device (Explanatory Panel).
E- Evaluation of the day's lesson as to the congruency of objectives, test questions, teaching strategy giving rise on the effectiveness of the teaching material.
F- Courses of action can be made as to the results of the assessment conducted.

Fig.20: Teaching Device Model Determination.

The Sequential Models as shown by Figs. 20 and 21 simply present the flow of activities on how the experimental photographs will be used as an aid (Explanatory Panel) and a sample illustration of the concepts to be used in teaching which are presented in general form where sub tasking analysis is applied.

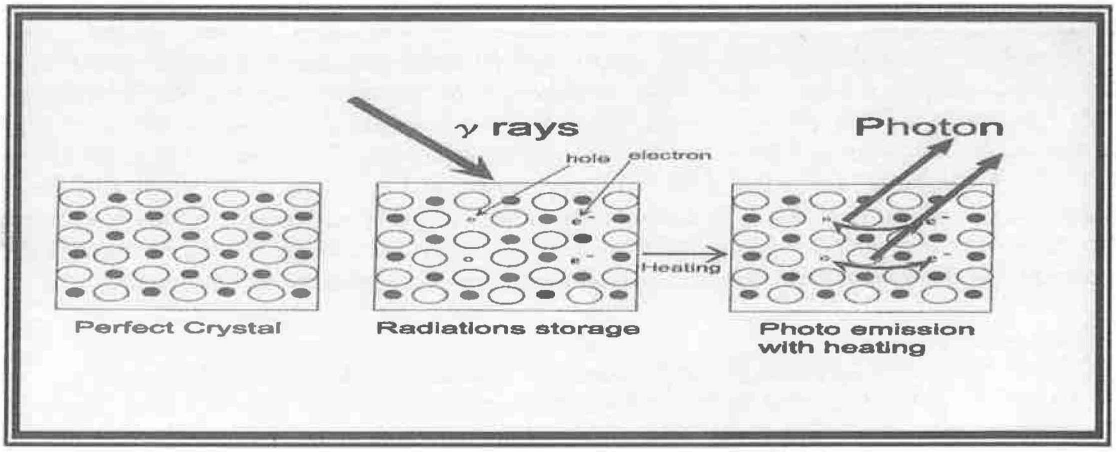

Fig.21: Concept Model of the Experiment

An in depth study of Fig.20 should also be given importance since how effective the teaching material is, but the lesson was not properly planned and executed, then, the purpose will always be defeated. Time wise, resources wise and energy wise will be meaningless and unworthy.

Figure 21 depicts the model of the basic concepts that can be taught to students during the day's lesson as one area of the teaching material's applicability. The first diagram shows the crystalline solid with no defects consisting of three dimensional arrays of unit cells, each containing the identical arrangement of atoms. When this material is subjected to radiation source (^{60}Cobalt) emitting gamma rays, some will be reflected and some will be absorbed in crystal thereby storing radiation. The absorbed high energy photons will undergo three dominant interaction processes, each of which produces energetic electrons; the photoelectric effect (PE), Compton Effect (CE) and pair production (PP). An atom of the crystal that receives sufficient energy, typically a few tens of electron volts, will permanently displaced from its lattice site. If the displaced atom (a "primary knock-on") has sufficient energy, it can, in turn displace other atoms ("secondary"), and so on, creating a cascade of displaced atoms (lattice defects). Thus, there exists the presence of vacancies and interstitial atoms in a crystal by creation of color centers. In essence, these defects are created during the recombination of electrons as shown by the second diagram. Lastly, photo emission will follow and later converted into visible light as shown by the third diagram.

3. SUMMARY

It has been clear and possible that problems met in teaching nuclear topics can be remedied with much care and attention to the application of the experimental photographs converted into a classroom science teaching device; a proposal which was conducted at Kyoto University Research Reactor Institute. Under Methodology, materials that comprised the experimentation process were provided with simplicity and clarity. Instructions on how to carry out the experiments were logically arranged so as to ensure systematic execution and organization of experimental processes. The inclusion of the experimental set ups were also manifested and of the experimental results (developed photos) presented in a manner suitably good for learners. Determination of the sequential models of the study was reflected, highlighted and specifically simplified as appropriate as possible. Further results and discussions were not shown but can be proposed and suggested that as to further application of the device, peak area spectral measurement and nuclide identification of irradiated samples can be made possible using DSA-1000 Digital Spectrum Analyzer System for countries equipped with "high touch" apparatus and facility as spiral basis for concept development. Production and dissemination of photographs can be realized for schools far beyond to cope and afford to buy these expensive laboratory and experimental facility to perform the same task.

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The authors would like to show their earnest and profound gratitude first and foremost to, Japan International Cooperation Agency (JICA) staffs and personnel for that untiring support, Mr. Shiro Kanayama, the Officer In-charge of JICA Shikoku Branch Office, for his wholehearted cooperation, Professor Moritami Okada and his division staffs and personnel for their sincere accommodation in using the Kyoto University Research Reactor Institute (KURRI), Kyoto University facility and apparatus in the conduct of the study, Professor Tetsuo Hashimoto, Niigata University for his endearing guidance, Professor Tokou Matsukawa and Makoto Honda for their moral support, Professor Takeshi Kozai and Hiroaki Ozawa for providing some materials and their analyses and Mr. Tetsuya Koizumi for his helpful suggestions and cooperation.

References

[1] OECD, "Literacy Skills for the World of Tomorrow "Further Results from PISA 2002," Japan

[2] Chiapetta, E.L., and T.R. Koballa Jr. 2002 Science Instruction in the Middle and Secondary Schools, Upper Saddle River, N. J. Merrill/ Prentice Hall.

[3]Warapon, Wanitsuksombut and Chanti Decyththin " Radioactive Source Simulation for Half Life Experiment., "Proceedings of International Symposium on Radiation Education" (ISRE 98), September 1999, p.194.

[4] Jerez, Adoracion, "Development and Validation of Modules for Selected Deficiencies in Physics", Marikina Institute of Technology, 1991.

[5] Deming, C. J., and M.S. Cracolice, 2004. "Learning How To Think" 14 (6): 42.

[6] Bacay, Virginia, D. "Instructional Materials in Thermodynamics as Applied in Refrigerators", Unpublished seminar Paper, Marikina Institute of Science and Technology, 1984.

[7] Alturas, J., "Instructional in Improving Water Potability in High School Classes", Unpublished Seminar paper, Marikina Institute of Science and Technology, 1978

[8] Peterson, J. R., "An Island of Stability. p.54.

[9] Penick, J.E. 2003. "Teaching with purpose". NSTA Reports 14(6): 46

[10] Cutnell, John and Johnson, Kenneth. Physics Southern Illinois University at Carbondale: John Willy and Sons, Inc., 2001 pp. 389-392

7.11 Perception about Radiation by Students and Teachers ----Necessity of Bringing-up of "Radiation Literacy"

学生・教員の「放射線」に対する知識・意識と学校教育での「放射線リテラシー」育成

Seiji KUROKUI and others, Radiation Education Forum
黒杭清治 ほか教育課程検討委員会６名

NPO 法人放射線教育フォーラム

(Abstract) Perception about radiation and nuclear-relate4d matters by students and teachers were studies, and it has proved that the degree of acquisition of the knowledge about radiation by teachers is in general very poor. It is keenly felt that some fundamental policy for improving the present situation should be established for the goal of elevatins the "radiation literacy" of the teachers.

