3. Poster Session

（ポスターセッション）

3 . 1 RADIATION EDUCATION IN BANGLADESH : STATUS NEED & OPPORTUNITIES

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Introduction

Since the emergence of Bangladesh as an independent state, the provision of radiation education and training have expanded greately. Still then, since it is a developing country with high population growth rate, low literacy level and located thousands of miles away from the developed ones, it is difficult to transfer & dessiminate knowledge, particularly about the subject of radiation at a speed & spread as required to meet the challange of future. So, not only professional training but also institutional and formal academic knowledge & skill development is essential in the process of acquisition and transfer of such knowledge. Accordingly the courses on radiation & radioactivety including risk perception in general have to be vigorously pursued for the sake of safety and attaining basic concepts about health effects of different levels of radiation.

Background

For radiation protection purposes, the health effects of ionizing radiation are considered in two classes : deterministic and stochastic. Deterministic effects can occur when relatively large doses are received, causing large numbers of tissue cells to be damaged or killed, with consequent insult to tissue or impairment of organ function. There is a threshold of dose below which deterministic effects are not observed, while above that threshold, the severity of effects increases with increased dose. Radiation protection against deterministic effects can be ensured by keeping doses below the threshold levels.

On the other hand, stochastic effects are usually associated with lower doses and may or may not occur in an exposed individual. The likelihood of occurrence increases with increased dose. No threshold is presumed for stochastic effects and, at low doses, the probability of occurrence of an effect is taken to be directly proportional to the dose received. The most common such effect is radiation-induced cancer, which typically does not become manifest until several years after the initiating exposure.

Scope and Reference of Radiation Education

In consideration of the foregoing, it has to be conceived that at least some general knowledge on the research and application of radoactive materials as well as radiation and radioactivity it self should be imparted to students and concerned members of the public to avoid unmeessary fear of risk and radiophobia.

As such, it is further required to review the current status, need & opportunities of such education in Bangladesh in these fields in the context of National & International regulations and recommendations of IAEA, UNSCEAR, ICRP and Bangladesh Atomic Energy Commission (BAEC). In this connection due provision has been made in Nuclear Safety & Radiation Control Act- 1993 of Bangladesh.

Current Status

Though introduction of Tracer Technology and Nucleonic Control System in Bangladesh is still in the nascent stage,Bangladesh has been experiencing ionizing radiation in the application of X-ray & Gama ray in QA & QC through industrial radiography including food preservation and sterilization of medical products and research investigation in different fields, for example, radio pharmac-eutical, soil science & agriculture, ground water studies, environmental studies, assessment of pollution of air, water, sediments, sewage as well as exploration of coal, oil & gas applications in terms of logging of borehole. Further, so far as gas industry is concerned, all high pressure pipelines and installations are subjected to NDT involving high strength of X-Ray and Gamma-Ray radiography. Inadequate training and in appropriate precautionany and monitoring measures taken there of have already caused some severe and tragic radiation injuries too.

Need of Radiation Education

In an exercise of assessment of need of such radiation education, a comprehension of definitions of basic terms, viz radiation, radiation dose, low (absorbed) radiation dose and dose-response relationship including radiobiological & epidemiological estimates are essential. Further, risk of effects on malignancy, hereditary effects and effects on embrio etc. have to be explained in an attempt to examine the potential day to day exposure of working persons in particular and members of public in general so far as industrial, health care and research application of radioactive materials and protection measures are involved thereof.

Opportunities

This sort of radiation literacy if properly imparted would help to take action or precaution if any and thereby must relive the people at work and in the periphery of the psychological stress resulted from radiophobic feeling so far as peaceful use of nuclear technology is concerned as pointed out by Prof. T. Matsuura at 2ICI,Sydney in October 1997. Such effort to enhance radiation education may not only start with secondary schools/colleges but also include technical, vocational and polylechnic institutes too.

Upgradation of capabilities including evaluation of the scope, extent, rationale & involvement of radiation education methodology in these spheres shall have to be made keeping in view that innovative technologies have made it possible either to reduce the radiation levels or to enable establishment of appropriate protection measures.

Conclusion

Finally,it has to be stressed that an active and collaborative support of the country's partners in progress as well as co-operation & linkage programs of respective organizations of Bangladesh & its friendly countries all over the world are developed on mutual benefits. Simultaneously, national effort as per existing rules and regulations along with recommendations of relevent International agencies may continue.

Acknowledgement

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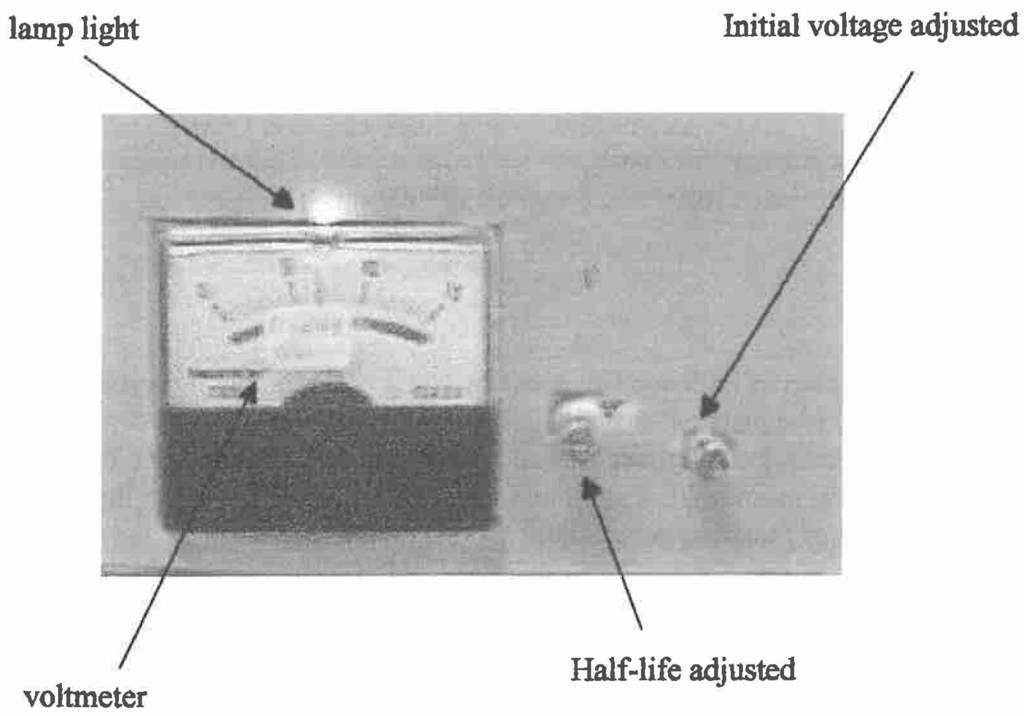

Fig. 1 Radioactive Source Simulation Prototype

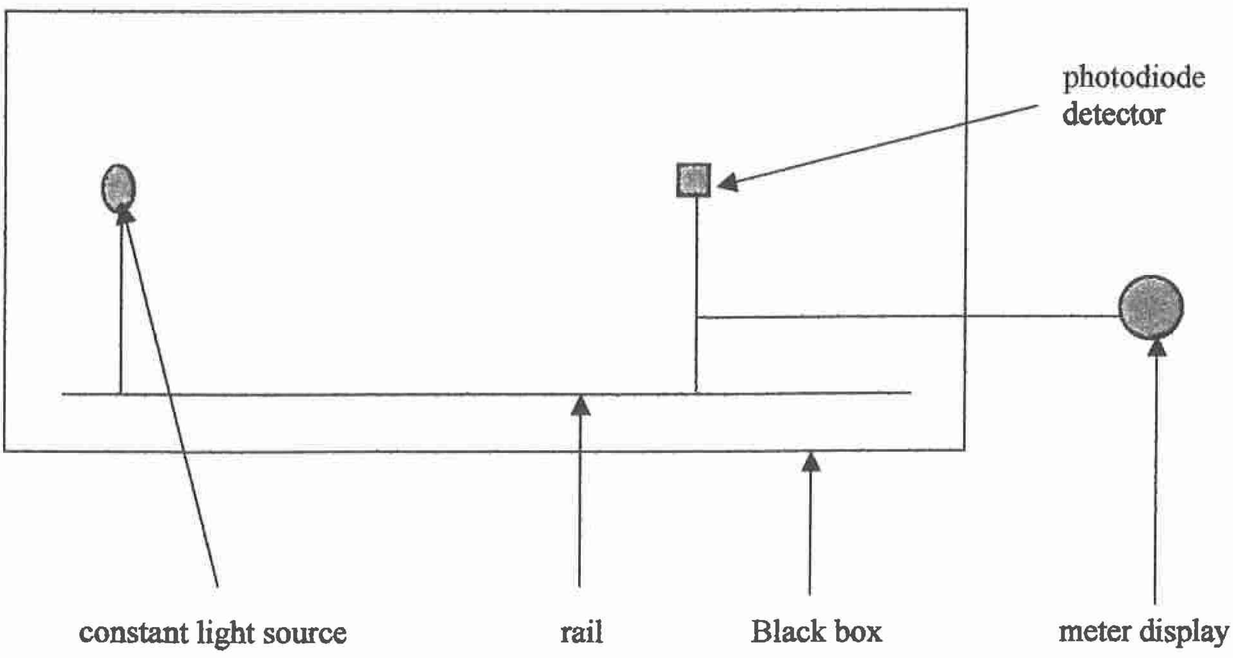

Fig. 2 Diagram of Inverse Square Law Setup

3.2 RADIOACTIVE SOURCE SIMULATION FOR HALF-LIFE EXPERIMENT

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ABSTRACT

A simulation of radioactivity decay by using programable light source with a few minutes half-life is suggested. A photodiode with digital meter label in cps is use instead of radiation detector. Both light source and photodiode are installed in a black box to avoid surrounding room light. The simulation set can also demonstrate Inverse Square Law experiment of radiation penetration.

1. INTRODUCTION

Learning Nuclear Physics in school is quite difficult to understand. One methed of teaching is trying to have the student learned by experiment. Most schools can not 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 of such laboratory in ordinary schools. This simulation set is aimed at providing simple and low-cost experiment to schools.

2. METHODOLOGY

2.1 LIGHT SOURCE TO SIMULATE RADIOACTIVE SOURCE

A small lamp is used connecting to RC circuit in order to simulate radioactive source. The intensity of light is synchronized with voltage reading from a voltmeter. Student will notice the decrease of light intensity along with the decrease in voltage at the meter. With stop watch, student can determine half-life of the simulated radioactive source.

2.2 FOR INVERSE SQUARE LAW EXPERIMENT

A constant light source is set on a stand located on a rail. A photodiode detector is set on the same rail as light source and marked distance from the light source. Both light source and photodiode are installed in a black box to avoid surrounding room light. Readings electrical current passing through the photodiode detector are observed with varying distance from the light source. Hence, Inverse Square Law is demonstrated.

3. CONCLUSION

Gamma radiation emitted from radioactive source is the same electromagnetic wave as light. The advantage of light is that it can be observed by eyes. The radiation emission of any radioactive source is decreasing with time. It means the radioactive source becomes less active, but the mass is not smaller than previous. Lamp light can show similar effect by decreasing light intensity. A voltmeter is provided for determination of half-life because the decreasing in light intensity could not determine by eyes.

If half-life of a radioactive source is long compared to observing period, the radiation emission rate assume to be constant. For inverse square law experiment, constant light source can be used. Since light and gamma radiation have the same natural phenomena, Inverse Square Law can be demonstrated.

The radioactive source simulation by light source may find their application in secondary school, if it is desired to put the subject of radiation and radioactivity into school level. Cost of the simulation set is substantially less than the true radioactive source set. The problem on handling of radioactive source is also eliminated.

3.3 小学生における放射線教育
Radiation Education in Elementary School

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要旨

平成７年度から東京都練馬区光が丘第四小学校の５、６年が理科の時間に簡易放射線計測器「はかるくん」を用いて小学校校内及び周辺の自然放射線を測り、身の回りに自然放射線があり、高い所や低い所があり零の所はないことを実験を通じて学んでいる。食物を撮ったイメージングプレートで食べ物からも放射線が出ていることを知る。霧箱でアルファ線の飛跡も観察している。この体験授業は、予備知識がなく好奇心の旺盛な時代に自然放射線の存在を素直に認識するために非常に有効である。さらに、子供たちの家族にも理解が広まり相乗効果がある。

Radiational education in elementary school [The Lessons to Measure Natural Radiation]

ABSTRACT

Lessons to measure natural radiation have been given at the fourth elementary school of Hikari-gaoka, Nerima-ku, Tokyo, for three years.

The Method of Lessons: After hearing a brief explanation about natural radiation and usage of a simple instrument of gamma ray named "Hakaru-kun."by a lecturer (Fig.1), every child participates to measure dose rate at several measured points within the range of school campus(Figs.5 ～14). They calculate the average value of measured dose rate(Fig.2) and affix tags written the average value (Fig.3). In addition, by looking at the photographs, through the imaging plate, of radiations released from vegetables and pork,they are surprised at the fact that all the food have such activities. Finally, they watch marks of alpha particles released from the ore of samarskite in a cloud chamber.The alpha particles fly in alkohole vapor oversaturated cooled with dry ice(Fig.15). They express their impression of lesson for finding out the existance of natural radiation in their reports(Table 1 and Fig.4).