Ⅰ．はじめに

本委員会は 1998 年度に設立して以来、放射線に関連する様々な資料を収集・分析してきた。2003 年度はその一環として、学校教育での「放射線リテラシー」育成のために、教員と学生が放射線についてどの程度の知識・意識調査をもっているかを調べるためのアンケートを行った。本委員会の調査のみでは母集団が少な過ぎるので、日本原子力文化振興財団（以下原文振）が行ったアンケート※と比較しながら考察して見ると、質問事項が異なっていても傾向はよく一致していた。

放射能・放射線は、二酸化炭素・紫外線等と同様に自然界に存在する物質・自然現象の一種として科学的に正しく扱われなければならないが、なぜか特別視され、誤った理解や、いわれのない恐れを抱く者が多いことがアンケート結果に表れている。

※2001 年度に原文振が行ったアンケート。この調査は 4400 人を対象（回収数 2843 人）にし行った大規模なもので、属性を一般市民、理工学専門家、医療関係者、報道関係者、学校の教員に分けて、「放射線という言葉に関する意識調査」という印刷物にまとめられて配布された。

Ⅱ．教員の放射線に対する知識・意識調査

本委員会では放射線に関する事項について、誤りを含む文章、因果関係のない事象を、無理の関連づけて、それがいかにも正しいことのようにマスコミ流表現の文章で 16 問、内容の正しい文章を 1 問作成し、2004.3.15 の**南関東地区エネルギー・環境・放射線セミナー**※受講者 30 名からアンケートを取り、どのような誤解が多いかを調べた。以下はその結果と、受講者に送った解説の一部を削除・加筆したものである。（※ **文部科学省・（財）放射線利用振興協会主催、NOP 法人放射線教育フォーラム共催により、毎年全国 10 地区で開催。主として文系教員を対象にし、総合的な学習の時間に活用できる情報を提供することを目的にしている。**）

調査対象者の内訳　（ ）内数値は人数

性　別　　男 (25)　女(5)　合計(30)
年　齢　　20 代(3)　30 代(8)　40 代(12)　50 代(7)
勤務先　　小学校(3)　中学校(14)　高等学校(8)　中・高等学校(3)　その他(2)
担当教科　小学校全科(2)　小理科専科(1)　国語(1)　社会科(1)　数学(1)　理科(15)
物理(1)　化学(3)　生物(1)　工業(1)　総合的な学習(1)　情報(1)　その他(2)
教職の経験年数　～3 年(2)　～10 年(6)　～20 年(10)　～21 年以上(11)

1. テロが原子力発電所に大形旅客機を突入させると、原子炉は原子爆弾と同様の爆発を起こす（旅客機の墜落事故でも結果は同じ）。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
5（16.7）	5（16.7）	4（13.3）	8（26.7）	7（23.3）	1（3.3）

数値は回答数　(　)内は%　以下同じ

原子炉が破壊されても原子爆弾と同様の爆発を起こすことはない。原子炉内では核燃料（ウラン 235 を３～４％以上含むウラン）が、遅れて出てくる中性子も含めてちょうど臨界に達している程度に制御されている。炉が破壊されて、もし、燃料棒の被覆が壊れて燃料ペレットが周囲に飛び散ったら環境の放射線量は増加するが、原子炉の炉心は臨界状態でなくなり連鎖反応も止まり爆発は起こらない。このように正しく理解している教員は半数しかいないことがわかる。

2．1999 年 9 月茨城県東海村の㈱ジェーシーオー核燃料加工工場での臨界事故で従業員２名が死亡した。このような事故が起こるのであるから原子力発電も安全とは言えない。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
7（23.3）	12（40.0）	6（20.0）	2（6.7）	3（10.0）	0（0.0）

２人亡くなる臨界事故を起こした上記核燃料加工工場は、**高速増殖炉に使う高濃度のウラン燃料を製造する工程中で、八三酸化ウランを硝酸に溶解する作業を、取り扱い上必要な教育を受けていない作業員がマニュアルを無視した手順で行った結果**であり、会社の管理責任が厳しく問われた。この事故に「やはり起こった原子力事故！」「原子力発電安全神話は崩れた！」などと見出しをつけた新聞によって人々の不安が煽られた。しかし、**事故原因になった作業は原子力発電の作業工程にはなく、商業発電を行っている原子力発電所で同様の事故を起こすことはない。原子力発電も安全ではないという理由にはならない。このように区別できている教員は上記１．より少なく、わずか 16.7％である。**

3．高速増殖炉「もんじゅ」が原子炉冷却用のナトリウム漏れを起こし、名古屋高裁が二審判決で「もんじゅ」の設置許可処分の無効とする判決を言い渡した。このことにより原子炉でいつ事故を起こしてもおかしくない証拠が出来たと言える。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
3（10.0）	8（26.7）	10（33.3）	5（16.7）	3（10.0）	1（3.3）

高速増殖炉「もんじゅ」の事故は、２次系で冷却用ナトリウムが漏れたもので、原子炉本体の事故ではなく、放射能・放射線漏れは全く起こしていない。高裁判決の理由は設計基準に対する見解の相違であり、**専門家ではない裁判官が専門的知識を十分に理解できていない結果**とみるべきである。やがて最高裁で科学的に正しい結論が下されるであろう。

開発途上の実証炉「もんじゅ」がトラブルを起こしても、方式が「もんじゅ」と全く異なる商業運転中の原子炉も安全ではないということにはならない。このように正しく区別できている教員は 26.7％である。

4．東京電力福島第二原発で原子炉のシュラウドに生じたひび割れを隠していたことが露呈した。もし、このまま放置してシュラウドが破損したら大事故になるところであった。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
6（20.0）	11（36.7）	2（6.7）	5（16.7）	3（10.0）	3（10.0）

シュラウド：炉心の圧力容器内にあって、円筒形のステンレス製品、燃料集合体とその付属物を囲んで燃料を支持している。また下から冷却水を流す隔壁の役割と、仮に冷却水がなくなる事故が起こったとき炉心

を冷却する水位を保つ役割をしている。原子力発電所では日常点検を行っているから、ひび割れが大きくなり、水が漏れ出す状態まで放置する事は考えられない。たとえステンレス製のシュラウドが突然破裂していても、緊急冷却水が自動的に圧力容器内に入り、制御棒が燃料集合体に入って連鎖反応を止めてしまう。

今回の「ひび割れ隠し」とは、点検した技術者がその時点で直ちに修理する程のひびではないと判断して報告しなかったという出来事で、そのような姿勢は厳しく問われ、安全管理体制が一段と厳しくなった。情報公開が進んできたので、今後同様の事が再発することはないであろう。

正しく理解している教員は上記3。と同様26.7%しかいない。

5．原発、原子力産業関連企業・研究機関で度々放射能漏れ等の事故があり、その危険性がマスコミによって警告されているにもかかわらず、原子力関係の研究者がそれらの警告を否定する発言を耳にすることがほとんどないのは、専門家も原発の安全性に自信がもてないことの証拠である。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
3（10.0）	3（10.0）	12（40.0）	6（20.0）	4（13.3）	2（6.7）

実際には**原子力施設での事故率は他の産業より低い**※にもかかわらず、原子力発電所を含めて**原子力関係施設で度々放射能漏れの事故を起こしているように思っている一般市民は多い**。それは、日頃**マスコミがいかにもそう思わせるような報道姿勢**を取っていることが原因になっているのであろう。

※岡　芳明氏（東京大学工学系研究科原子力工学研究施設　教授）によると、スイスの研究所で 4290件の事故の統計を分析したところ、原子力発電の発電電力当たりの死者数を1（チェルノブイリを含めて）とすると、水力101、石炭火力39、ガス火力10となる結果が出たという。（エネルギーレビュー2004.1号より引用）

一般市民が原子力関係の研究者（以下専門家と記載）から話を聞く機会は少ないし、専門家がどのように考えているかもわからないのは事実であろう。専門家の中には、原子力は危険であるから原発は廃止すべきであると思っている者もいるが、多くの**専門家は自信がないというより、何をどう説明しても一般市民は聞く耳をもたない、半ばあきらめの心境**になっている者が多い。この**一般市民とのギャップを埋める**ために専門家は、たとえば、一般市民が参加したくなるようなイベントを企画し、理解できるような解説を工夫するべきであろう。

この質問にはやや無理があったようで、どちらとも言えない、わからないを合計すると46.7%になってしまった。

6．原子力推進が国策であるにもかかわらず、それを選挙公約にしている国会議員候補者は一人もおらず、学習指導要領での取り扱いも少ないのは、国が原発の安全性に自信をもっていない証拠である。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
7（23.3）	6（20.0）	3（10.0）	10（33.3）	2（6.7）	2（6.7）

資源の乏しいわが国では、**原子力発電は電力の基幹安定供給源として全電力の 35%程度を賄うために推進すべきであるという考えが国策**になっているが、このことを知らない一般市民が多い。

選挙での公約に、新エネルギー・燃料電池の推進を唱える候補者はいても、**原子力推進を唱える候補者が一人もいないのは、それが票に結びつかず、**落選の恐れすらあるからである。国会でも原子力問題はほとんど議題にならない。

現在の学習指導要領は原子力に限らず教育内容を大幅に減らしてしまった。しかし、学習指導要領から原子力関係の項目を完全に無くした訳ではなく、教科書から記載が消えた訳でもないが、原子力は、触らぬ神にたたりなしとの考えが働くのであろう。この問も答えにくかったようであ

るが、問の通り打と思っている教員が43.3%もいるということに考えさせられてしまった。

7. 高レベル放射性廃棄物の最終処分方法が技術的に未解決のまま原子力発電を続けているのは国が問題点を先送りしているからである。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
8 (26.7)	10 (33.3)	8 (26.7)	4 (13.3)	0 (0.0)	0 (0.0)

技術的に未解決と思っている教員が60%（2）達している。最終処分場の設定などが先送りになっているのは事実であるが、**高レベル放射性廃棄物の最終処分方法は技術的には解決されている※。先送りになっているのは地元の合意が得られない、政治的に解決出来ないことが原因である。その通りだと思っている教員が**60.0%**もおり、そう思わない教員はわずか**13.3%**である。**

※まず、カラスと混ぜて水に不溶の「ガラス固化体」にし、腐食しにくい容器に入れて30～50年間程度冷却のために貯蔵する（既に青森県六ヶ所の貯蔵施設で保管されている)。その後、地下300mより深い安定した地層に埋蔵する方法が基本的に取られることになっている。

8. 原子力発電から撤退する国が増加している中で、わが国がリスクを負ってまで原子力発電を推進しているのは経済性を優先しているからである。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
1 (3.3)	12 (40.0)	7 (23.3)	8 (26.8)	2 (6.7)	0 (0.0)

日本が原子力推進を国策にしているのは経済性ばかりではなく、子力だけを使おうとしているのでもない。**原子力を電力安定供給のベースに位置付け、火力、水力などを次のように最も合理的な組み合わせて（ベストミックス）使っている。**

しかし、新しい原子力発電施設の建造費は地元への保障を含め、必要以上に安全設計を図ることになるなどで、一機 4000 億～5000 億円程度かかると言われ、地球温暖化防止対策にはなっても、経済的に得策でないという事情も生じている。**経済を優先するのであれば、原子力発電より石炭火力発電の方が有利**であるとの意見もある。

日頃考えていないことを聞かれて戸惑ったのであろう。答えは全体に広がってしまった。

9. 原子力発電所を、送電ロスを無視してまで都会の遠隔地に建設しているのは、事故が起きたときの被害を最小限にくい止めるためである。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
10 (33.3)	8 (26.7)	7 (23.3)	4 (13.3)	1 (3.3)	0 (0.0)

原子力発電所は原子炉を**冷却するために多量の水が必要**なため日本では海岸が選ばれる。また**地震での倒壊を防ぐために活断層がなく**、第三紀層のような**堅い岩盤の上**に、その地域で考えられる**最大級の地震に耐えられる構造でないと建造が許可されない**。そのためには古文書まで調べて現在原子力発電所のある場所が選ばれたのであって、**結果的に都会から離れた過疎地**になっている。そして、仮に事故が起きたときのことを考えると、人的被害は最小限にくい止められることになるから、全く無関係とは言い切れないが、人口の集中している都会に原力発電所の建設に適した条件の所はないので、都会からの遠隔地にあるのは結果であって、主たる理由ではない。

60.0%の教員がその通りだと思っている。

10. 原子爆弾の被爆を世界で初めて受けたわが国は、原爆と表裏関係にある原発を含め、原子力の利用を永久に捨て、核兵器の恐ろしさを世界に訴えていくべきである。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
3 (10.0)	7 (23.3)	3 (10.0)	11 (36.7)	6 (20.0)	0 (0.0)

核兵器は廃絶すべきだが、原子力は発電のみならず、放射線が研究の他、医療、非破壊検査、工業製品の品質改善、育種、発芽防止などに使われており、**生活を豊かにするためにも原子力・放射線の利用を推進**した方がよい。危険なものを遠ざけるのではなく、安全管理を厳重にして活用するのが人類の英知である。この問の文章は極端な書き方になりそう思わない教員が５６．７％になった。

11. 原発を止めても、太陽・風・地熱・風波、燃料電池、その他の代替エネルギー利用、新エネルギーの開発により必要なエネルギーを確保することができる。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
4 (13.3)	5 (16.7)	7 (23.3)	7 (23.3)	6 (20.0)	1 (3.3)

今後技術開発が進んだとしても、**新エネルギーは**総使用電力の補完的な使い方しかできず、**今後の開発を見込んでも基幹産業の大電力を賄うことはできない。**

太陽、風、風波は天候に左右され、安定供給ができない。安定供給をするためには電力貯蔵技術が必要になるが現在の見通しでは経済的に成り立たない。

太陽電池パネルは製造に高額の費用を要し、大量の電力を必要とする。家庭の屋根などに小規模に設置するなら効果があるが、パネルの裏側は日陰になるから、大電力を得るために広大な面積に太陽電池パネルを敷き詰めると生態系が変化することになる。

その他の自然エネルギーも大規模にするほど環境破壊につながるので設置には限界がある。

燃料電池は今後の開発により改善されるであろうが、原子力発電の代替にするほどの発電量にすることはできない。

今後、比較的注目されているのが廃材などを使う**バイオマス**で、デンマークでは全発電量の30％近くをバイオマス発電に頼っている。

この問も正しい理解者が多かった。

12. 女性の放射線関係従業者には子孫に奇形児の生まれる確率が高い。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
0 (0.0)	6 (20.0)	9 (30.0)	7 (23.3)	5 (16.7)	3 (10.0)

男女に関係なく、子孫に奇形児が生まれたり、本人が白血病などになったりする確率が高くなるような統計はない。**一般の人と変わらない。**

13. ジャガイモの発芽防止、品種改良などに放射線照射が行われているが、残留放射線の影響が心配である。食の安全確保のため食品に放射線照射をするべきではない。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
5 (16.7)	6 (20.0)	8 (26.7)	7 (23.3)	4 (13.3)	0 (0.0)