１．はじめに

高校生が修学旅行中『はかるくん』という簡易放射線計測器で場所場所での自然放射線の変化を測定しているという話をしたところ、当時の小学校長に『小学生に自然放射線が測れますか』と聞かれたのがきっかけとなり、東京都練馬区光が丘第四小学校で平成八年の三月に、同校ではじめての放射線の授業が環境教育の一環として理科の２時間の授業で６年生の３組に行われた。

「開かれた学校」に向けた取り組みが全国で進められているが、東京都練馬区でも数年前から「地域に根差した教育」を目指して、その地域に在住する人材を学校の裁量で招き、人材のノウハウを生かす特別な授業を行っている。校長先生は『小学校では目に見えな

いものは教えられないのですが、「地域に根差した教育」としてお願いします。』と話された。播磨は小学校の西隣の高層住宅に住んでおり、運動場で元気よく走り回る子供たちを毎日ベランダから眺めている。小学校の先生の中にも、原子力反対の人がおられ、転居して1年余りの播磨には周辺の人々の考えが分からず、どのような対処を必要とする問題が起こるか予想もつかなかった。

授業を始めるに当たり、問題の対応のできる後ろ盾のある日本原子力文化振興財団の派遣講師の制度を利用して、放射線の授業は子供の扱いに習熟した派遣講師にお願いした。授業の始めに「はかるくん」の使い方の説明を聞き、学校内の自然放射線を測る、測定結果を付箋に書いて校内の大きなマップに貼る。最後に感想を書く。最初の年は、30分余り、子供たちは「はかるくん」で校内好きな所を測って回った。二年目は「はかるくん」の測定に加えて、イメージングプレートで撮られた野菜や豚肉などの食べ物からも放射線が出ている様子をOHPで見る。三年目は、さらにアルファ線の飛跡を霧箱で見る。

授業の終わる前に記録用紙に授業の感想を書いてもらい、それをお借りして、レポートにまとめている。この体験授業を通じて、小学生の理解度に応じた内容を検討したり、理解の深まる説明の言葉を捜したり改善を重ねている。また子供むきの簡単な放射線の説明がしてある「放射線探偵団」やキュリー夫妻のラジウム発見100年に当たり、キュリー夫妻の伝記が日本アイソトープ協会で刊行された。

次章から、小学校の対応や、授業の内容、今後の問題を項目ごとにくわしく述べる。

2．小学校側の対応

放射線の授業を始めるに当たり、平成7年暮れ校長と理科担当の先生と話し合いを持った。その前に放射線計測協会から身の回りの放射線に関係のあるパンフレットをいくつか送って頂いたがそれらは皆小学生には難し過ぎるものばかりであった。先生方と小学生で理解できること、子供の興味の持ち方、授業の進め方等を話し合った。理科の先生は、最初新しい授業に尻込みしておられたが、いろいろ資料を差し上げて冬休みの間に勉強していただいたところ、段々乗り気になってこられた。小学校のこの体験授業には小学校の先生方の子供へ対応のご経験が生かされている。例えば、”実験：身近な場所の放射線を測る”の記録用紙の形式がある（表1）。「はかるくん」の測定は3回測って合計と平均を計算する。（注：高校生は10回測っているそうだが、小学生ではとても10回の繰り返しは無理ということだった）又、子供たちに「はかるくん」の値段をあてさせるのも理科の先生の発案である。今の子供たちは、ファミコンに親しんでいるので、興味を引き出す手段と、高価なものは慎重に扱うことに役立つということであった。授業の終わりには『「はかるくん」で測って”0”だった人は手を上げて』と問いかける。誰も手を上げない。『何処にでも放射線があるのがわかったね』と授業をしめくくることで、この授業の一番の目標を徹底する－－等等。授業のあと、校長先生からは『子供たちがこんなに大喜びした授業は初めて』と評価していただいた。

小学校では、一人一人に実験器具を使わせてもらうような授業はないということで、普段、おとなしくて、活発な子の影にかくれていたと

実験　：　身近な場所の放射線を測る

測定場所		「はかるくん」測定値				
		理科室	校庭	石がき	プールの水の上	トイレ
測定回数	1	0,044	0,019	0,080	0,022	0,054
	2	0,041	0,020	0,081	0,020	0,058
	3	0,042	0,019	0,080	0,023	0,060
合計		0,127	0,058	0,241	0,065	0,172
平均		0,042	0,0195	0,08	0,022	0,057

わかったこと・質問したいこと

○放射線は、身近にあることが分かった。
○放射線は、さえぎる物があったり、遠くなったりすると、少なくなったりすることが分かった。
○放射線はふきそくにでていて、アルコールの気体をきゅうげきにひやしてみるとその放射線の通ったあとが見れた。とてもおもしろかった。

測定器番号	
測定者氏名	
6年　組	

測定年月日	
平成10年11月5日11時	
天気	晴れときどきくもり

Table 1 ：記録用紙

思われる子が嬉しそうな顔で測定していたのが印象的だった。又、放射線については予備知識がなく、全員同じスタート台にだった授業であるため、子供一人一人の個人の能力が試される授業でもある。これらが原因となって、緊張感のある授業になるのかも知れない。主事さんの一人が『トイレを掃除していたら、生徒さんが放射線の測定に入ってきて、トイレに放射線がいっぱい出ているって教えてもらいました。身の回りに放射線がいっぱいでていると知りませんでしたので良い勉強をさせて頂きました。』とお礼を言われた。原子力反対の先生からも父兄からも反対の声は無かった。記録用紙は、預かって帰り、この新しい授業の結果をまとめ、子供たちの小学校時代の思い出に、また子供たちのご両親にこの授業をご理解いただく為に、レポートを作ることにした。現在のレポートの形式は校長先生のご提案で子供たちに呼びかけるように"「はかるくん」で自然放射線を測ってわかったこと "、"考えよう"、"しらべよう"、"答"、"比べてみよう"、"おぼえておこう"、"わかったこと、質問したいこと"が構成された。同じ場所を複数の子どもが測っている場合、平均値を記載し測定結果には括弧の中にクラス名を入れた。『これは子供たちが喜びますよ』と校長先生。レポートは記録用紙と共に子供たちに返され、関心のある人にも配られている。放射線をどのくらいあびると死ぬのかなという質問には、教頭先生の助言があった。ーーー死ぬことはないという表現がよいということだった。「理科室に１年間いたとして受ける放射線の量の２万倍の放射線を一度に全身に受けないと死ぬことはない。同じ量の放射線を体の一部に受けても死ぬことはないと。

本授業のように校長の裁量で行われる授業では、先生の異動の激しい小学校で継続していくために、普段から小学校の行事へ参加、歓迎されるような奉仕活動を通じて人間関係を構築することが重要である。

平成８年校長先生も理科の先生も他校へ転勤されたが、申し送りで、新しく来られた校長と理科担当の先生のもとで自然放射線を測る授業は継続された。両先生に授業を理解して頂くため、授業内容や子供たちの反応、他の職員、父兄の反応等お話し、ご理解頂いた。理科の先生には資料をお届けしながら放射線に関係のあるお話をしたり、先生が担当しておられる栽培委員会を手伝って先生や子供たちと信頼関係を高めた。

３年目は、放射線計測協会のお勧めで霧箱を加えた。　計測協会の職員から霧箱の作り方の講習を受け、理科の先生とご一緒に小学校で練習してみた。『これは子供がすごく喜びますよ』とご自分でも試みて同僚に見せたりしておられた。この年の夏休みには、３月に実験した６年生でもっとやりたいと言っていた１０数人が自由研究に光が丘の周辺の自然放射線の測定を行った。１１月の授業から受け持ちの先生も授業に参加されるようになり、他の先生方も霧箱は初めてと見て下さるようになった。子供たちと一緒に「はかるくん」をもって走り回っておられる先生、霧箱を子供たちと歓声挙げて見ておられる先生の姿を拝見して、やっと定着してきたなという感触を掴んだ。この授業の様子や子供たちを取材したナショナルピーアールの記者が当社の"ENERGY for the FUTURE"に「小学生、放射線を測る、学校と専門家が模索する新たな教育」[1]という見出しで掲載している。また、三菱重工業株式会社、原子力ＰＡ推進センターの"あとむぱわー"に「僕ら放射線探偵団」[2]として授業が紹介されている。

４年目は理科担当の先生の交代があり、新しい理科の先生には６月に行なった光が丘第三小学校の授業を見学していただいたり、資料持参でお話に伺ったりした。同じ学校に経験のある前の理科の先生が居られるので、先生の興味が上がるのに役立った。最初に放射線の授業のきっかけを作って下さった前校長先生が、光が丘のお知り合いの校長先生に声をかけてくださったので、一度に３校も増えた。そして、それらの小学校では、『５、６年生お願いします』といわれて、一度に忙しくなった。新しく加わった小学校は担任の先生が理科を教えておられるので、前もって授業内容の説明に伺った。授業には担任の先生

も参加され、霧箱ではお手伝いも頂いた。

小学校も2002年の週休二日制にむけて、総合学習が導入されることになるが、カリキュラムは各学校に任されており、どのような授業をするか、先生を悩ませている。この放射線の授業は「環境とエネルギー」の分野に相応しいということで関心が高まっている。

３．自然放射線の存在を知る

３．１「はかるくん」で自然放射線を測る

放射線は地球ができたときからでている。宇宙から、大地から、建物の壁から出ている、というお話を聞く。 放射線の多いところ少ないところがある。建物の中と外と比べるとか、トイレのタイルとプールの水の上や屋上を測って比較してみよう、と説明を受ける。そこで、放射線を測る「はかるくん」の器械を一人一人が手にする。この『「はかるくん」はいくらするか』と聞かれて、てんでに値段を付けた。安いのは２，９００円、高くても６５，０００円だった。１３万円もすると聞いて『高いなあ。大事にしなくちゃ』と一気に緊張感がただよった。「はかるくん」の使い方を聞く（写真１）。待時間の表示が消えて数字がでる。理科室では４人が一つの机に座っているが夫々の数値が違うので『どうして』とか『器械が故障かな』と騒ぐ。ここで放射線の出方にはばらつきがあるという説明を聞く。このように自然放射線の測定値にばらつきが多くあるときは、大勢で測るか、何回も測って平均するとばらつきを小さくすることができると説明を聞く。今年からクラスの測定値を棒グラフにすることにした（図１）。ブザースイッチを押すとピッピッという放射線の入射音で更に理科室全体に放射線の存在感が深まる。

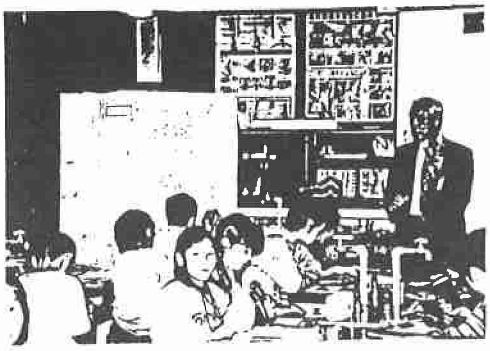

Photo.1「はかるくん」の使い方を聞く

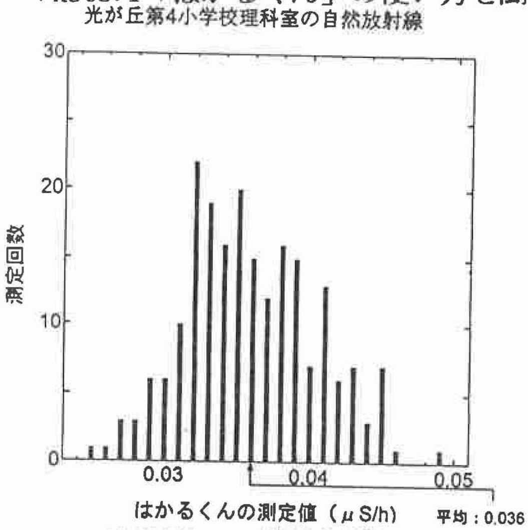

Fig. 1 理科室の自然放射線の棒グラフ

平均は５年生で習うが、実験する時期に習っていない場合もある。しかし、平均という言葉は日常生活やスポーツの得点でもよく出てくるので、誰かが３で割ればよいんだよといい出す。電卓で計算する子、筆算で計算する子もいる（写真２）。四捨五入は４年生で習っているのだが、忘れている子がかなりいる。基本的なことも繰り返し出てくると身につくのであろう。

Photo.2:平均を計算する

その後、第１回目は『校内なら何処測ってもいいよ』という校長先生のお声を頭の後ろで聞きながら教室から蜘蛛の子のように飛び出していった。教室外の危険と思われるところ、例えば、屋上とかプールとかには手分けして監視に立った。３０分程であったか子供たちは満足気に理科室に戻ってきた。派遣講師から、放射線の多そうなところ少なそうなところを聞いていたが、校内くまなく測られていて、筆者らが予想もしていなかった新し

い発見もあった。そのひとつが焼却炉のレンガで、『オーイ、たかいぞー』と叫んだ男の子の声に、数人が走って行った。焼却炉の中まで手をいれたのか煤だらけになって宝物をみつけたように興奮して戻ってきた。筆者らは煉瓦が高いというのに気付いていなかったので、良い勉強になった。３日のうち一日、朝、雨が降った。屋外の放射線の量は理科室より高くなった。これは、雨の降り始め、ラドンやトロンと埃が雨と一緒に降り、高くなるのだが、いい体験ができた。将来の科学者の卵かと思わせるような綿密な測定をした子供。例えば、教室の日の当たる場所と当たらない場所を比較したり、廊下の両端を比較したり、各階の教室、トイレ、廊下を高さで比較したり。繊細な神経の持ち主なのか、図書室の本の間を測ったり、下敷きの両側を比較したり。好奇心の旺盛な子供は、普段入れない場所、例えば、校長室、給食調理室、エレベータの中、体育館の屋上によじ登って測ったり。優しい心の持ち主は、飼育室の兎や鶏を測ったり、自分の靴の中を測ったり。理科室に戻り、平均値を求めた後付箋に線量値を書き、校内の拡大されたマップの上に貼って行く（写真３）。この実習は、同じ場所を測っても測定値はある値の回りにばらついていること、理科室と比較して場所により高いところ、低いところがあることを実験を通じて学ぶことにある。最後に”わかったこと、質問したいこと”の欄に感想を書く（写真４）。

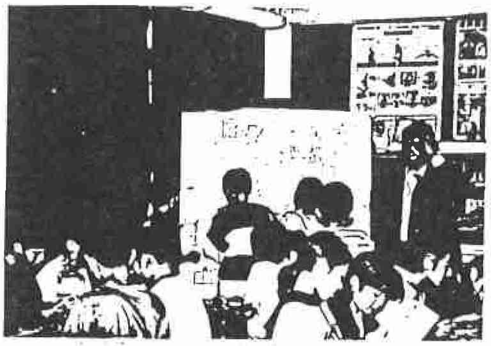

Photo.3 : 測定値をマップに貼る

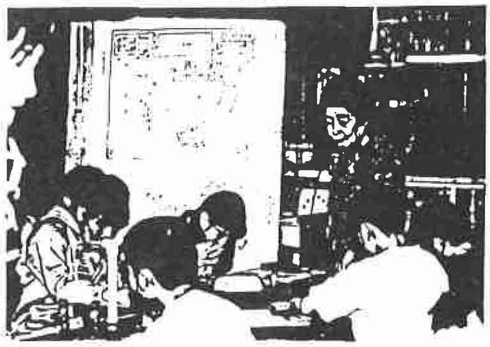

Photo.4 ：感想を書く

Photo.5: 理科室を測る

Photo.6: 運動場を測る女の子

Photo.7: 運動場を測る男の子

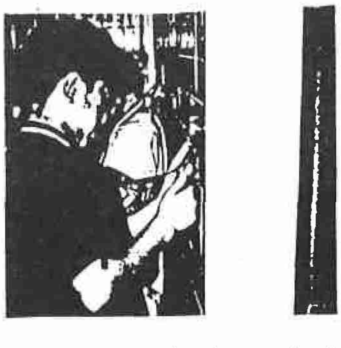

Photo.8: トイレのタイルを測る

二年目の授業は５年生の３組に行われた。カリ肥料や湯の花からも出ているベータ線の測定をＧＭ計数装置を使って入射音とともに実演してみせる。光が丘はモニュメントや石垣に花崗岩が多く使われていて、小学校の隣の保育園の石垣も花崗岩である。「はかるくん」の測定を放射線の高いところ低いところを体験できるように、理科室（写真５）、土の運動場(写真6、7)、トイレ（写真8 ）、プール（写真9 ）、歩道橋の上（写真10、11）、花崗岩の石垣又は焼却炉のレンガと限定し、時間も短くした。しかし、それ以上測りたい子は、余白に測定値を書いてもらうことにした。花崗岩の石垣は0.100 μＳｖ／ｈぐらいもでていて、理科室に比べてかなり高いので、子供の印象が大きかったのか、女の子が写真１２に示すようなすばらしい絵を描いてくれた。測定記録用紙のあちらこちらにもマンガがかかれていた。