電気を消せば灯りが消えるように**放射線照射を止めれば放射線が残ることはない。**強烈な放射線を照射すれば細胞が破壊され、元素の壊変が起こるが、食品、品種改良に使われる放射線量は桁違いに少ない。食品への放射線照射が認められているのは、日本ではジャガイモの発芽防止のみであるが、諸外国では多種類の作物にわたっている。

14. 胸部Ｘ線撮影によって受ける放射線量は、自然界から１年間に受ける放射線量より多い。

強くそう思う	そう思う	どちらとも言えない	そう思わない	全くそう思わない	わからない
0 (0.0)	8 (26.7)	4 (13.3)	5 (16.7)	9 (30.0)	4 (13.3)

思うか』との問いを設けたところ、たぶんそうなるだろう(76.1%)、そんなことはありえない(19.6%)、無回答(4.3%)であった。受講中の学生でも８割近くがこのような誤った記事を信用してしまうのである（図２）。そのため原子力発電所はいつか必ず事故を起こすと思っている者が多く、「優秀な管理者が管理しているから安全」と思っている者は 6.5%に過ぎない（図３）。

教科書にはさすがに爆発とは書いてないが、核戦争なみの放射能被害を生ずるという表現は、やはり誤りである。

学生が以上のように放射線を怖がったり、誤った知識をもったり、偏った見方をするのは、高等学校卒業までの間に、マスコミから原子力に関する出来事について大げさで不安を煽るように報道するのを見聞きし、放射線は怖いと感じ、原爆を連想する教員がそのように教えるからであろう。児童・生徒はマスコミと教員からの影響を二重に受け、親兄弟も同様の考えをもっている場合は三重。四重に影響を受けていることになる。

原文振のアンケートによれば、放射線と聞いて直感的に「怖い・不安」と感じるのは６属性のうち一般市民（未成年を含む）のみである。 このような気持を抱く一般市民を育ててしまった報道関係者と学校の教員の責任は重大である。

Ⅳ．おわりに

教員の本アンケート結果をどのように読み取るかは人によって異なるであろう。まあこの程度の知識・意識なら問題は無かろうと思う向きもいるであろうが、調査対象は、始めに示したように南関東地区エネルギー・環境・放射線セミナーの参加者であるから、放射線について知識を得ようとしている積極的な教員と見て良い。また、主として文系教員を対象にしているが小・中・高等学校全教科教員を受け付けており、30 名中 22 名（73.3%）は理系教員である。理科教員の多い母集団としては余りにも知識・意識が低すぎると思わざるを得ない。無差別抽出でアンケートを取ったらどのような結果になるであろうか。

母集団が 30 名のみでは結論が出せないが、原文振の調査でも、質問内容は異なるものの、意識の程度は同様の結果が出ている。原文振では小・中・高等学校の教員 800 名にアンケートを送り、回収率が一般地域で 14.6%、原子力施設立地県で 19.3%、平均 16.5%であった。それでも回答した教員は多少なりとも放射線に対して関心がある方だと思うが、その教員の放射線に対する知識は報道関係者よりも低い。回答しなかった 80%以上の教員の放射線に対する知識・意識の程度が想像できる。

いま社会問題にまで発展している学力低下問題、特に理数科学力低下の原因は、実は教員の教育力低下ではないだろうか。このことは、以前より一部の識者に指摘されていたが、文部科学省は教員の再教育にあまり熱心ではなかった。最近になって東京都が平成 １８年度より若手教員の指導力向上のための「教師道場」を開く計画を発表するなど、ようやく現職教員の再教育の必要性について、行政が教員の教育力低下を懸念しはじめ、積極的な対策を取ろうとする姿勢が見られるようにうなった。

科学技術の進歩が激しい分野を担当する理科教員は言うに及ばず、新設された「総合的な学習の時間」の指導は全ての教員が当たらなければならないから、自分の担当教科領域を越えた幅広い知識をもっていなければ的確な指導はできない。全教員がエネルギー・環境問題を科学的に正しく考えることができないと児童・生徒に多大の悪影響を与えることになる。

放射線に対して無知な者程放射線を怖がる。マスコミが不安を煽るような報道をしようとも、それに惑わされない教員になるために、現職教員は放射能・放射線について一定の研修を受け「放射線リテラシー」を育成させることを義務づけることが必要である。

7.12 An Example of Radiation-Education Experiment Using a New-type Handy Cloud Chamber

新型簡易霧箱を用いた放射線教育実験

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Abstruct:

We have developed a new-type handy cloud chamber to overcome shortcomings in the conventional handy cloud chambers. The new-type handy cloud chamber has such advantages as: no dangerous parts or tools are used; can be assembled quickly; has a wider observation window; much less expensive, etc. We have also prepared a new text for this cloud-chamber kit to explain the basic theory of radiation and radioisotopes, which is divided into two levels for children and for adults. Using this new-type handy cloud chamber, we propose an example of an educational experiment on radiation and radioisotopes which can be carried out within one hour.

1．はじめに

放射線あるいは放射性同位元素（ラジオアイソトープ）は、その特性をうまく使えばきわめて有用であり、すでにエネルギー源としてあるいは生命科学、医学、農学、工学等の広い分野で利用されているが、扱い方を誤れば人体に対して有害な危険性を併せ持つ。これは放射線・放射性同位元素に特有のことではなく、火や電気などと全く同じことであるが、様々な要因から社会的には正しいとらえ方がなされているとは言えず、危険性に偏ったイメージが先行することも多い。

原子力を含めた放射線・放射性同位元素の応用の健全な発展のためには、専門家はもちろん、子どもや学生を含めた一般人もレベルに応じた形で放射線に対する正しい科学的な認識を持つことが臨まれる。そのためにはいろいろな角度からの啓蒙・教育が必要となるが、特に身の回りに普遍的に存在している環境中放射性物質・放射線の存在を体験的に教えることはこの目的を達成するために有効なアプローチであると考えられる。放射線は五感で捉えられない事がその潜在的恐怖心を助長していると言われるが、放射線を肉眼で「見る」ことができる霧箱による実験は、このような観点から優れた教育教材であり、実際にこれまでもよく利用されてきた。

霧箱は始め（1912年）C.T.R.ウィルソンにより断熱膨張型のタイプが開発され、以来様々な種類の霧箱が研究用あるいは教育用に利用されてきた。教育用としても、大仕掛けで高価なものから、廉価な簡易型のものまで様々な種類があり、それぞれ長所と欠点がある。ドライアイスを利用した温度勾配により蒸気の過飽和状態を作り出す拡散型の霧箱は比較

的簡易な教育用としてしばしば利用されている。ここでは我々が開発した新型簡易霧箱を紹介し、それを用いて1時間程度で行う、子供から一般成人までを対象とした放射線教育実験の一例を提案する。

2．新型簡易霧箱の構成

ここで提案する霧箱は従来型の簡易霧箱の欠点を改良した新しい簡易霧箱キットであり、次の部品から作ることができる（Fig. 1）。

・本体としてのフタ付き角形プラスチック透明容器（約 7x7x12cm）

・粘着スポンジテープ（幅約 1 cm）

・黒の塩ビ製シート（容器底面に収まる大きさ、厚さ約 0.2 mm）

・スポイト（あるいはプラスチックシリンジなど。アルコール滴下用。）

その他にドライアイス、エタノール（数 ml）、懐中電灯および放射線源（天然ウラン鉱石、トリウムを含有したガスランプ用マントルなど）が必要である。

なお本簡易霧箱は 2004 年に実用新案登録されている；第 3100601 号。

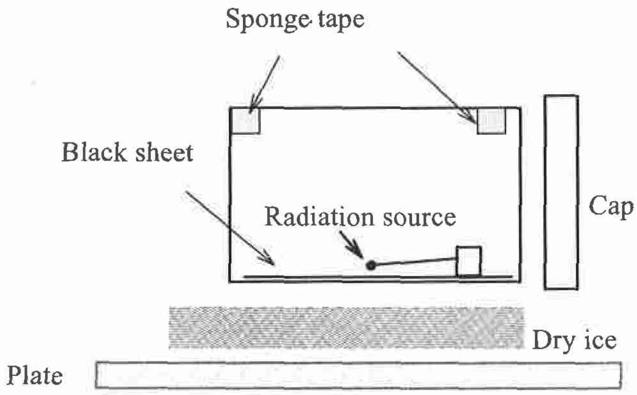

Fig. 1 Set-up of a cloud chamber

3．利 点

これまで我々の研究所（およびその関連する団体）ではしばしば一般社会人あるいは児童生徒を対象に放射線教育実験セミナーを主催あるいは支援開催してきた。その際使用していた簡易霧箱は、かつて当研究所で開発されたものであり有用なものではあるが、いくつかの不具合もあった。

今回提案する新型簡易霧箱は従来型に比して：安全性を考慮し危険性のある鋭利な部品や道具を用いていないため、小学低学年からの利用にも適しており、霧箱の組み立て時間が短く（約５分）、１時間程度の間に数種の実験を行うことができ、しかも観察した現象を十分詳しく解説する時間もとれる。また放射線の観察視野が広く、廉価であるなどの利点を有する。

また今回、この新型簡易霧箱キットの「組み立てマニュアル」に加え、小学低学年から成人まで共用できる放射線に関する「解説テキスト」を新しく作成した。テキストでは放射線の基礎的性質に関する内容を、フォントサイズも含めて２つのレベル、すなわち小・中学生を対象とした初級レベル、および高校生以上の中級レベルに分けて記述した。初級

レベルではできるだけ専門用語を避けて、絵を用いて放射線の基本的性質と身の回りにも放射線が存在していることを簡単に示した。中級レベル用には、「原子・分子・原子核・電子・半減期・放射性壊変・放射性同位元素・α線・β線・γ線・中性子線・半減期・飛程・透過力・シーベルト・ウランの壊変系列・ラドン・放射線利用」など放射線に関する基礎的事項についても簡単な解説をした。

テキストにはこの霧箱で観察したα線の典型的な飛跡の写真もつけてあるので、実験者が家に帰ってから実験で見た内容を家族に伝えることも容易になった。また組み立てた霧箱を持ち帰って家で実験をすることもこれまでより容易になっており、このことは放射線教育の波及効果としても意味があると考えられる。

４．実験例

この新型簡易霧箱を用いた１時間程度の放射線教育実験として次のような内容を提案したい：

①実験の概要と放射線に関する解説（15分）
②霧箱キットの説明と組み立て（5分）
③自然放射線の観察（5分）
④ウラン鉱石を用いたアルファ線飛跡の観察（10分）
⑤ラドンの観察（10分）
⑥最後の補足と質疑応答（10分）

・・・合計55分程度

以上の実験指導手順・内容をやや詳しく以下に示す。

00:00　①実験の概要と放射線に関する解説（15分）

○「放射線」に関する基礎的な事項を解説する。テキスト中の図を利用。（見やすい大きな解説図を準備するのもよい）。内容は参加者の学年・年齢によってレベルを考慮する。（小学生、中・高生、大人）

00:15　②霧箱キットの説明と組み立て（5分）

○スポンジの粘着テープ保護紙をはがさないで一度練習する。霧箱容器は机に置いた方が安定してやりやすい。人差し指と中指の先でスポンジテープを横から挟み、容器に指を差し入れて奥側の貼る位置を確認する。手前側は、端から5-6 mmほど内側の位置。次に保護紙をはがし、実際に貼る。

○線源の針金をゴム栓の横に刺し直し、ゴム栓を置いたときに線源部が底面から3-5 mm程度に位置するようにあらかじめ調節しておく。

○シリンジでアルコールを2 mlほどスポンジ（２本）に滴下する。

○黒いビニール板を文字の有る側に置く（底面と隙間がないことを確認）。

○線源の先端が底面の中央付近になるよう黒いビニール板の上に線源を置くきは、その位置がずれないように静かにフタをする。

00:20　③自然放射線の観察（5分）

○ドライアイスを断熱材の上にセットする。（※ドライアイスには素手で触らないよう注意する。）板状のドライアイスが入手できる場合はそれを利用するが、ブロック状の場合は砕いて粉末状にして利用する。

○霧箱をドライアイスの上に乗せる。この時本体が水平になるよう注意する。

○実際には自然放射線の飛跡が観察できる確率は小さいが、まれに空気中の天然ラドンガス（主にRn-222）などによる飛跡が見られる場合もある。

00:25　④ウラン鉱石を用いたアルファ線飛跡の観察（10分）

○灯りをつけ、フタを開けてウラン鉱石線源を容器中央にセットし、フタを閉じて霧箱をドライアイスの上に乗せる。この時線源の位置・高さに注意する。

○室内を暗くし、ウラン鉱石の線源から花火のように放射される放射線を観察する。ライトを向こう側のほぼ水平方向から、飛跡が一番よく見える角度で照らし、上から覗いて観察する。

○この時飛跡が流れて乱れる場合は、高さ調節用段ボール紙をさし込んで流れてゆく方を少し高くして霧箱底面を水平にすると、飛跡が乱れず安定して観測できるようになる。

○飛跡の太さ、長さを観察する。アルファ線が空気中で数センチしか飛ばないことを確認。ただし過飽和層（有感層）の中でしか飛跡が見えないことを注意。横からも観察する。

00:35　⑤ラドンの観察（10分）

○灯りをつけ、フタを開けて線源を取り出す。

○フタをして半分ほど開け、トリウムを含有したガスランプ用マントルから放出されるラドン（Rn-220、トロンともいう）を含んだ空気をプラスチック容器から吹き込んですぐフタをする。

○ドライアイスの上に霧箱をセットし、灯りを消して、ラドンからの放射線の飛跡を観察する。

○「V」サイン状に見える飛跡があることを観察。その理由は始めの説明時間に説明しておくのがよい。数分観察していると、見られる飛跡の数が減ってくる（Rn-220の半減期である56秒毎にほぼ半分になる）ことにも注意する。これは肉眼による「半減期」の確認である。

00:45　⑥最後の補足と質疑応答（10分）

○灯りをつけ、ドライアイスを回収。

○実験に関する補足の説明をする。質問があれば答える。

○特に、身近な自然環境にも放射線が存在し、我々が常に微量の放射線に接していることを理解してもらう。

○霧箱のフタは乾燥のため開けて持ち帰ること、また家で実験するときの注意（ドライアイスの扱い方、線源の廃棄法）等を説明する。

00:55　終了

以上の実験で、天然ウラン放射線源からは花火のような放射線の飛跡が見られ、またトロンからの飛跡が「Vサイン」に見えることは特に子どもにも興味をもって受け入れられるようである。さらにVサイン状の飛跡が観察される意味を考えることは、高校生以上成人にとっても放射線壊変系列や半減期などに関しての理解を深めるよい実験材料となる。すなわち、トリウム（Th-232）からの壊変系列中に希ガスのラドン（トロン、Rn-220）が生

まれ、半減期56秒で減衰してゆく。その壊変の娘核種であるポロニウム（Po-216）が0.1秒の半減期なので、最初の放射線を出した直後にポロニウムが再度放射線を出すため、それらの放射線の放出位置と角度により、Ｖサイン状の飛跡が見られるのである。