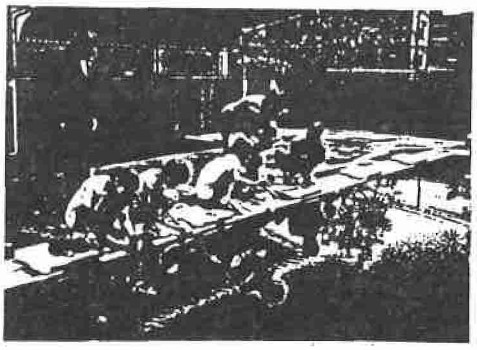

Photo. 9: プールの水の上を測る

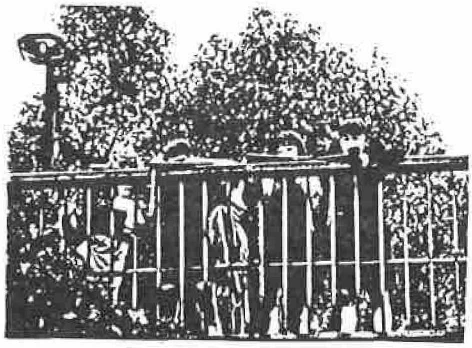

Photo. 10:歩道橋の上で測る

Photo. 11: 歩道橋の測定を終わって教室に戻る

Photo. 12: 石垣を測る（女の子の絵）

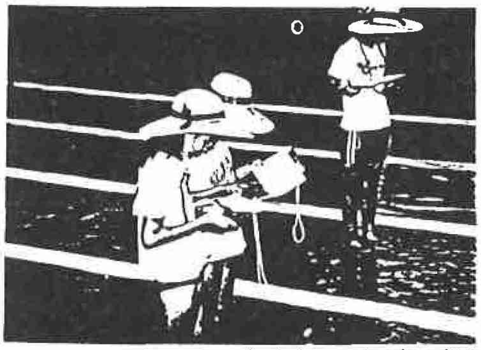

Photo. 13 : プールの水を抜いた時に測る

Photo. 14: プールサイドを測る

自由研究の中で、水で放射線がさえぎられていることを確かめるために夏休みのプールの水がぬかれたときに測り、プールサイドと同じであることを確かめ、水で放射線がさえぎられることを体験した（写真13, 14 ）。

３．２　食べ物に自然放射線が含まれている

子供の理解力に合わせて「はかるくん」の測定以外に名古屋大学の森先生がイメージングプレートで撮られた野菜や豚肉などの食べ物からも放射線が出ている様子をＯＨＰで見せる。食べ物の放射線は肥料に含まれているカリウムで野菜から放射線が出ている。それを食べている豚肉からも放射線が出ていると説明している。子供たちにとってインパクトが大きかったのか感想に殆どの子供が驚きを伝えている。豚肉の脂身のところは放射線の出方が少なかった訳を聞く。またたけのこからは放射線がほとんどでていないのも不思議だとの感想があった。

３．３　霧箱で放射線の飛跡を見る

三年目は、サマルスキーという鉱石からのアルファ線の飛跡が見られる霧箱を加える（写真15）。霧箱は飛跡をみる装置であるが、放射線を見たと感想を書いている子もかなりいた。まがりなりにも、放射線が見えたことで、自然放射線の授業は「目に見えるものなら小学校で教えられる」という大義名分が整った。感想には子供らしい表現で飛跡をみた印象を書いている。例えば、ときどきぴよっときりがでてくるのがわかった／ふわふわしているようにみえた／放射線がまがったりまっすぐいくのがおもしろかった／白い線のようなものがいっしゅんスーとして見れた／まるでおいておいたみそ汁をはしでかきまぜたみたいだ／ピュンピュン飛んでいたのでちょっとちがうけどオーロラみたいでした／放射線を見て生きているみたいで感動した。

Photo.15: 霧箱で放射線の飛跡を見る

３．４　放射線に関係したお話

最初の年の派遣講師の放射線の授業は『レントゲンって知っている？』という問いかけで始められた。レントゲンという言葉は胸の集団検診で知っていた。その年は「レントゲンのＸ線発見１０１年」であった。レントゲンの顔写真を見て、人の名前だと聞いてびっくり。ノーベル賞の物理賞の第一号をもらった人、ベクレルやシーベルトも彼らの功績により単位に名前が使われていると聞いて、「僕の名前も残るかな」と発言した子供がいた。校長先生が「一生懸命勉強して立派な研究をしたら君の名前も残るよ」と声をかけられた。感想に「お父さんが放射線科に勤めているので、いっぺんやってみたかった」と書いていた子供がいた。何らか放射線に関係している仕事についておられる両親の子供はかなりいるのではないかと考えられる。その人々が、自分の仕事の内容を誇りをもって我が子に話してもらえば、子供たちの関心も高くなるであろう。

３年目には派遣講師が小学校の授業の経験から日本アイソトープ協会で「放射線探偵団」というパンフレットを作った。この冊子は子供むきにまる文字でかかれており、放射線のことが易しく書かれている。派遣講師は小学生を対象としていたが、一般の人、特に家庭婦人に「これなら放射線のことがわかる」、と好評である。考えてみれば、放射線について何も知らされていなかった人には、新しい知識の導入は小学生と同じようなレベルで始めるのが、拒絶反応がなくてよいのではないか。この表紙の絵は子供たちに返すレポートの表紙に借用させて頂いている。

４年目の今年はキュリー夫妻のラジウム発見１００年にあたり、子供むけのキュリー夫妻の伝記も派遣講師が書き日本アイソトープ協会から刊行された。最近はキュリー夫人の伝記は、小学校の教科書から消えてしまっているということだが、名前だけは知っている子供がかなりいた。感想にキュリー夫人がノーベル賞を２度も受けた話を聞いて彼女の功績を書いた子供がかなりいた。ただ、キュリー夫人のあの血のにじむような研究を支えた

のが、祖国の独立への強い願をこめた小さい時からの不屈の精神であったことは、豊かな日本で育った子供たちにはわかってもらえたであろうか。

４．今後の問題：小学生に理解できる内容を検討

放射線を測らせる授業は「はかるくん」で測るだけから始まって、食べ物に放射線がはいっていることを知らせる、霧箱で放射線の飛跡を見せると増やしていった。子供たちは今まで学校で教えられていなかったこと、子供の周囲の社会や家庭でも知らされていなかったこと、まさに初体験の授業にびっくりしながら、しかし抵抗なくはいっていった。この初体験の授業は予告なしに行われる方が効果がある。予習している子供がいると、同じ土俵でなくなり、予習の中で自分が持った興味や疑問が邪魔して初体験の感激の度合いが分散し、授業中に話を折るような質問がでて全体の緊張した雰囲気を壊してしまう。あらかじめ学校には、この授業が子供たちの”驚きと発見の初体験”に重点を置いていることをご説明し、子供たちにこの授業の予告や予習をしていただかないようにお願いしている。私どもは小学生では「自然放射線は０でない、高いところ低いところがある」を理解してもらえばよいと考えている。小学校の時は学校で習ったことを親に話すであろうし、レポートも読んで頂けるであろう。最近授業を受けた子供の祖母が孫から放射線授業のことを聞いたという話を聞いた。おかしなもので子供や孫が学校で習ってきたことは簡単に受け入れられる。それは長い教育の歴史の賜物ではなかろうか。これが常識になれば、”日本は変わる”。

授業内容の量と質は小学校の２時間の理科の授業としては、これが限界ではないかと考える。これ以上になにか増やせば、消化不良を起こすであろう。

同じ光が丘の中でも、子供たちの家庭環境により、また指導される先生方の影響もあるのか、子供たちの授業の受け止め方に変化のあることがわかり、この授業を広げていくのには、絶えず子供たちの環境の変化に対応ができるような緻密な準備を心がけることが必要である。そのためには、小学校の先生方を陰で支え、子供たちの質問に的確に答えたり、子供たちの理解がより深まるような言葉で説明する方法を考案して、小学校の先生方の良き相談相手になる専門家の協力が是非必要である。

レポートを書く時、使っている漢字を子供が習っているか、使っている言葉が子供に理解できるか、小学生にわかる表現をしているか、をチェックして頂いている。その交流を通じて子供の今の関心の対象や考え方など小学校の先生方に教えて頂いている。

総合学習が導入され、時間に余裕ができたら、放射線教育を４年生ぐらいからはじめて５年生、６年生と理科の体験的学習を増やしたい。「はかるくん」で測る時間も、もっと増やしたい。最初の授業のように、高いところ低いところを捜している子供の目は輝いている。高くなったり低くなったりするわけを子供にわかるように説明し、その中で、子供たちが広い視野で物事を考える力をつけてあげたい。

自分の理科室の測定結果をクラスの友達全体で集めるとガウス分布に近いグラフになり、平均の意味を理解したり、全国の測定値と比較したりもできるだろう。これを通じて物事を一点で判断せず、広く眺めて物事の判断をする習慣がつけばと考える。

また、放射線が身近かにあることが認められれば、原子力の勉強もできるだろう。放射線が身の回りの生活にいかに多く使われ、自分の生活を豊かにしてくれているかを、自分達で調べ、放射線を無闇に恐れることなく、技術革新の道具として受け入れられる。将来、放射線を利用した開発研究をする子供がこの中にいるのではないかと夢が膨らむ。

１）「小学生、放射線を測る、学校と専門家が模索する新たな教育」"ENERGY for the FUTURE"、1998 No.1 、38-39 、ナショナルピーアール株式会社
２）「僕ら放射線探偵団」三菱重工業株式会社、原子力ＰＡ推進センターの”あとむぱわー” Vol.42(1998)

3.4 How would we deal with radiation related issues in high school educational programs?

Kuniko Saeki
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Motivation and Purpose:

We imagine that current educational curriculums we rely on will be more improved and the materials in schools will be somewhat different by the year of 2002 when students have two days off in a week. Unfortunately, it is a well known fact that recent Japanese people's level of understanding about Science and Technology is the second from the bottom among OECD nations and, as a matter of fact, few schools are dealing with scientific issues such as atomic energy or radiation. If the day comes when those issues become very close to our ordinary lives, or it might have come already, we would hardly expect most of the people to be ready for the situation.

I consider that we, teachers, should be more involved in planning the school materials and educational curriculums that directly cultivate thoughts and knowledge of young adults who are going to lead this country in the near future. And then, we should actually encourage the Ministry of Education or the committees of education to reconsider current educational programs and to increase materials that include more issues related to nuclear power and radiation.

Since I have a freshman class this year, I surveyed what students know about atomic power and radiation, how deep they studied in previous schools and what kind of interest they have in conservation of world energy sources or environmental issues discussed today.

Method: Obtain information from 328 students (7 classes) by the questionnaire method.

Date of the Survey: April 8, 1998 (A week after the entrance ceremony of freshman classes)

Results: Following

Questionnaires

This year is the 100th anniversary of discovery of "Radium" by Marie Curie. Now, I would like to ask you following questions; please circle the most appropriate ones for you.

(1) Do you know what Radiation is? ① Yes ② No

(2) Do you know what Radioactivity is? ① Yes ② No

(3) Do you know the difference between "Radiation" and "Radioactivity"?
① Yes ② No

(4) Please write anything that Radiation and Radioactivity remind you of.

	Reasons
①	
②	

(5) Are you familiar with the word "Nuclear power generation"?
① Yes ② No

(6) If YES, please answer the following questions.

(a) When did you learn about it for the first time?
When you were in ①Elementary School ②Junior High School

(b) How did you learn about it?
①In class(____grade) ②Mass media

(c) What do you want to know more about nuclear power generation?
① The effects of radiation and radioactivity on others
② Accidents and break downs
③ Management and nuclear wastes disposal
④ The mechanism of nuclear power generation
⑤ Future plans and something else

(7) I would like to ask you about the energy sources and their scarcity.

(a) Since when have you been interested in them?
① Elementary School (____grade)
② Junior High School (____grade)
③ Never

(b) How did you learn about them? ①In class ②Mass media

(c) Please write anything that you want to learn about the energy sources and their scarcity.

(8) Please circle the subject(s) you know and explain briefly.

① X-ray pictures	
② Radiotherapy	
③ Nuclear wastes disposal methods	
④ Nuclear power generation mechanism	
⑤ Atomic Bomb	

(9) We would like to ask you about various environmental issues.

(a) When did you learn about the word "environmental issues" for the first time?

When you were in ① Elementary School (____grade)

② Junior High School (____grade)

(b) How did you learn about them? ①In class ②Mass media

(c) What do you want to learn more about environmental issues? Please write whatever you want to know or study.

(d) Please write all you know about environmental issues.

The results of questionnaires

(1) Do you know what Radiation is?

	Yes	206 students (62.9%)
	No	121 students (37.1%)

(2) Do you know what Radioactivity is?

	Yes	215 students (65.7%)
	No	112 students (34.3%)

(3) Do you know the difference between "Radiation" and "Radioactivity"?

	Yes	21 students (6.4%)
	No	306 students (93.6%)

(4) Please write anything that Radiation and Radioactivity remind you of.

1. Atomic Bomb, War, Nuclear Missile	92 students (28.1%)
2. Medical treatment, X-ray picture	40 students (12.2%)
3. Chernobyl, Nuclear power plant accident	37 students (11.3%)
4. Nuclear power plants	34 students (10.4%)
5. Skin cancer, Leukemia, Diseases	34 students (10.4%)
6. Fearful, Noxious, Bad for health	23 students (7.0%)
7. Light	19 students (5.8%)
8. Uranium, Plutonium	9 students (2.7%)
9. Godzilla	7 students (2.1%)
9. Hiroshima, Nagasaki	7 students (2.1%)
11. Bikini islands, H-bomb test	5 students (1.5%)
11. Baldness	5 students (1.5%)
11. Air pollution, Pollution	5 students (1.5%)
11. Radiation, X-rays	5 students (1.5%)
Other	34 students (10.4%)

Radioactive wastes, Russia, USA, Aomori, Fukui, Infrared, Ultraviolet, Microwave, TV, Sun, Acidic rain

(Total of 22 students: 2 students of each topic)

Ozone layers, Green house effect, Black cloud, Atom, Universe, Smoke, Melt, Movies, Malformed child, Hadashi No Gen (Cartoon), UV protection glasses, Electrocardiogram

(Total of 12 students: 1 students of each topic)

(5) Are you familiar with the word "Nuclear power generation"?

	Yes	305 students (93.3%)
	No	4 students (1.2%)

(6) When did you learn about it for the first time?

When they were in	Elementary School	207 students (63.3%)
	Junior High School	120 students (36.7%)

How did you learn about it?

In class	154 students (47.0%)
Mass Media	146 students (44.6%)
No answer	27 students (8.4%)

What do you want to know more about nuclear power generation?

① The effects of radiation and radioactivity on others	137 students (41.9%)
② Accidents and breakdowns	67 students (19.7%)
③ Management and nuclear wastes disposal	87 students (26.6%)
④ The mechanism of nuclear power generation	61 students (18.7%)
⑤ Future plans and something else	51 students (15.6%)

▲ Notice

Among 207 students who said "Elementary schools," they learned

In class	106 students (51.2%)
Mass media	101 students (48.8%)

Among 120 students who said "Jr. high schools," they learned

In class	48 students (40.0%)
Mass media	72 students (60.0%)

(7) & (8) Please circle the subject(s) you know and explain briefly.

	Who became interested in the topic of the energy sources and their scarcity when they were in (From question (7a))		
	Elem. School. (41 students)	Jr. High School (142 students)	Unconcerned (134)
① X-ray pictures	16 (39.0%)	60 (48.6%)	94 (70.1%)
② Radiotherapy	6 (14.6%)	36 (25.6%)	14 (10.4%)
③ Nuclear wastes disposal	11 (26.8%)	22 (15.5%)	8 (5.9%)
④ Nuclear power mechanism	8 (19.5%)	57 (40.1%)	43 (32.1%)
⑤ Atomic Bomb	16 (39.0%)	57 (40.1%)	43 (32.1%)

(9) We would like to ask you about various environmental issues.

(a) When did you learn about the word "environmental issues" for the first time?

When you were in①	Elementary School	181 students (55.4%)
②	Junior High School	122 students (37.3%)
	No answer	24 students (7.3%)

(b) How did you learn about it?

① Elementary School

In class	97 students (53.6%)
Mass Media	77 students (42.5%)
No answer	7 students (3.9%)

② Junior High School

In class	49 students (40.2%)
Mass Media	71 students (58.2%)
No answer	2 students (1.6%)

▲ Notice:

The students who answered "I'm Interested" in section (7)&(8).