ウラン鉱石からのアルファ線の飛跡とトロンからの飛跡の長さに違いがあることも、放射線のエネルギーと飛程の関係を考えるよい材料になる。

また別な実験としては、集塵機あるいは掃除機などでろ紙上に空気中の塵を集め、ろ紙を竹串かクリップなどに挟んで試料とすると、空気中で塵に付着しているラドン娘核種からのα線を観察することも可能である。また磁石を近づけてアルファ線の飛跡が曲がることを観察させることも考えられる。このような身近な放射線の観察実験は、放射線やラジオアイソトープに対する不必要な恐怖心を和らげ、科学的な正しい理解を得るために有用である。

筆者らはすでに本装置を用いて上記のような実験を小中学生、あるいは東南アジア人の放射線関係の研究者に対して行ってきたが、その有用性を確認することができた。

５．結 言

この新型簡易霧箱を用いることにより、小学生低学年から成人までを対象にして、１時間ほどの時間内で数種の実験を行い、安全で、放射線に関してより深い理解が得られる教育実験が可能となった。本装置が放射線教育の場でより広く利用され、放射線の正しい理解を広げる一助となることを期待したい。

7.13 Response from Youths and Teachers with Regard to the Encyclopedic Database on Nuclear Power, ATOMICA

原子力百科事典データベース ATOMICA に関する若年層及び教師の反応

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Abstract

An encyclopedic database on nuclear power and its related fields, commonly named ATOMICA, was first established and released on a PC communications basis in 1995. The database started to be operated on the internet in October 1996. Now ATOMICA contains more than 2,300 encyclopedic data which include tables and figures over 9,300 in total. The fields the database covers are categorized into 18 areas: energy and environment, nuclear power generation, advanced reactors, fuel cycle, back end technology, safety research, basic and advanced research, radiation application, radiation influence and protection, governmental policy, regulation and rule, statistics of operation of nuclear facilities, international cooperation, etc.

The number of access to the database has increased steadily, reaching more than one and a half million a year in 2003. The influence of and protection against radiation are most frequently accessed being followed by energy and environment, nuclear power generation, and nuclear fuel cycle and status of foreign countries. People with different backgrounds are believed to have an access to the database.

This paper gives firstly an overview of the activities on the establishment and maintenance of ATOMICA including its historical background. Then accesses to the database are analyzed form the aspects of their number and fields. PA Center has also received questions and comments on the database from various people. In this regard the features of questions and comments are summarized with special reference to those from youths and teachers as well as from general public. This is done to elucidate the requirements to the database from the viewpoint of education. In general youths and teachers are interested in the characteristics of radiation in the nature and from

nuclear facilities. They are concerned about the effect of radiation on human bodies. Besides radiation the areas they pay keen attention to are mechanism of fission and principle of nuclear power generation. From these facts it is believed that the database for youths and teachers should contain a set of systematic data which is attractive and easy to understand covering the microscopic characteristics of matter, radiation, and principles of nuclear energy. In this paper, structure and contents of good database for youths and teachers are discussed and future activities will be presented.

[要旨]

原子力や放射線に関する百科事典的データベースであるATOMICAはインターネットを通じて一般に供されている。ここでは、このデータベースを紹介するとともに、データベース及び関連事項についての質問、コメント等のうち特に学生や教師からのものを抽出・解析して教育的観点から望ましいデータベースの内容を検討した。その結果、放射線、原子力に関する基礎的事項及び人体への影響についての関心が高いことが明らかになった。

1．はじめに

原子力・放射線に関する知識・情報は、物理・化学・生物・数学などを基礎的分野から、広範囲の応用分野にまで関連しており、容易には理解できない面がある。また、国民の一部には、原子力・放射線に対する不安や疑問があることも否定できない。原子力・放射線及び関連する分野の多くの知識･情報を理解しやすい形にまとめ､国民に提供することは、これらの問題を解決する一助となると考えられる。この際、知識・情報の科学的技術的公正さが必要である。このような視点からインターネット（http://mext-atm.jst.go.jp/atomica.html）でアクセスできる情報をデータベースにまとめて提供することで、国民の原子力・放射線に対する理解に役立てることを目的としたのが原子力百科事典である。

2－1．原子力ＰＡ用情報検索システム開発の経緯

「原子力ＰＡ用情報データベース」については、平成元年(1989)に科学技術庁（現文部科学省）から日本原子力研究所（原研）に「原子力ＰＡ用情報検索システム」の開発要請があり、これを受けて原研で開発が始まり、その後、（財）高度情報科学技術研究機構（RIST）の前身である（財）原子力データセンター（NEDAC）が平成７年(1995)３月から「原子力百科事典ATOMICA」としてパソコン通信で公開運用を開始した。平成８年(1996)10月からインターネットによる運用（平成14年(2002)度から（独）科学技術振興機構が運用）し、現在に至っている。

システム開発の目的は、国民の原子力に対する疑問にすみやかに応え、効果的にＰＡを支援するため、旧科学技術庁傘下の原子力関係機関の保有する原子力ＰＡに有用なデータを整理･統合し､原子力ＰＡを支援するための情報検索システムを作成することであった。

また、原子力ＰＡ用情報検索システム（情報検索システム）のデータ利用者として、当初は、原子力ＰＡに携わる講師、行政府の政策立案者、原子力発電所立地サイトの原子力連絡調整官と、将来のユーザーとして、報道関係者を想定しており、その後、各機関の広報担当者、立地自治体（道府県・市町村）の原子力担当部署にいる方々、大学・高校・中

学校の先生、各界・各層のオピニオンリーダーなどを含めた。

実施に当たって原研は、情報検索システムの構築、原子力情報（試験データ）の取りまとめと作成、データの構造化、原子力ＰＡ用情報検索システム検討委員会の事務局、「NEWSLETTER」の発行及び受託事業の総括を担当し、これらの業務は放射線医学総合研究所、動力炉・核燃料開発事業団（現在の核燃料サイクル開発機構）、（財）原子力安全研究協会、（財）日本原子力文化振興財団、（社）日本原子力産業会議等の原子力関係機関・団体の協力を得て行われた。協力いただいた事項は、検討委員会及び専門部会への参加、実際の原子力情報の提供、試験データの評価、学識経験者を含む約350人の限定メンバーをユーザーとして想定した３年余りに及ぶ実用試験（商用全国通信ネットワークを介するパソコン通信）などであった。

情報検索システムの全データは、平成６年(1994)の時点で、エネルギーと電力、国の方針・計画、原子力発電の技術と現状、安全規制と運転管理データ、安全研究と新しい原子力（核融合など）、放射線、国際協力と海外動向、Ｑ＆Ａなどの分野に大きく分類されている。また、平成６年(1994) ３月には、情報検索システムの愛称が「原子力百科事典 ATOMICA」に決まり、公開運用できるレベルのデータベースとして整備された。その後、平成６年(1994) 10月に、NEDACは「原子力ＰＡ用情報データベースのネットワーク運用」の事業を旧科学技術庁から受託し、原研から「原子力百科事典 ATOMICA」を引き継ぎ、準備期間を経て、平成７年(1995) ３月22日からパソコン通信による公開運用を開始した。