(a) When did you learn about them?

1. Elementary School	134 students (69.4%)
2. Jr. High School	39 students (20.2%)
No answer	20 students (10.4%)

(b) How did you learn about them?

1. Elementary School

In class	69 students (51.5%)
Mass Media	58 students (43.3%)
No answer	7 students (5.2%)

2. Jr. High School

In class	20 students (51.3%)
Mass Media	17 students (43.6%)
No answer	2 students (5.1%)

The students who answered "Unconcerned" in section (7)&(8).

(a) When did you learn about it?

3. Elementary School	47 students (35.6%)
4. Jr. High School	83 students (62.9%)
No answer	2 students (1.5%)

(b) How did you learn about it?

3. Elementary School

In class	28 students (59.6%)
Mass Media	19 students (40.4%)
No answer	0 students (0.0%)

4. Jr. High School

In class	29 students (34.9%)
Mass Media	54 students (65.1%)
No answer	0 students (0.0%)

(c) What do you want to learn more about environmental issues?

	(Interested)	(Unconcerned)	Total
How to solve the issues	33 students (18.0%)	26 students (19.4%)	59 students (18.6%)
Global environmental problems	3 (1.6%)	8 (6.0%)	11 (3.5%)
Greenhouse Effect	15 (8.2%)	7 (5.2%)	22 (6.9%)
Garbage disposal	4 (2.2%)	6 (4.5%)	10 (5.7%)
Ozone Layers	12 (6.6%)	6 (4.5%)	18 (3.2%)
El nino	3 (1.6%)	2 (1.5%)	5 (1.6%)
Deforestation	5 (2.7%)	2 (1.5 %)	7 (2.2%)
Air Pollution	6 (3.3%)	1 (0.8%)	7 (2.2%)
Environmental Hormones	8 (4.4%)	0 (0.0%)	8 (2.5%)
Topics less than 5 students:			
What can we do?	0	2	2
Acidic Rain	3	1	4
Influence on Human body	3	1	4
Freon	0	1	1
Desert expansion	2	0	2
Water	1	0	1
Diminution of nature	2	0	2
Next car generation	2	0	2
Clone	1	0	1
Chernobyl	2	0	2
Land subsidence	1	0	1
The Kyoto conference	1	0	1
New energy sources beside oil	1	0	1
Dioxin	0	2	2
Total	19 students	7 students	26 students

(d) Please write anything that you know of environmental issues.

	(Interested)	(Unconcerned)	(Total)
Greenhouse Effect	68 (37.1%)	41 (30.6%)	109 (34.4%)
Garbage disposal	9 (4.9%)	8 (6.0%)	17 (5.4)
Ozone layers	46 (25.1%)	41 (30.6%)	87 (27.4%)
El nino	7 (3.8%)	5 (3.7%)	12 (3.8%)
Dioxin	7 (3.8%)	10 (7.4%)	17 (5.4%)
Deforestation	20 (10.9%)	34 (25.6%)	54 (17.0%)
Acidic rain	62 (33.9%)	20 (14.9%)	82 (25.9%)
Air pollution	18 (9.8%)	12 (9.0%)	30 (9.5%)
Desert expansion	25 (13.7%)	13 (9.7%)	38 (2.9%)
Diminution of nature	3 (1.6%	4 (3.0%)	7 (2.2%)
Topics less than 5 students			
Freon	2	0	2
Land subsidence	4	0	4
The Kyoto conference	1	0	1
New energy sources beside oil	3	0	3
Minamata diseases	1	0	1
Surface of ocean	1	1	2
Milk container	1	0	1
Radioactive wastes	1	1	2
Medical treatment	1	0	1
Recycled paper	1	0	1
Food additive	1	0	1
Recycle	0	1	1
Soil contamination	0	1	1
Noise	0	1	1
Photosynthesizing plants	0	1	1
Influence on human body	0	4	4
Total	17 students	10 students	27 students

Conclusion

I was able to obtain very interesting results that something I have never thought of. For this time, I would like to present here just what I have noticed throughout this survey.

Question 1.2.3

Results were as I expected. Students are familiar with the words, but they do not seem to know those exact meanings. They would need to lean much deeper in high schools.

Question 4

They seem to have both negative and positive impression, and it was also interesting that there were almost the same number of students who thought of Godzilla and Hiroshima or Nagasaki from the same words: radiation and radioactivity. This might be suggesting that generations are certainly shifting.

Question 5

93.3% of the students know about Nuclear power generation.

Question 6

Two third of them learned it when they were in primary schools and, among those students, more than half: 51.2% said they studied in classes. On the other hand, 60%, out of those who have known about it since junior high schools, said they learned it through papers or TV programs. Namely, they do not teach much about Nuclear power generation in junior high schools probably because the topic is not very much related with problems of high school entrance examinations.

The topic that was the most interesting to them (41.9%) about Nuclear power generation was the effect of radiation or radioactivity on any kind of things in the environment. We could include it in our educational curriculum in the near future.

Question 7

About problems related energy sources and their scarcity on earth, 43.3% of the students have been interested since junior high schools, and 64.8% of those students said they learned in classes. We can see teachers are emphasizing the topic in Junior high schools. However, we also have to pay attention to the fact issues at all, and 59.7% of those students learned about those problems in schools. This seems more problematic to me.

Their particular interest about the topic varies, but more than one third of them are worried about the shortage of oil and the emergence of new energy sources that can be replacing it.

Question 8

56.5% of the students know about X-rays, and even 70%, out of those who said they were unconcerned at all in the question 7, also know about it. Next well-known topic was about an atomic bomb, and 36.6% of the total and 32.1% of those who were unconcerned about energy related issues seem to know about it well.

Question 9

About environmental issues, 69.4% of the students have known since primary schools and 20.2% have known since junior high schools among those who said they were concerned about or interested in the problems (in question 7) somehow. It seems that more students learned about problems related to nature and environments for the first time when they were in primary schools than in junior high schools, and 51.1% of them said they have seen those issues in classes.

On the other hand, 60% of the students, out of those who said those issues were interesting and they came to know when they were in junior high schools, learned through papers, magazines or on the TV. It is also interesting that large number of students (62.9%), who first studied about the issues in the classes of junior high schools, were not concerned about them at all.

The topic they want to know the most (in question 9) is solutions for those problems such as Greenhouse effect, Ozone layers and Garbage disposal (18.6%).

Topics they already know well are also Greenhouse effect, Ozone layers, Acidic rain and Deforestation, and Air pollution, Desert expansion, Garbage disposal problems, Dioxin are following.

3.5 物理１Ｂでの「原子と放射線」のカリキュラム

久保田信夫

立花学園高校　259-0005 神奈川県足柄上郡松田町総領 307 の 2

要旨

物理１Ｂの授業では原子の単元が非常に簡単に扱われると共に時間の確保もできない状況があった。しかし、物理授業において現在の文化の中で利用されているエネルギーにまったく触れずに終了していくことに疑問を感じ、授業の中で原子力エネルギーを取り上げていく取り組みを数年前から実施してきた。現在では約１０時間の「原子と放射線」のカリキュラム実施している。今回はその内容を発表することとした。

１、はじめに

日本の一般家庭で利用する電気約 30%が原子力発電所によるものである。このような現実の中で生徒たちに原子力と放射線に関わる正しい知識を持ってもらうことを今回の授業の目的とした。カリキュラムとしては下記の点をポイントとした。

a,放射線発見から戦争を背景とした核爆弾の開発、そして原子力平和利用への歴史を教える。

ｂ、放射線について知識を放射線計測協会の実験キットを利用した放射線実験から学ばせた

ｃ、原子力施設の見学ビデオなどを取り入れた授業を展開することにした

ｄ、原子力発電に対する生徒の意識調査を授業の始めに実施し、最後に生徒たちとの意見交流をしながら生徒たちの意識の変化を確認してみた。

２、内容

A，実施した授業カリキュラムと内容を表に表わしてみました

項目	内容	実験・実習
核エネルギー発見と開発の歴史	①放射線発見から核分裂発見 ②核爆弾開発から原爆投下 ③戦後の平和利用 （学ばせること） 核が戦争に利用させたことがマイナスイメージとなっていることをしっかりと理解させ、エネルギーとしての価値	核の時代 Ｎｏ１ 「ＮＨＫ作成」

	を認めていく必要を説いていくこと	
放射線と放射線発生のメカニズム	①電子と原子 ②放射線とはなにか ③放射線とその種類 ④原子核と放射線 （学ばせること） 電子と原子について学び 原子核内から発生す放射線について正しい知識を持たせる。	教科書を使った授業 ＊クルックス菅 ＊偏向板付きクルックス菅
放射線計測１ 自然放射線と身近な線源	①放射線計測の方法 ②自然放射線の計測 ③放射線の危険性について （学ばせること） 放射線は自然界にあることを理解させ、生活の中でいろいろな物質が放射線を発していることを教えていく。 放射線とは特別なものではないことを教え、放射線の危険性についても学ばせる	「はかるくん」
放射線計測２ 放射線からの距離と線量との関係	放射線源と距離の関係を実験から求める （学ばせること） 放射線を安全に取り扱うためには線源との距離が重要な要素となることを学ばせる。	「実験キット」
放射線計測３ 放射線の遮蔽効果実験	アクリル・鉄・アルミ板・鉛による遮蔽効果を確認する実験 （学ばせること） 放射線を遮蔽するとはどのようなことなのかを教える。 放射線を出す物質を取り扱うながで遮蔽するための知識を学ばせる。 放射線計測２と合わせて放射線を安全に取り扱うための知識を理解させる	「実験キット」
キリ箱の観察	手作りキリ箱によるアルファー線の飛跡を確認する実験 （学ばせること） 放射線を目で確認することで感覚として認識させる。 キリ箱の原理にも触れていく。	自作キリ箱 （ドライアイス型）

核分裂	① ウランの核分裂について ② 連鎖反応 （学ばせること） ウランの核分裂原理と連鎖反応を学び、核爆弾と原子炉の違いを教えていく	チェレンコフ散乱ビデオ
原子力エネルギーの原理	①原子炉の原理 ②原子炉の構造 （学ばせること） 原子炉がどのようにエネルギーを作り出しているのか教えていく	核施設見学時のビデオ
核燃料と核廃棄物	①核の燃料について ②核廃棄物について ③ 廃棄施設について （学ばせること） 核燃料と使用後の核廃棄物について学ぶ。 核廃棄物をどのように処理しようとしていると考えているのかを学んでいく	
エネルギーとしての原子力について	生徒の意見をききながらディスカッションを行なう （目的） 授業を通して生徒たちの考えがどのように変化していったのかを知り、エネルギーの問題に感心を持たせていく	

B，授業に取り入れた実験紹介

①放射線計測１「自然放射線の計測とその他物質からの放射量の計測」

この実験で放射線量の測定についての方法を教えます。

基本的に１０回測定し、その平均を求めることでそのときの線量が求められることを教えます。はかるくんは１０秒ごとにその前の１分間の平均値を求めているので、測定するためには、まずはかるくんを測定状態にして１分間放置しその後１０秒ごとのデーターを１０回測定させます。自然計数より多いものを選ばせ、全体で確認していきます。 一般に花崗岩、塩化カリウムからの線量が自然計数より多くなります。

放射線はどのように場所にもあり、身近なものからも発生していることを確認させことができます。

②放射線計測２「距離と線量の関係を求める実験」

実験用キットには線源としてセシウム１３７が入っていますので、線源を実験用の台座にのせ、はかるくを１０ｃｍ，２０ｃｍ，３０ｃｍ，４０ｃｍ，５０ｃｍの位置において各点での１０回ごとの測定をし平均を求めます。 この実験から、線量が距離の二乗に反比例することを確かめます。

放射線を発するものから十分に距離を置くことで安全が確保できることを確認していきます

③ 放射線計測３　「遮蔽効果についての実験」
実験用キットを使った遮蔽実験です。 遮蔽物による線量の違いを確かめる実験
同じ厚さのアクリル板、アルミ板、鉄板、鉛板を線源の前に置き、線量の違い
を確認します。鉛板以外はほとんど遮蔽が出来ないことが分かります。
材料を選ぶことで放射線が遮蔽できることを学んでいきます。

④ 放射線実験　「放射線を目でみる」
ドライアイスと透明タッパを使った自作のキリ箱によるアルファー線の飛跡を
観察します。放射線を目で確認することで実感として放射線を体験させます。

キリ箱の材料と作成手順

＜材料＞

１、容器（底が透明で文字の少ないものなら良い）半径１０ｃｍ程度
＊今回はマリスのシール容器（丸型）を利用します。底が透明のプラスチック容器であれば利用できます。マリス製品の値段１個約 200 円
６個セットで販売しています。（製品名シール容器　丸型ＳＶ－９）

２、カラーアルミ板（厚さ 0.3mm で裏が黒のものを利用）20cm×20cm

３、アルミ板（0.3mm）の物に黒い紙や布を張ったりしたものでも良い枚 130 円

４、すき間テープ（幅約 1cm、長さ 30cm）
一巻き、長さ 5m、幅１cm　約 200 円

５、針金（30cm）

６、アルミテープ（幅 2cm、長さ 40cm）
一巻き＝長さ 4m、幅 2cm 約 450 円

７、スポイト

８、エタノール（少量）

９、ドライアイス　10cm×10cm×5cm　　1Kg＝500 円

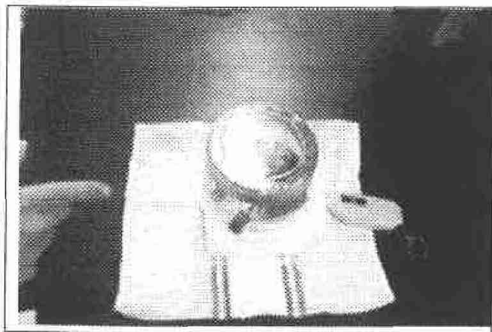
１０、ゴム栓　＃０　(12×10.5×12mm)　　約 150 円

＜作成方法＞

（準備として容器の開け口から高さ 2cm 程度の所に直径 1cm の穴を開けておく。＊ケースが壊れ安いので半田コテで穴を開け、リーマーで広げる方法が良い）

①容器の開け口を下にしてアルミ板の上に載せ、鉛筆やマジックなどで容器の外側の大きさに沿った線を書く
②はさみでアルミ板を①の線に沿ってきり円盤状にする。
③すき間パットを容器の内側に合う長さで切り、容器の底の側面に沿って張る
④針金で③を押さえるように取り付ける
⑤アルミの板を開け口に取り付ける。（容器側が黒い面になるようにする）
アルミのテープで密封状態を保てるようにする。

＜観察＞



セットした状態

観察の様子
懐中電灯を横から当てて観察をする。

３、 授業を実施したことの対してのまとめ

ａ，授業をやる前の生徒の意識調査（対象 約１２０人）

問１、　原子力についての印象

危険なもの・危ない物＝３３人
発電所　＝１８人
原子爆弾や兵器　＝１７人
分からないなど　＝２０人

問２、　放射線・放射能についての印象

戦争・原爆・被爆・戦争＝３４人
危険・恐い　＝５５人
レントゲン。治療など　＝１８人

問３、　原子力のエネルギーへ必要だと思うか

必要　３４人
不要　１０人
分からない７４人

問４、　エネルギーの需要は増加していますがどうのようにしたら良いと思いますか

省エネルギー　５１人
（法的な規制の必要がある）
代替エネルギーの開発　２０人
発電所を増やして対応　６人

原子力についてまったく教えない段階では、原子力と原爆が結ぶついていることがわかります。また、放射線や原子力に対して危険であるとのイメージが中心となっている。

ｂ、授業終了後の生徒との話

原子炉について知識に関して

1) 放射線についての正しい知識があれば、恐れる必要がない
2) 原爆と原子炉とはまったく違ったものである
3) 放射線について良く分かった
4) 原発の原理が分かった

授業を通して一定の知識を伝えることはできた
しかし
エネルギーの問題や原子力発電所を作ることについてはいろいろな意見が出てきた

＠日本ではエネルギーを無駄に使っている。規制が必要ではないか
＠自分としては豊かな生活を失いたくないが原発には問題を感じる
（動燃問題がイメージの中にあるようです）
＠自分の町に原発を作るといわれたら反対する。
（完全に安全といえないのではないか）
＠エネルギーを無駄にしないようにていくことが一番のポイントではないか。

C,授業の成果

この授業を通して、放射線や原子炉について正しい知識を教えることができた。
放射線を実験を通して理解させることができた。
生徒達に原子力発電の原理を理解させながらエネルギーの問題を考えるきっかけとなった。

3.6 高等学校における放射線指導実践上の課題

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〔アブストラクト〕
　１９９５年１２月８日の高速増殖炉「もんじゅ」のナトリウム漏れ事故の直後に、当時高校１年生の２０５名を対象に「放射線に関するアンケート調査」を実施した。その調査項目は、1.　放射線に対する興味、2.　放射線とはなにか、3.　身近な放射線、4.　放射線の被害、5.　放射線の利用　であった。この調査結果は、高校入学時つまりはほぼ義務教育終了時点での生徒の放射線に関する興味・知識・理解の度合いを示す内容であった。
　その後、２年後の１９９７年１２月に物理を選択した理系の生徒３クラス１２５名を対象にして、２年前と全く同じ調査項目でアンケート調査を実施した。この時点で高校物理の学習を一通り終えていて、２年間の学習の成果を測定する意味もあったわけであるが、これら２度の調査によって放射線指導実践上の課題を一層明確化することができた。
　生徒の放射線に関する学習環境としては、マスコミによる報道を通した情報入手の機会があったであろう。学校教育では、教科書の記述内容による学習、及び筆者が補足的に取りあげた教材（副読本、霧箱、γ線遮蔽実験、簡易ＧＭ管、オートラジオグラフィ、陰極線の観察実験など）による学習の機会があったことになる。これらの学習機会の成果としては、興味度の向上、α線・β線・γ線などへの理解向上、自然放射線に関する理解向上があげられるが、放射線の被害と利用については指導上の課題が多く残された。
　これらの放射線に関する指導実践を通して、(1)　生徒（親）サイドの課題、(2)　教師サイドの課題、(3)　指導条件の課題　を明確にすることができた。つまり、危険な代物と思われている放射線とそのことによって予想されるトラブルを回避したい教師側のモーチベーション上の課題、教材である教科書の記述上の課題、入手が容易な実験教材の提供上の課題などがあげられるが、これらは近未来のエネルギー供給問題を解決する上で避けて通ることができない解決を求められる課題と思われる。

1.　はじめに

1995年12月８日に起きた高速増殖炉「もんじゅ」のナトリウム漏れ事故から２年の歳月が流れた。その当時高校１年生であった本校34期生10クラスの内、５クラスの生徒２０５名を対象として「放射線に関するアンケート調査」[1]を実施した。その調査結果は、高校入学時点、つまりは義務教育終了時点での生徒の放射線に関する興味・知識・理解の度合いを示す内容であった。それから２年が経過し、「もんじゅ」はその後どのような経過を辿ったのかは詳らかではないが、本校34期生は２年時で理系３クラスの生徒が物理を選択し、３年時ではそのほぼ全員が継続して物理を学習し、1997年12月に一通りの高校物理の学習を終えた。その時点で、この２年間の学習成果の一端を測定するために、２年前と全く同じ調査内容の「放射線に関するアンケート調査」を３クラスの１２５名の生徒を対象に実施した。
本論では、生徒が主に２年間の物理の学習指導を受けることによってもたらされた放射線を巡る認識の変化を、指導実践の一事例として紹介する。

2.　放射線を巡る生徒の学習環境

生徒の放射線を巡る学習環境として学校内と学校外の区分して考えることにする。テレビとラジオ及び新聞の報道内容を逐一調査してはいないが、学校外では様々なマスコミ報道を通した放射線に関わる情報入手の機会があったであろうと想像される。例えば、核関連施設事故とか核廃棄物処理場建設や核兵器処理の原子力関連の報道など。一方、学校内では高校物理の授業内容を通した学習が中心になることと思われるが、放射線に関わる教科書の記述内容としては、物理ＩＢの第５編「電子と原子」で「放射線とその性質」及び「原子力の利用」さらには教科書の口絵写真、物理Ⅱの第３編「原子」では「核エネルギー」と口絵写真があげられる。
その他に私が授業で補足的に取り上げた教材は次の通りである。
副読本としては「生活環境と放射線」（原子力実験セミナーのテキスト）の一部を著者の許可を得て複写し、生徒に配付して授業中に用いた。生徒実験としては「液体窒素を用いた霧箱によるα線とβ線の観察」（森式霧箱[2]）及び「はかるくんによるγ線の遮蔽実験」（放射線計測協会から借用）を４名程度の班単位で実施した。演示実験としては「簡易ＧＭ管によるα線とβ線の観察」、「オートラジオグラフィの写真観察」（ラットといんげん豆）「各種クルックス管による陰極線の観察」及び「クロス真空管による陰極線の観察」を行なった。これらを組み合わせて放射線の学習指導を展開した。

3. 調査用紙

『放射線に関するアンケート調査』

年　　組　　番・氏名）

※ 次の設問に該当する番号に○印を記して下さい。

1. 放射線について

(1) 興味をもって調べたことがある
(2) 調べたことはないが興味がある
(3) 興味がない

2. 放射線と思うものはどれか？　＜複数選択可＞

(1) 紫外線、 (2) 赤外線、 (3) レーザー光線、 (4) 電気通信用電波、
(5) 宇宙線、 (6) 中性子線、 (7) X線、 (8) γ線、 (9) β線、 (10) α線

3. 放射線が日常生活のどんな身近なところにあるか？　＜複数選択可＞

(1) レントゲン検診車、 (2) ＴＶ、 (3) 大気中、 (4) 蛍光灯、 (5) 地中、
(6) 原子力発電所、 (7) 歯科医院、 (8) ガン治療病棟、 (9) 核廃棄物貯蔵施設
(10) 変電所、 (11) カメラ、 (12) 食物、 (13) 電子レンジ、 (14) 酸性雨、
(15) その他（　　　　　　　　　　　　　　　　　　　）

4. 放射線（放射能）の被害と思うものはどれか？　＜複数選択可＞

(1) ボケる、 (2) 免疫力が低下する、 (3) 骨が弱くなる、 (4) 筋肉痛をおこす、
(5) 遺伝子に異変をおこす、 (6) 障害をもつ子供が生まれる、 (7) ガンになる、
(8) 植物が枯れる、 (9) 髪が抜ける、 (10) 白血病になる、
(11) その他（　　　　　　　　　　　　　　　　　　　）

5. 放射線（放射能）を利用している思うものはどれか？　＜複数選択可＞

(1) 物体の内部構造や厚さの測定
(2) 化学反応を促進させる
(3) 農作物の品種改良
(4) ジャガイモの発芽防止
(5) 害虫の駆除
(6) ガンの治療や骨の診察などの医療
(7) 生物体内の移動物質の観察
(8) 遺跡発掘物の年代測定
(9) エネルギーを取り出す（発電）
(10) 新しい物質（元素）を作り出す
(11) その他（　　　　　　　　　　　　　　　　　　　）

4. 調査結果

放射線に対する興味度	第１回〔1995年12月〕（２０５名中）	第２回〔1997年12月〕（１２５名中）
(1) 興味をもって調べたことがある	2 名（ 1%）	7 名（ 6%）
(2) 調べたことがないが興味がある	100 名（49%）	85 名（68%）
(3) 興味がない	103 名（50%）	33 名（26%）

放射線と思うもの	第１回〔1995年12月〕	第２回〔1997年12月〕
(1) Ｘ線	181 名（88%）	115 名（92%）
(2) 紫外線	74 名（36%）	56 名（42%）
(3) レーザー光線	56 名（27%）	22 名（18%）
(4) 赤外線	55 名（27%）	33 名（26%）
(5) 宇宙線	54 名（26%）	97 名（78%）
(6) β線	40 名（20%）	114 名（91%）
(7) 中性子線	37 名（18%）	79 名（63%）
(8) α線	35 名（17%）	108 名（86%）
(9) γ線	29 名（14%）	116 名（93%）
(10) 電気通信用電波	16 名（ 8%）	20 名（16%）

身近な放射線	第１回〔1995年12月〕	第２回〔1997年12月〕
(1) レントゲン検診車	171 名（83%）	120 名（96%）
(2) 原子力発電所	160 名（78%）	117 名（94%）
(3) 核廃棄物貯蔵施設	122 名（60%）	101 名（81%）
(4) ガン治療病棟	115 名（56%）	105 名（84%）
(5) 歯科医院	54 名（26%）	80 名（64%）
(6) 電子レンジ	45 名（22%）	50 名（40%）
(7) 大気中	42 名（20%）	94 名（75%）
(8) ＴＶ	32 名（16%）	41 名（33%）
(9) 蛍光灯	30 名（15%）	61 名（49%）
(10) 酸性雨	30 名（15%）	16 名（13%）
(11) 地中	26 名（13%）	62 名（50%）
(12) 変電所	16 名（ 8%）	23 名（18%）
(13) 食物	15 名（ 7%）	57 名（46%）
(14) カメラ	15 名（ 7%）	23 名（18%）

放射線の被害	第１回〔1995年12月〕	第２回〔1997年12月〕
(1) 髪が抜ける	152 名（74%）	103 名（82%）
(2) 遺伝子に異変をおこす	139 名（68%）	116 名（93%）
(3) 障害をもつ子供が生まれる	136 名（66%）	113 名（90%）
(4) 白血病になる	104 名（51%）	83 名（66%）
(5) 植物が枯れる	97 名（47%）	64 名（51%）
(6) ガンになる	92 名（45%）	97 名（78%）
(7) 免疫力が低下する	75 名（37%）	76 名（61%）
(8) 骨が弱くなる	47 名（23%）	29 名（23%）
(9) ボケる	16 名（ 8%）	7 名（ 6%）
(10) 筋肉痛をおこす	5 名（ 2%）	8 名（ 6%）

放射線の利用	第１回〔1995年12月〕	第２回〔1997年12月〕
(1) ガンの治療や骨の診断などの医療	143 名（70%）	109 名（87%）
(2) エネルギーを取り出す（発電）	110 名（54%）	87 名（70%）
(3) 物体の内部構造や厚さの測定	99 名（48%）	107 名（86%）
(4) 新しい物質（元素）を作り出す	72 名（35%）	89 名（71%）
(5) 遺跡発掘物の年代測定	42 名（20%）	92 名（74%）
(6) 生物体内の移動物質の観察	40 名（20%）	50 名（40%）
(7) 農作物の品種改良	38 名（19%）	80 名（64%）
(8) 害虫の駆除	38 名（19%）	41 名（33%）
(9) ジャガイモの発芽防止	38 名（19%）	110 名（88%）
(10) 化学反応を促進する	37 名（18%）	36 名（29%）

5. 考　　察

(1) 興味度の推移〔図１〕

第１回の調査では半数程度の生徒が示していた放射線に対する興味が今回の調査では４分の３程度の生徒に増加していることが伺える。
これは、授業中の学習指導の中で特に実験・観察による関心の高まりであると思われる。

(2) 放射線と思うもの〔図２〕

X線は第１回の調査では最も高い回答率であったが、今回の調査ではさらに高い回答率を示した。　第１回の調査で低かったα線・β線・γ線が特に回答率の大幅な増加を示している。また、中性子線と宇宙線も次いで高い回答率を示している。
しかし、放射線に分類されていない紫外線と電気通信用電波の回答率が増加している点と、レーザー光線と赤外線も依然として放射線と考えている生徒が５分の１前後もいる点が気掛かりである。実験・観察による指導効果が現れたと思われる調査結果も見受けられるが、放射線の定義に関わる指導が徹底していなかった点も反省材料としてあげられる。

(3) 身近な放射線〔図３〕

第１回で低かった大気中・地中・食物といった自然放射線に関する回答率の増加が著しい。これはバックグランドとしての放射線への関心が高まった成果とも思われるが、回答率自体は半数から４分の３程度であることを考慮すると、残りの半数から４分の１程度の生徒に対する指導が足りなかったことにもなる。
電子レンジ・酸性雨・変電所・カメラからも放射線が出ていると考えている生徒が見られるが、特に電子レンジについては高周波の電磁波と放射線を区別できなかったことによるものと思われる。

(4) 放射線の被害〔図４〕

放射線の被害と関わりが薄い「骨が弱くなる」、「ボケる」、「筋肉痛をおこす」は少ないものの、「骨が弱くなる」は４分の１程度の生徒が依然として被害と考えていることが伺える。「筋肉痛をおこす」については回答率がやや増加している点が気掛かりである。
その他の項目については、遺伝子レベルの損傷によって引き起こされる各種の被害・障害を考慮した回答が増加していることが伺える。

(5) 放射線の利用〔図５〕

全てが放射線の利用に該当する項目であるが、項目毎の回答率に差がみられる原因として、授業中の解説や教科書の口絵写真等を生徒が様々な受け止め方をしたことが推測される。
回答率では「ガンの治療や骨の治療などの医療」「物体の内部構造や厚さの測定」「ジャガイモの発芽防止」が高く、今回の調査では特に「遺跡発掘物の年代測定」と「ジャガイモの発芽防止」に大幅な回答率の増加を示した。
これらの項目の指導には、適切な実験実習教材やシミュレーション教材の開発が必要と思われる。

6. 放射線指導実践上の課題

(1) 生徒（親）サイドの課題

放射線に対するイメージ　：　危険な代物

① 原子爆弾・水素爆弾による被爆
② 原子力発電所事故
③ その他核関連施設を巡るトラブル

⟹ われわれの身近にある物で、一市民として必要な科学的知識のひとつであり、適切な判断をするために必要な知識である。

(2) 教師サイドの課題

放射線指導のモーチベーション

(1)との関連で、積極的に取り上げることによって起こるであろうトラブルを回避したい.

⟹ CO_2，CH_4，O_3，NO_x，フロン，騒音，紫外線，ＥＭＦ等と同等の地球環境を構成する一要素である.

(3) 指導条件の課題

教育課程及び教材整備

① どの教科・科目で実施するか？
② 教材をいかに入手するか？

⟹ 教育課程上の位置づけ、及び容易に使える実験教材の開発

参　考　文　献

1）森　雄兒（1995）「陽電子の見える霧箱－液体窒素を使った森式霧箱」，物理教育，43-3，pp.269-272.
2）徳田肇道（1992）「高校生の所有する原子力関連の日常的知識について」，筑波大学大学院教育研究科修士論文.
3）村石幸正（1995）「放射線の学習」の実践報告，物理教育，43-2，pp.154-159.
4）笠　耐（1989）「放射線と私たち」，プロジェクトサイエンスシリーズ1，コロナ社.