２－２．インターネットによるシステムの運用開始

平成７年(1995)度は公開運用の実質的な初年度に当たるので、「原子力百科事典 ATOMICA」の公開運用を継続するとともに、ユーザーの利用便宜を向上するため、ATOMICAの新規データの加工と旧データの更新、用語辞書の作成、検索キーワードの整備、文字データのSUMMARY（要約）を選択的に出力させる新出力機能の作成、図表データをパソコンＣＲＴ画面に表示させるダウンロード機能の付与、利用者管理プログラムの改良のほか、通信速度を高めるなどのパソコン通信における通信環境の改善を実施した。平成８年(1996) 10月には、インターネット版の運用を開始し、急速に普及した通信環境に対応した整備を行い、ユーザーへのサービス向上に努めた。平成９年(1997)度にはパソコン通信版を停止して、インターネット版のみの提供となり、インターネット版検索ソフトウェアの幾つかの改良を行うとともに、新データの増加等に対応するため、大項目を中心にデータ全体の構成番号を見直して、データの置き換えを行い18分類とし、現在に至っている。

平成12年(2000) 10月から「原子力百科事典ATOMICA」システムの運用がＪＳＴに移行した。平成13年(2001) １月６日以降は、「原子力図書館げんしろう」の中で、「文献データベースNUCLEN」とともに原子力ＰＡ用情報データとしてATOMICAが公開され、平成13年(2001) 10月からは独立行政法人科学技術振興機構が運用している。

３．「原子力百科事典ATOMICA」データベースの紹介

継続的にデータベースを利用するユーザー層を拡大していくためには、日頃から原子力動向と関連する資料・情報を収集し、ユーザーのニーズに応えてATOMICAデータに反映させることが必要である。理解しやすい図表を備えた、新鮮で信頼性の高い良質なデータの

作成および更新ができるよう、それぞれのデータは、できるだけ分かりやすい図表を用いて、原子力関連機関などの研究者・技術者の方々のご協力により、公正・的確にまとめてある。データ内容の記述は、高校の教科書が理解できるレベルを目標として、本文のテキストデータ（平成16年(2004) 8月現在で2,401件）と図表のイメージデータ（平成16年(2004)年8月で約9,900件)、用語辞書2,213語で構成されている。新規データの加工の際には、前述のユーザーを念頭におき、原子力に関心をもつ国民に参考になるように留意してデータタイトルを決定している。例えば、地球環境問題とエネルギー、国際的に安全上の問題が指摘された旧ソ連型原子力発電所、原子力行政とＰＡに影響を与えたもんじゅのナトリウム漏洩事故、阪神淡路大震災で関心がもたれた発電炉施設の耐震試験、産業廃棄物からの放射線漏洩事故等に注目してタイトルを決定している。

データベースの構成は、大項目としてエネルギーと地球環境、原子力発電、開発中の原子炉及び研究炉、核燃料リサイクル、バックエンド対策、原子力安全研究、基礎研究、放射線利用、放射線影響と防護、原子力安全規制、国際協力・原子力関連機関、海外情勢、Ｑ＆Ａ、放射線と原子力に関する歴史とトピックス、原子力年表、原子力基礎データなどの原子力に関わる幅広い知識・情報が含まれている。

４．「原子力百科事典ATOMICA」の現状

平成8年(1996)度からインターネットによる公開が始まり、その後、いくつかの残念な事故がきっかけになったと考えられるアクセスも含め、原子力百科事典ATOMICAデータへのアクセス数が急速に増加した（図１参照：ATOMICA データベースアクセス件数の推移)。特に、平成11年(1999) 9月30日（株）ジェー・シー・オー（ＪＣＯ）における臨界事故の際には、ユーザーからのアクセス数の増加にシステムが対応できず、一時的にシステムがダウンするという事態になった。その後も何か関連の動きがあると、電話、メールなどによる問い合わせが、アクセス数の増加とともに増している。

「原子力百科事典ATOMICA」データへの平成13年(2001)度に入ってからのアクセス回数は、これまでの様子から一変して、例年同月の２～３倍の回数に増えている。これは平成12年(2000)度総計の３割以上を２か月で超えてしまう勢いである。その後、利用回数は着実に増加し、平成15年(2003)のアクセス総数は2,343,348と平成14年度の３割増に達するとともに、平成16年(2004)度には毎月30万のアクセス数が続いている。特に、開始当初から同じ傾向であるが、アクセスデータの分野別で一番多いのは「放射線影響と放射線防護」、次に「エネルギーと地球環境」、「原子力発電」、「放射線利用」、「核燃料リサイクル」の順になっている。

平成14年(2002)にATOMICAの利用者を対象にアンケート調査を実施したところ、「ATOMICAデータで必要な情報が入手できた」という方が87%と、システム及びデータの内容が利用者の期待に概ね応えていると考えられる。また、利用者の年齢層は、20代と30代で全体の50%、10代と40代を合わせると83%となり、学生から社会人までの現役の人々の利用が大部分である。国外からの利用者も１%あり、在外大使館や駐在員などで時折、メールや電話での問い合わせがあることからも頷ける。

質問に対しては、それぞれの専門家に内容を確認して間違いのないように、また出来るだけ早く（即日あるいは翌日まで）回答するように努めている。

これまで何度か「原子力百科事典 ATOMICA」の英語版に対する要望が原子力関係者から持ち上がっている。現在では平成12年(2000)度に韓国原子力研究所（KAERI）によりデータベース提供の要請があり、韓国語版「原子力百科事典 ATOMICA」の運用が開始された。また、インドネシアからも同様な要請があり、近々にはインターネットでの公開の運びとなる。