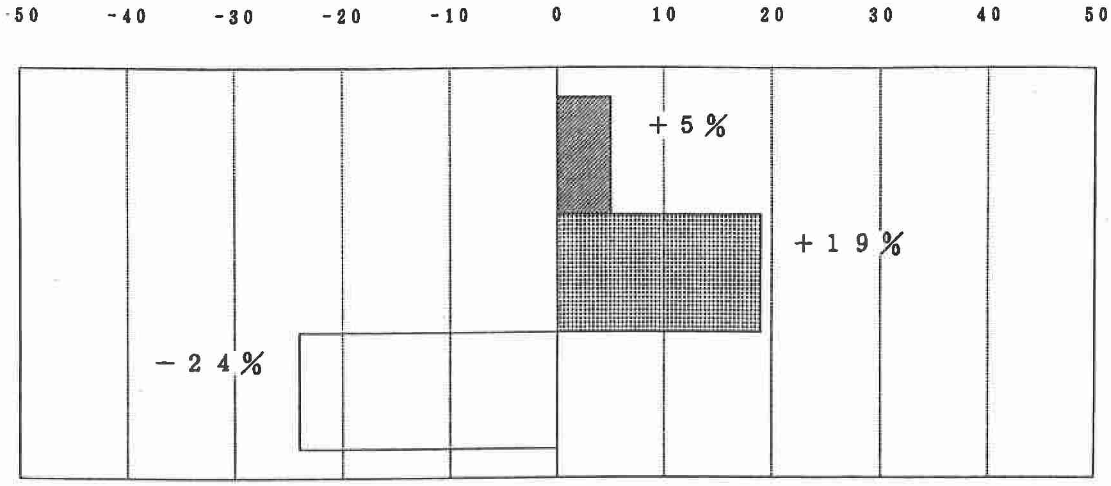
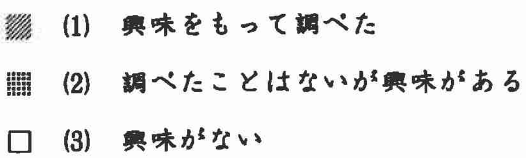

-50
-40
-30
-20
-10
0
10
20
30
40
50
+5%
+19%
-24%

図 1　興味度の推移


(1) 興味をもって調べた
(2) 調べたことはないが興味がある
(3) 興味がない

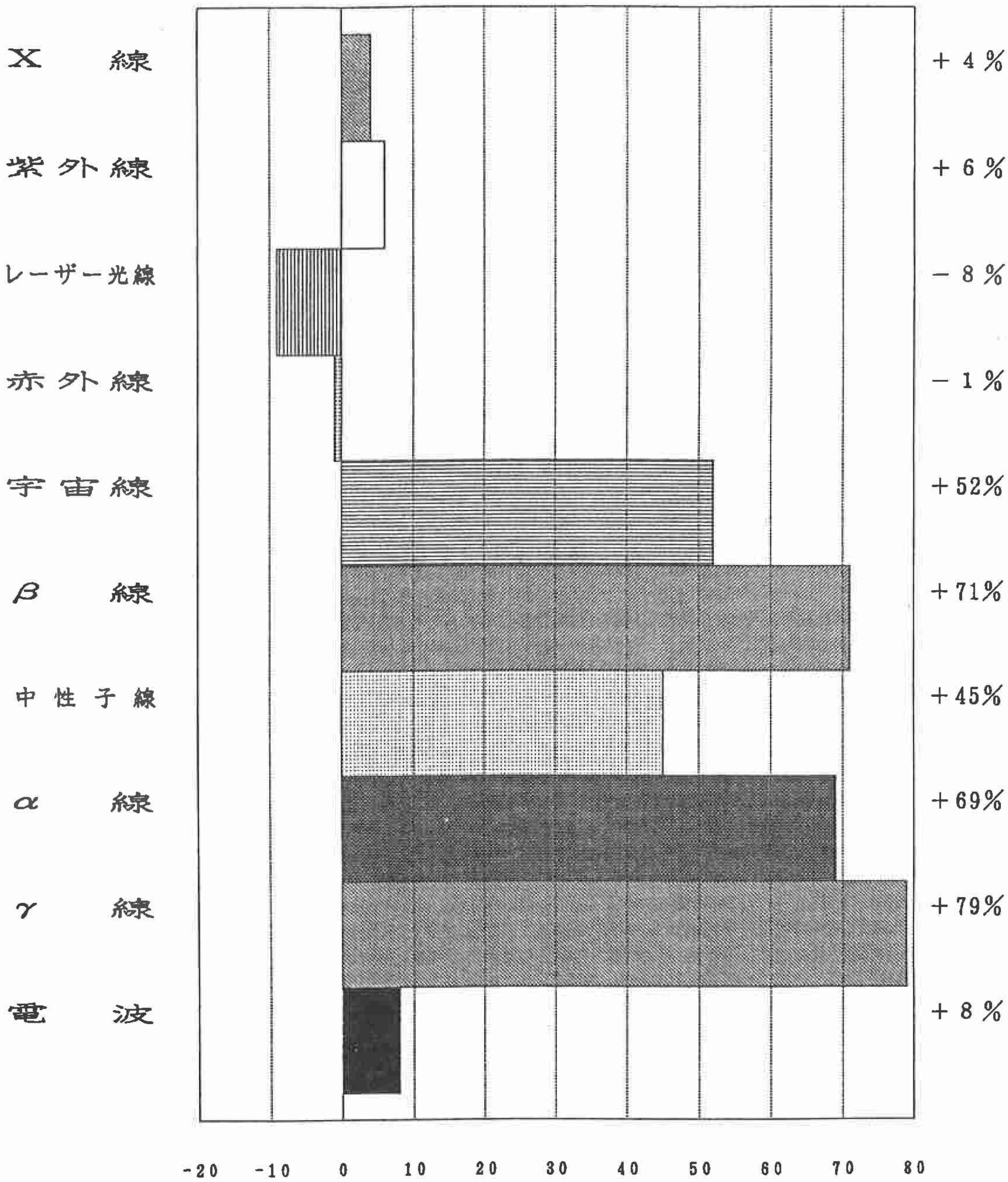
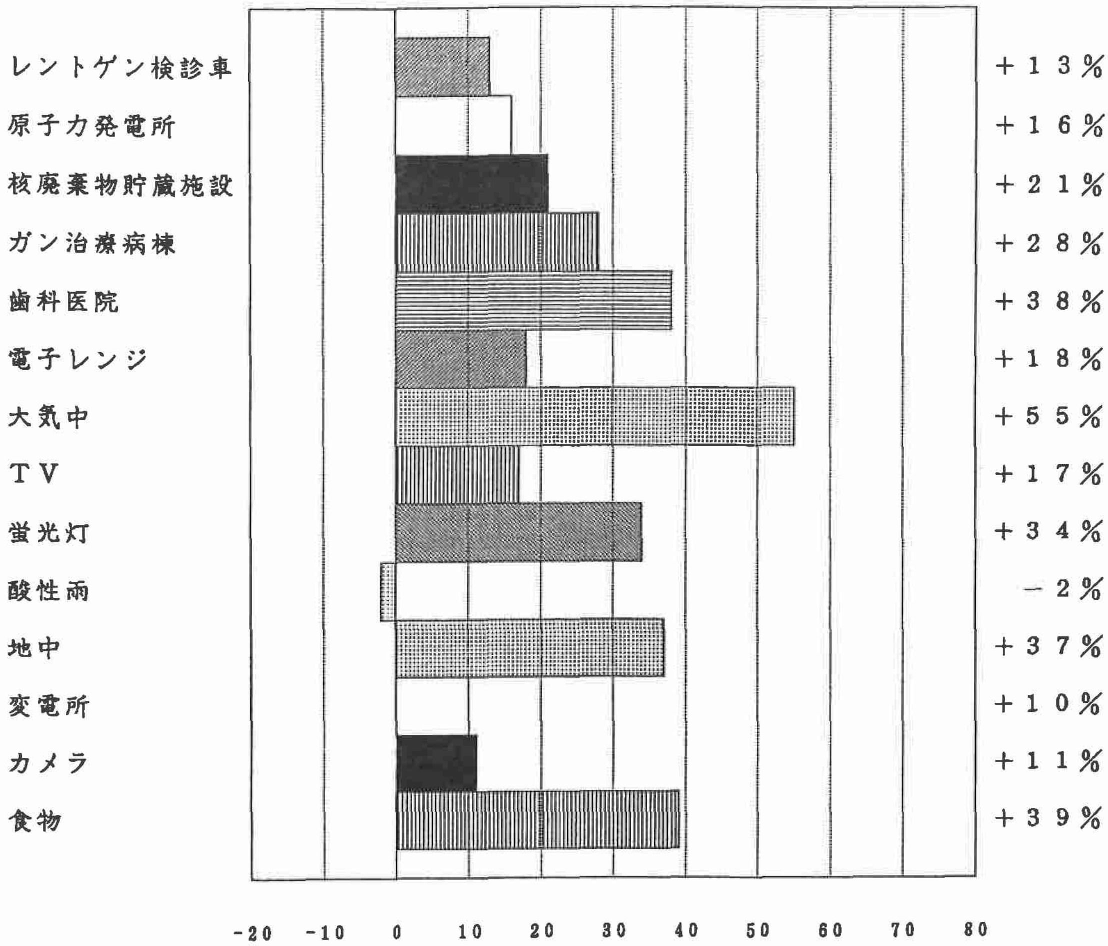

X 線
紫外線
レーザー光線
赤外線
宇宙線
β 線
中性子線
α 線
γ 線
電 波
＋4％
＋6％
－8％
－1％
＋52％
＋71％
＋45％
＋69％
＋79％
＋8％
-20
-10
0
10
20
30
40
50
60
70
80

図2　放射線と思うもの



レントゲン検診車
原子力発電所
核廃棄物貯蔵施設
ガン治療病棟
歯科医院
電子レンジ
大気中
ＴＶ
蛍光灯
酸性雨
地中
変電所
カメラ
食物
＋１３％
＋１６％
＋２１％
＋２８％
＋３８％
＋１８％
＋５５％
＋１７％
＋３４％
－２％
＋３７％
＋１０％
＋１１％
＋３９％
-20 -10 0 10 20 30 40 50 60 70 80

図３　身近な放射線

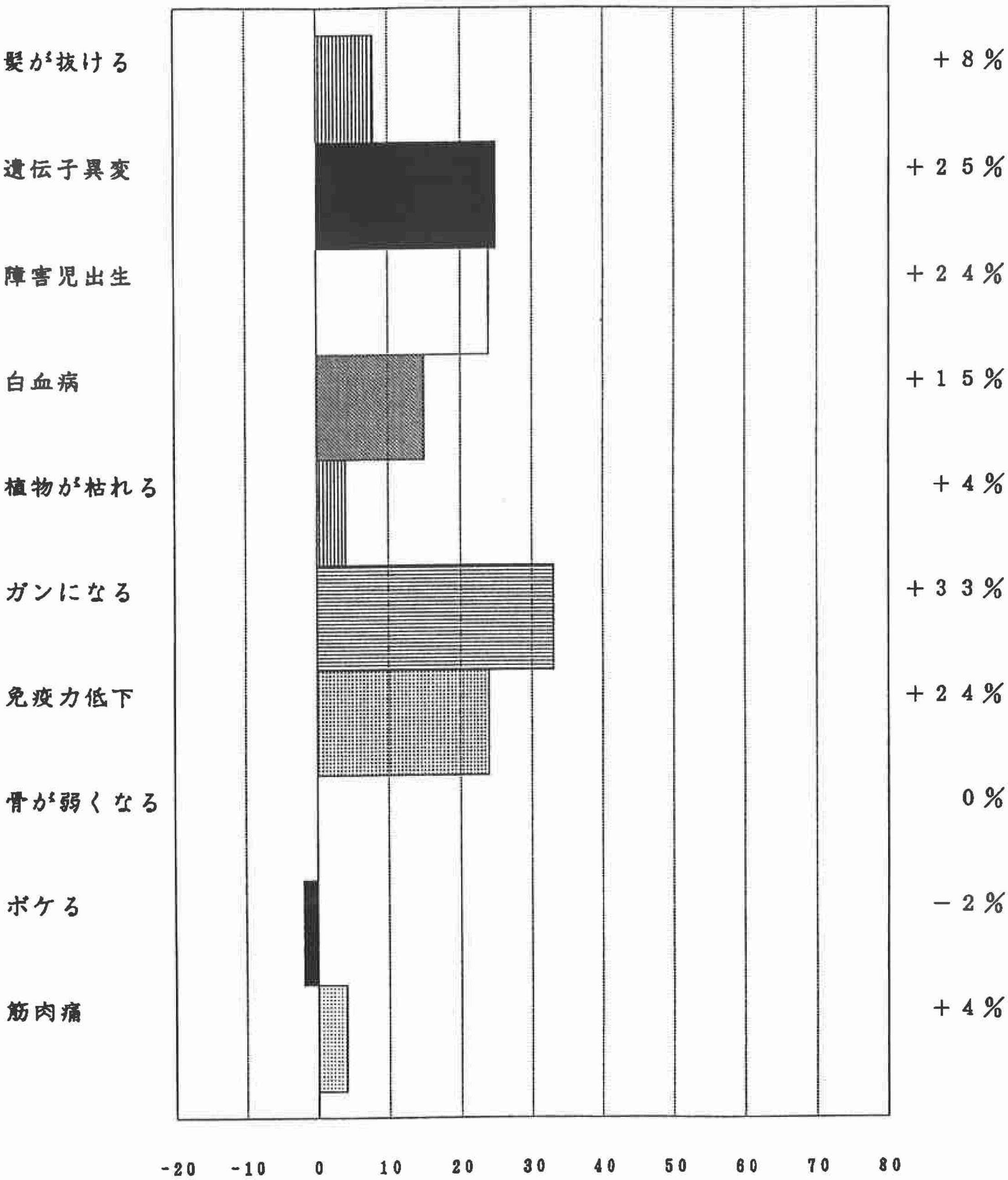
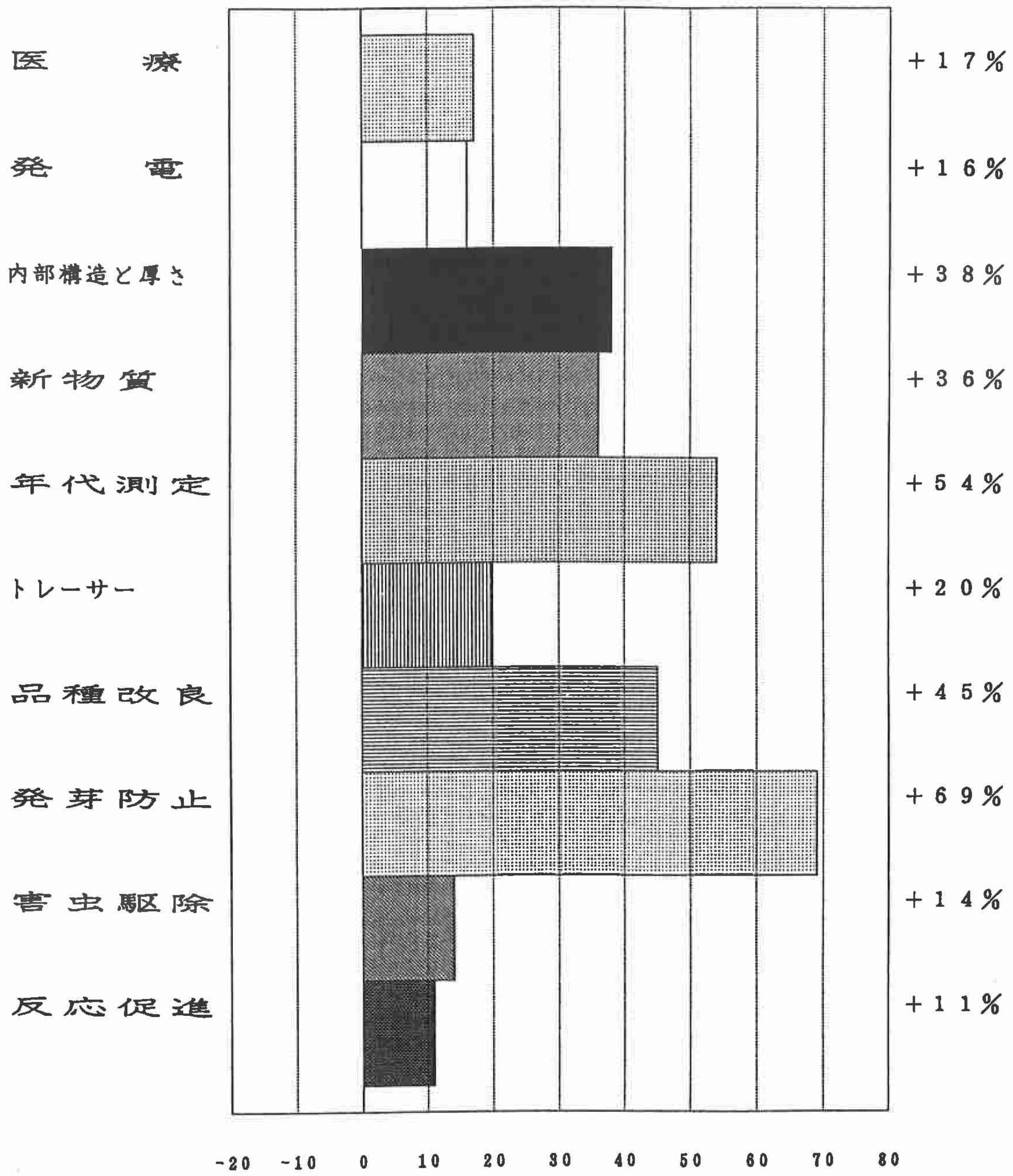

髪が抜ける
遺伝子異変
障害児出生
白血病
植物が枯れる
ガンになる
免疫力低下
骨が弱くなる
ボケる
筋肉痛
+8%
+25%
+24%
+15%
+4%
+33%
+24%
0%
−2%
+4%
-20
-10
0
10
20
30
40
50
60
70
80

図4　放射線の被害


医療
発電
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品種改良
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図5 放射線の利用

3.7 TEACHING MATERIAL FOR RADIATION EDUCATION USING RADIOGRAPHY TECHNIQUE.

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Abstract

In order to develop a teaching material that helps learners to understand the interaction between substances and radiation, a periodic table was prepared on which pure pieces of nearly thirty element were fixed and radiographic images of the periodic table were taken using X ray and neutron beam under several conditions. Obtained images are so clear that they can be expected to be very helpful in intuitive understanding on the magnitude of the interaction.

1.Introduction

Figure 1[1)] illustrates that X-ray can be shielded effectively in case the shielding material is composed of heavier elements and that the interaction of X-ray toward substance is completely different from that of thermal neutron. However, it is not easy for learners to grasp the magnitude of these interactions intuitively even if they can read the data in Fig.1 correctly. This is not only because radiation itself is insensible and invisible, but also because we have almost no opportunity to be conscious of the intensity of radiation in our daily lives. Radiation is something too far away from our daily lives and most of us do not have rigid concept on it.

Despite this situation, a radiographic image for medical use is something exceptionally familiar to us. Besides, it includes quantitative information on X ray transmittance across substance, or the magnitude of interaction between X-ray and substance. This means that most people, who are well acquainted with normal optical photographs, can read (or image) the intensity of radiation from optical density of the radiographic images.

From such a viewpoint we made a periodic table on which pure pieces of many elements were fixed and took its radiographic images under several conditions.

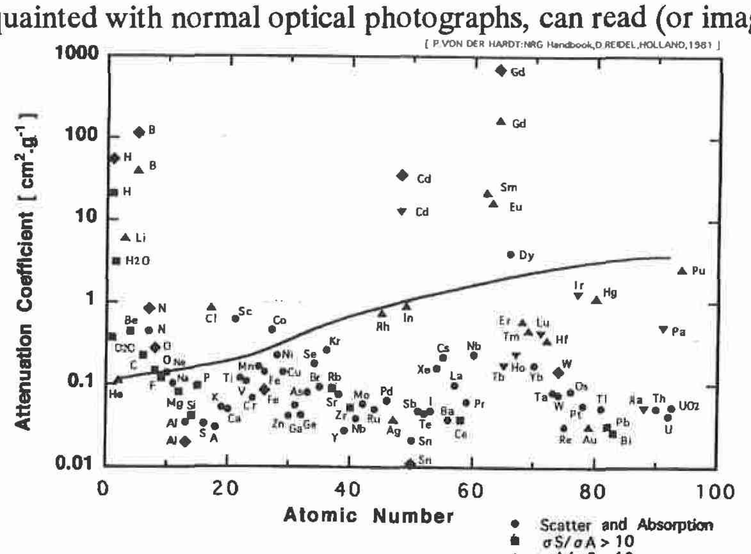


Fig.1 Neutron and X-Ray Mass Attenuation Coefficients for the Elements.

2.Experimental

2.1 Preparation of a periodic table

The number of samples used in this work is about 30 and they are schematically illustrated in Fig.2. The length and the width of each sample is equal to or smaller than 10mm and 8mm, respectively and its thickness, which accords with the direction of radiation, is 0.014mol/cm^2 (corresponding to 1mm in case of iron). In case of X-ray radiography, these samples were fixed on a plastic sheet with a thickness of 0.7mm, and in case of neutron and gamma ray radiography, they were fixed on an aluminum sheet with a thickness of 1mm.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Unq	Unp	Unh	Uns	Uno	Une									

Fig.2 Periodic Table (Prepared elements are hatched)

2.2 X-ray and Gamma radiography

X ray was irradiated to the periodic table as shown in Fig. 3 and the irradiation was repeated varying X ray energy from 50kV to 150kV in order to clarify how transmittance of X ray across a substance depends on its energy. The intensity of X ray that passed through the sample was recorded on an imaging plate and was read out with an IP reader BAS5000(FUJI).

For gamma radiography (GR), the neutron radiography facility of Kyoto University Research Reactor Institute (KURRI) was used. As shown in Fig.4, the facility has two beam shutter; one is made of lead to shield Gamma ray and the other one is made of boron carbide to shield neutron. GR of the periodic table was taken with the former one opened for 5 min.

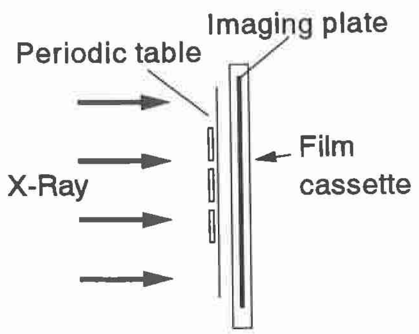


Fig.3 Arrangement for X-ray radiography

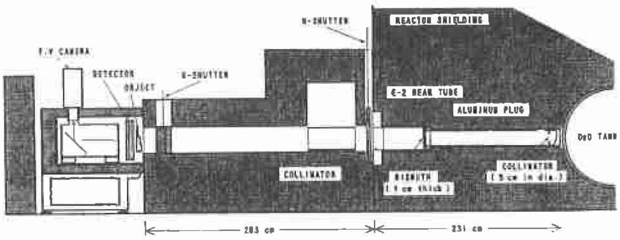


Fig.4 NR facility (KURRI)

2.3 Neutron radiography

Neutron radiography facility and CNS facility (Fig.5) of KURRI were used to take thermal neutron radiography (TNR) and cold neutron radiography (CNR), respectively. Yayoi Facility of Tokyo University (Fig. 6) was also used to take fast neutron radiography (FNR). Although the principle and arrangement for neutron radiography is similar to those for X-ray radiography (XR), imaging plates for neutron (Fuji) were used for TNR and CNR while Kodak SR (X ray film for industrial use) was used with the converter F20 for FNR. Irradiation time was 3 and 20 minutes for TNR and FNR, respectively. In case of CNR, the beam size is 10mm in width and 100mm in height. Since width of the beam is narrow, the periodic table was traversed in sideward with an imaging plate during 8 minute irradiation at the rate of 300mm/8min.

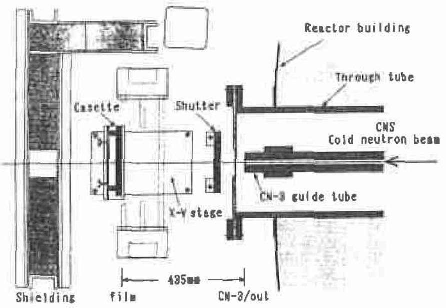


Fig.5 CNS facility (KURRI)

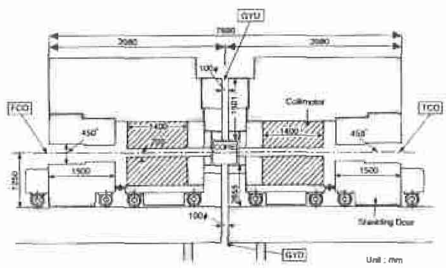


Fig.6 Yayoi facility (Tokyo Univ.)

2.4 Neutron activated autoradiography

When the periodic table is irradiated with neutron for relatively long period, some of the samples are activated. This work was designed to visualize which elements are easily activated and decay in relatively short time.

After the periodic table was irradiated for 9.5 hours in the neutron radiography facility of KURRI, it was enclosed in a film cassette with an imaging plate so that the surface of the periodic table was kept in good contact with that of the imaging plate for tritium use as long as 1.5 hours. Seven and half hours after irradiation, this procedure was repeated to obtain the image that illustrates how activated elements would decay.

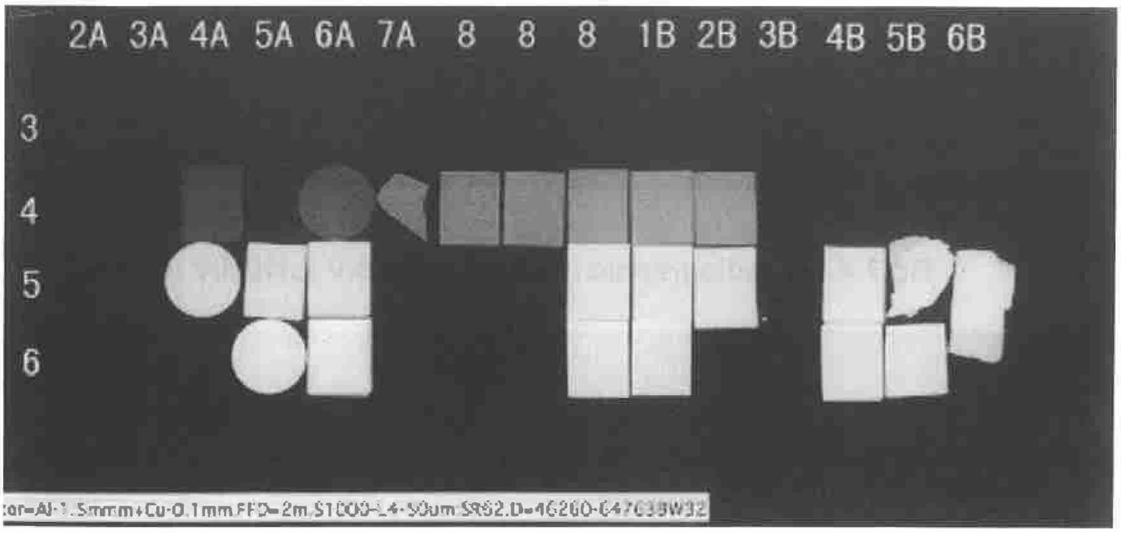
3. Results and Discussion

3.1 Results of XR and GR

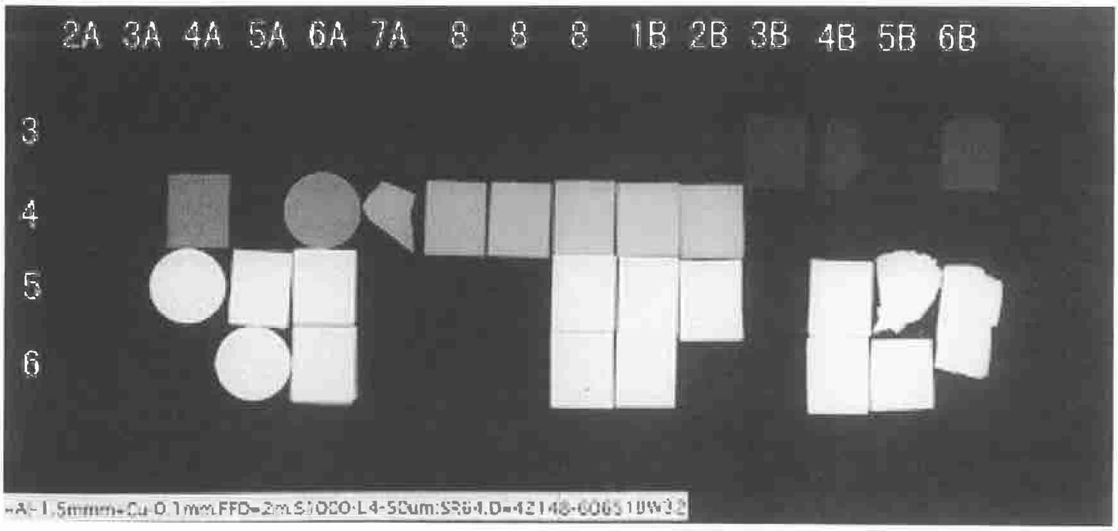
XR images of the periodic table were presented in Fig.7. Since the image of each sample is getting white according to the increase of atomic number, it can be easily understood that the ability to shield X ray increases according to the increase of atomic number of the substance, which reflects the fact that electrons in an atom play an important role in the interaction between X-ray and substances.

In case of Fig. 7(a), all samples in 3rd period are black and invisible. This means that they are too transparent to 150kV X ray. In case of Fig.7(c) elements in 3rd period are visible and those belonging to 5th and 6th period are all white. Thus, the energy dependence, as well as atomic number dependence, of X-ray transmittance has been visualized in these three photos.

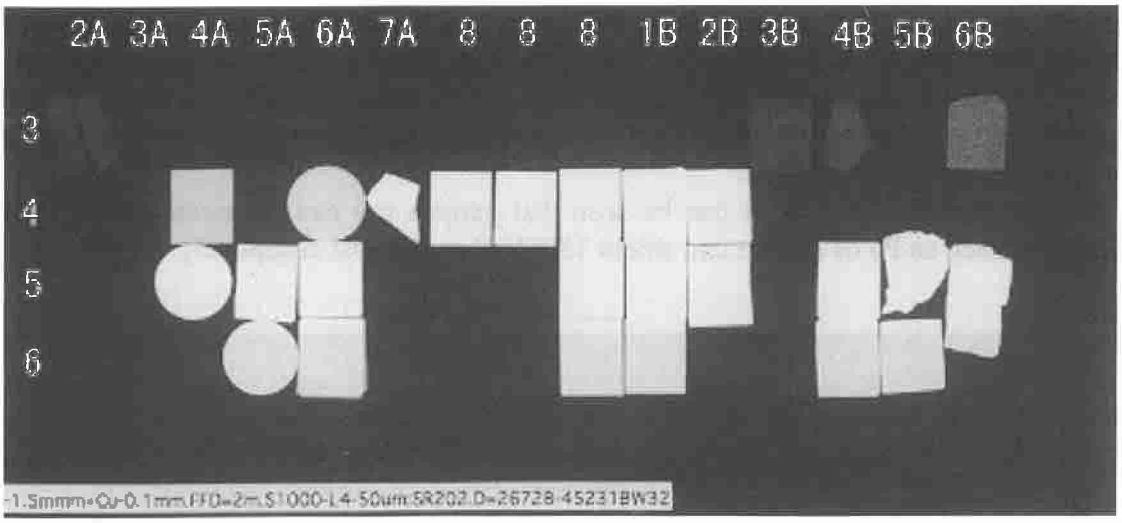
As for GR in Fig. 8, it can be seen that gamma ray can penetrate through heavy substances such as Pb or Bi that can shield 150kV X ray almost completely.