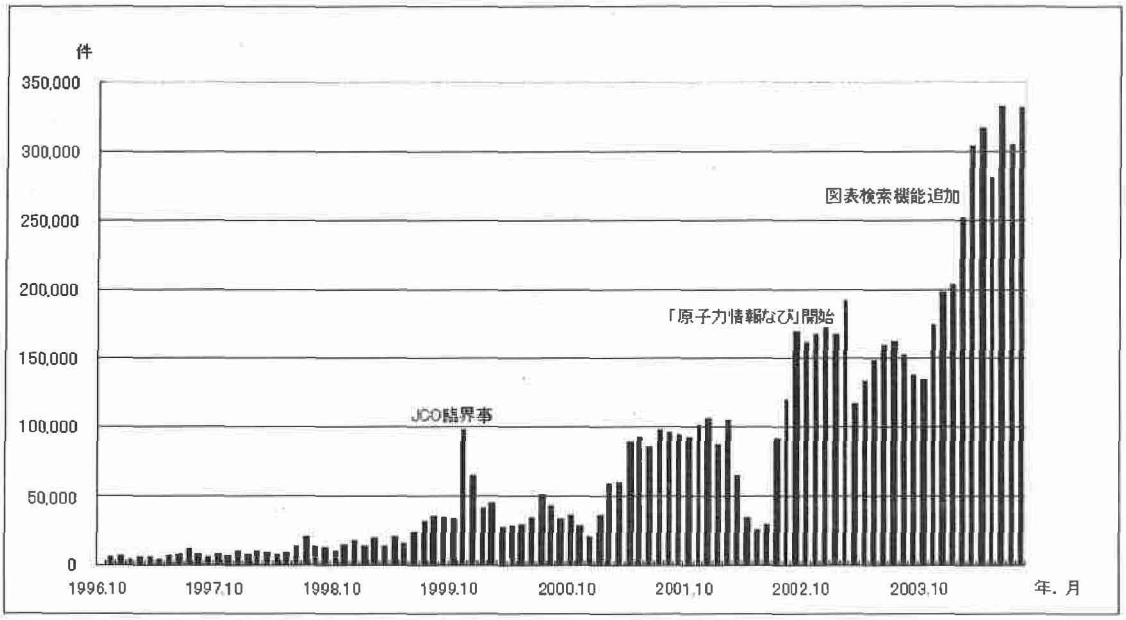

図1　ATOMICA データ（本文）へのアクセス回数の推移

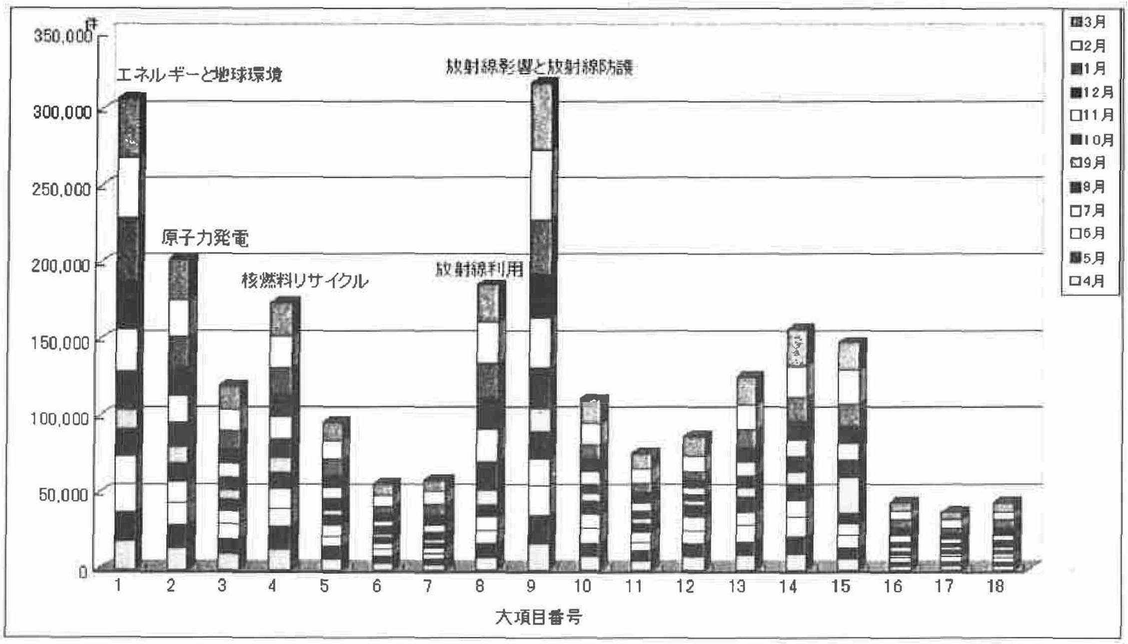

図2　平成15年度　分野別アクセス回数（本文）

５．利用者からの問い合わせ及びコメント

初歩的な内容から高度な知識に関わる内容といろいろであるが、概して専門的な質問内容が多い。その対応には正確を期すために、センターで知り得た情報に加えて専門家に確認してから回答している。いくつかを紹介する。

○小学生から“原子力の長所と短所、危険性と安全性について調べています。原子力の事について教えてください”

「原子力の能力を生かして行われる最新プロジェクトがあるのでしょうか？」

「日本は原子力発電所について、どれくらいの安全性を認めているのでしょうか」

「絶対に事故の起きない原子力発電所は造れるのでしょうか？」

○中学生から“ぼくは、12 歳の中学生です”

「原子力（核）を宇宙（無重力）で爆発させたらどうなりますか？」

○高校生から

「世界初の原発事故と2001年までの原発及び臨界事故の年表はATOMICAのどこに載っていますか」

「ウィンズケール再処理工場事故、サンローラン原発事故、紛失放射線源による被ばく事故などの国際原子力事象評価尺度について、教えてください」

○大学生から

「蒸気配管内での流動状況は気液二相流でしょうか？」

「電子が発見される以前における原子の存在の根拠について教えてください」

○医学部学生から“電離放射線には許容基準が存在し得るのかをテーマに放射線の勉強をしています。放射線量について質問があります”

「感受性の高い細胞の DNA が修復できないほど傷害を負う放射線量はいくらなのですか？」

○大学院生から

「ATOMICA データの“トカマク型核融合装置の研究の進展の図”を論文に引用したいのですが、どのようにすればよいですか？」

○教師から授業をしていて生徒からの質問を受けて疑問を感じた内容として、

「ウランが燃えるとは、どのようなことなのですか？“燃える”とは酸化することなのですか？」

「ウラン 235 が核分裂する際、分裂してできる原子（元素）は何か一定の法則はありますか？例えば、セシウムが何パーセントとか」

「“核分裂する”というのは理解するのですが、分裂したウランはどうなりますか？」

「核分裂したウラン 235 やプルトニウム 239 は、どんな元素に変化するのですか？」

「プルトニウム 239 の使い道は何ですか？そのままだと、核兵器の材料しかならないと思うのですが」

「プルトニウム 239 は、そのまま保管すると熱が発生すると聞いたのですが、どんな理屈で熱を持つのですか？」

「水素爆弾は、そのメカニズムから“核融合爆弾”と思うのですが、なぜ水素爆弾というのですか？」

教育現場の生の声とのやり取りを新たなデータの作成に生かすこともあり、非常に貴重

な情報である、と受け止めている。
また、利用者からのコメントとして、度々、「ATOMICAデータは書籍の形になっていないのですか？」や「原子力用語辞書は書籍の形のものはありませんか？」という問い合わせを頂く。大部分のデータ内容の新鮮さを保つので１年～３年毎に内容を更新しているため、出版物としてのデータ公開については現在、その計画はなく、インターネット版のみの提供となっている。

６．まとめ

データへのアクセス回数の頻度及び利用者からの問い合わせなどから推測すると、利用者の関心は、大項目で言えば「放射線影響と放射線防護」、「エネルギーと地球環境」、「原子力発電」、「核燃料リサイクル」、「海外情勢」などである。アクセス回数の約半分を占めている。また、図表データのアクセスは、「原子力発電」、「核燃料リサイクル」、「エネルギーと環境」、「放射線影響と放射線防護」が多く、この４分野でアクセス回数の約半分を占めている。平成14年(2002)度から図表のタイトルで検索が可能となり、急速に利用頻度が増加している。これらの分野のデータを重点的に構築する必要性を痛感する。

また、利用者からの直接の声であるメールによる問い合わせなどから推測すると、放射線、放射能、核分裂など基本的な用語の説明については、絵図や動画など様々な手段や説明法を用いて理解してもらうことが必要であり、そのために役立つデータを増やしていくことが責務であると考える。

「原子力図書館げんしろう」を構成するものの一つである「げんしろうクイズ」は、公開後すでに5年以上経過しているため、平成15年(2003)には原子力、エネルギー、放射線、環境の４部門における内容の全面的な見直しを行い、すでに新たなクイズとして公開されている。

ATOMICA 利用者の反響や原子力やエネルギーに対する教育現場の状況を踏まえて、現在新たな試みを含めた「キッズデータベース（仮）」を制作中である。現「原子力百科事典ATOMICA」とともに、更に多くの利用者の期待に応えるように進めている。

「原子力百科事典 ATOMICA」のデータ作成に関わる担当者として、アクセス回数が増えることが何にも増して励みである。国民の疑問にすみやかに応え、情報を使い易く整理し、常にデータを更新していくという当初の目標を念頭において、今後もデータベースの整備を進める。

参考文献

（１）伊勢武治、桂　知巳：インターネット版原子力百科事典（ATOMICA)、FUJITSU,49.3 pp235-239(1998)
（２）伊勢武治：原子力百科事典（ATOMICA)、自由空間、Isotope News, pp24-25 (1997)