(a)



(b)



(c)

Fig.7 X-ray radiographic images (a)150kV (b)100kV (c)50kv

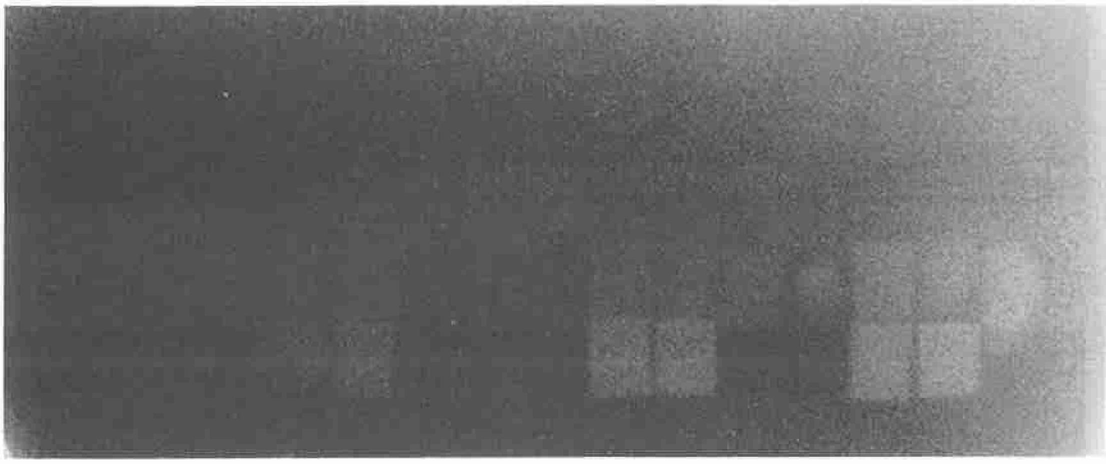


Fig.8 Gamma radiographic image

3.2 Results of TNR, CNR and FNR

The obtained images of TNR, CNR, FNR are presented in Fig. 9. Since neutrons do not interact with electrons around a nucleus but nucleus itself, the obtained images are completely different from XR images. Take B and Pb in Fig. 9(a) for instance, B is opaque and Pb is transparent to neutron, which is exactly the opposite result of what was seen in Fig.7.

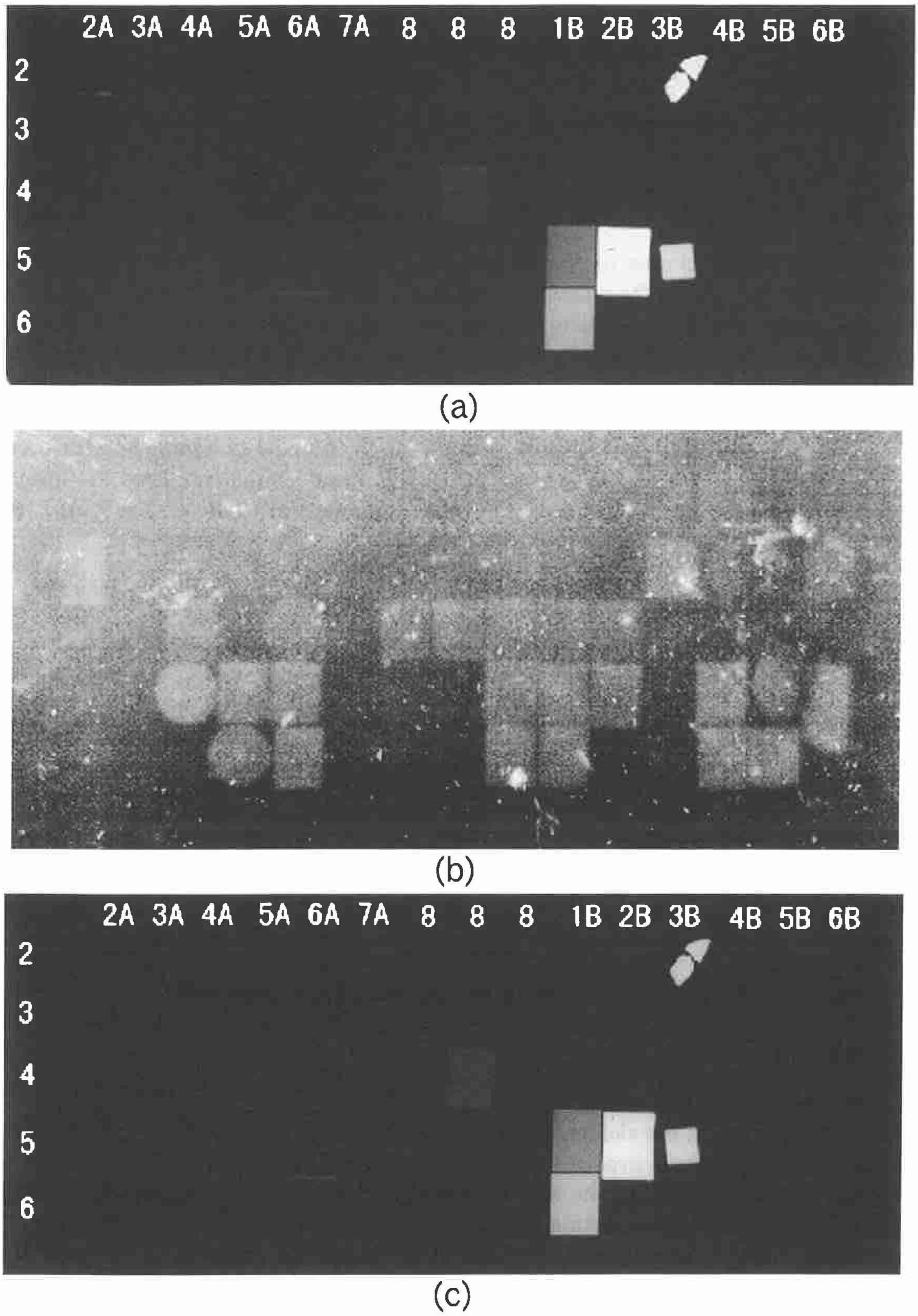


Fig.9 Neutron radiographic images
(a)TNR (b) FNR (c)CNR

In case of thermal neutron, neutron transmittance Io/I for each element can be approximately evaluated by the following equation;

$$Io/I=\exp(-N\sigma x) \quad (1),$$

where, N, σ and x denote number of atoms in unit volume [cm^{-3}], total cross section to neutron [barn] and thickness of the sample [cm], respectively. In Fig.10 the calculated values were plotted against the measured ones that were derived from digitalized data of the NR image, which was obtained using Rikkyo University Reactor instead of KUR. Although they are in coincidence to certain degree, the deviation is not negligibly small. It is considered that the imaging plate used in this work has some sensitivity also to the Gamma ray as well as neutrons.

Generally, as energy of neutron becomes larger, peculiarity among species become less conspicuous because elastic interaction become more prominent. Thus the image of FNR(cf. Fig. 9(c)) is similar to that of GR while the image of CNR (cf. Fig.9(b)) is more contrasted in comparison with the image of TNR.

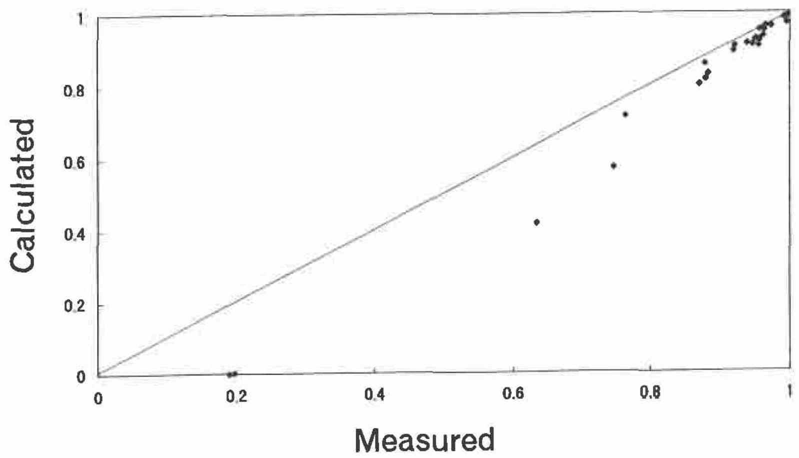
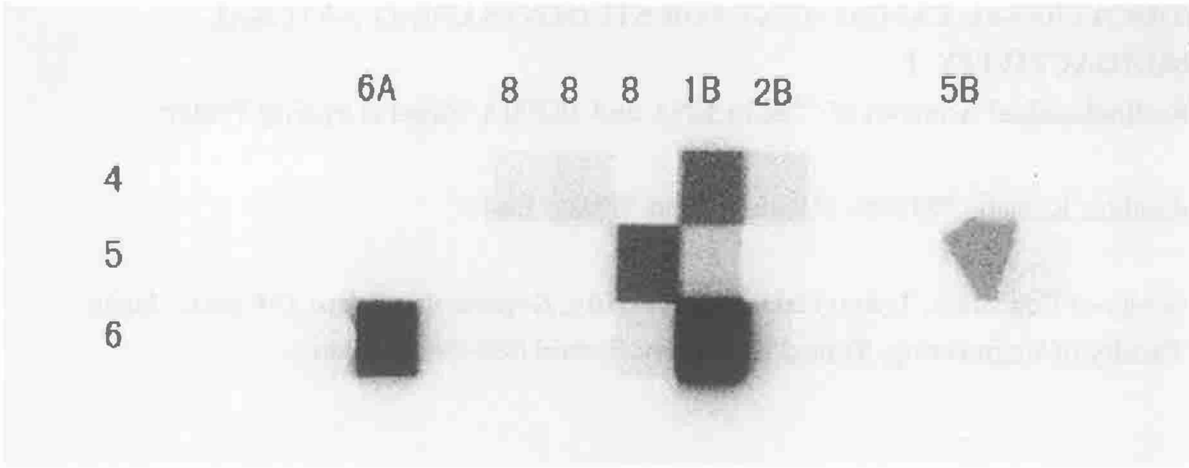


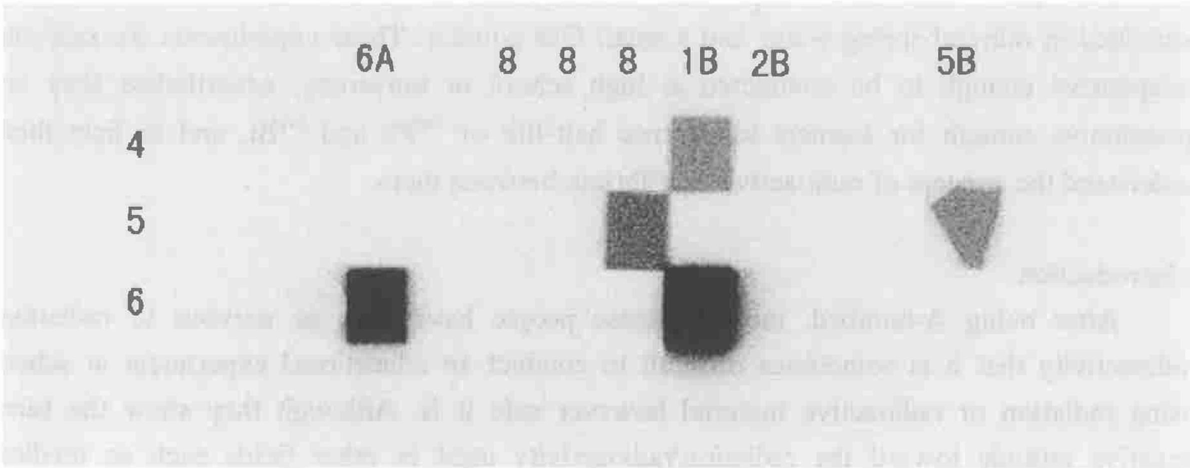
Fig.10 Neutron transmittance of various elements

3.3 Neutron activated autoradiography

As shown in Fig. 11, the elements such as Fe, Co, Cu, Zn, Pd, Ag, Sb, Te, W, Pt ,Au are easily activated by neutron irradiation and Cu, Pd, At, W, Au are still radioactive even after 7.5 hours. These images illustrate how the activity of the irradiated element is determined by the half-life and the cross section for activation. Take Cu and Ag for instance, activation cross section of Ag is nearly ten times larger than Cu, but the image of Cu is much denser than that of Ag. This means, since half life of activated Ag is 2.41min and that of Cu is 12.8h, the activity of Ag was saturated during the irradiation.



(a)



(b)

Fig11 Neutron activated radiographic images.
(a) Immediately after irradiation (b) 7.5hours after irradiation

4. Conclusion

A couple of photographic teaching materials have been developed which help learners

1. To understand how X-ray transmittance through a substance depends on atomic number of the substance as well as X-ray energy,
2. To understand that the interaction of neutron toward substances are completely different from those of X ray.
3. To understand which species are easy to be activated and how soon they decay.

Reference

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3.8 EDUCATIONAL EXPERIMENT FOR STUDENTS USING NATURAL RADIOACTIVITY. I (Radiochemical Analysis of ^{214}Bi in ENA and IKEDA Mineral Spring Water)

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*Faculty of Engineering, Tottori University, Tottori 680-0945, Japan

Abstract

A couple of educational experiments have been developed using natural radioactivity contained in mineral spring water and a small GM counter. These experiments are safe and inexpensive enough to be conducted at high school or university, nevertheless they are quantitative enough for learners to observe half-life of ^{214}Pb and ^{214}Bi, and to help them understand the concept of radioactive equilibrium between them.

1.Introduction

After being A-bombed, most Japanese people have been so nervous to radiation/ radioactivity that it is sometimes difficult to conduct an educational experiment at school using radiation or radioactive material however safe it is. Although they show the same negative attitude toward the radiation/radioactivity used in other fields such as medical treatment and power generation, they have exceptionally accepted natural radioactivity included in mineral spring water as harmless one since before World War II. This means if natural radioactivity in mineral spring water is available as a material for an educational experiment, it can be easily conducted at school. From such a viewpoint, we have developed several kinds of experiments for high school or university students using natural radioactivity(1-8) and this paper will present a couple of examples which use mineral spring water of Ena in Gifu prefecture and Ikeda in Shimane prefecture.

2.Experiment

2.1 Natural radioactivity in mineral spring water of Ena and Ikeda

Mineral spring of Ena and Ikeda belong to the most radioactive spring in Japan along with Misasa spring in Tottori prefecture and Masutomi spring in Yamanashi prefecture. These four springs are used and loved as spas for long time and even now a large number of people visit for a hot- spring cure. Ena spring is located in the middle part of Japan, 4km northeast of Ena station of JR Chuo Line. The water used in this experiment was sampled at Rousoku spring (TEL:+81-573-72-5047). Ikeda spring (TEL:+81-8548-3-2833) is located in the western part of Japan, near (20min by taxi) Oodashi station of JR San-in Line. The maps and photographs of the sites where water was sampled are presented in Fig.1.

The results of gamma spectrum of these two spring water are presented in Fig.2. The results indicate that the radioactivity contained in these samples belong to uranium decay series and that the radioactivity of ^{222}Rn was 3500Bq/L in case of Ena spring water and 2400Bq/L in case of Ikeda spring water.

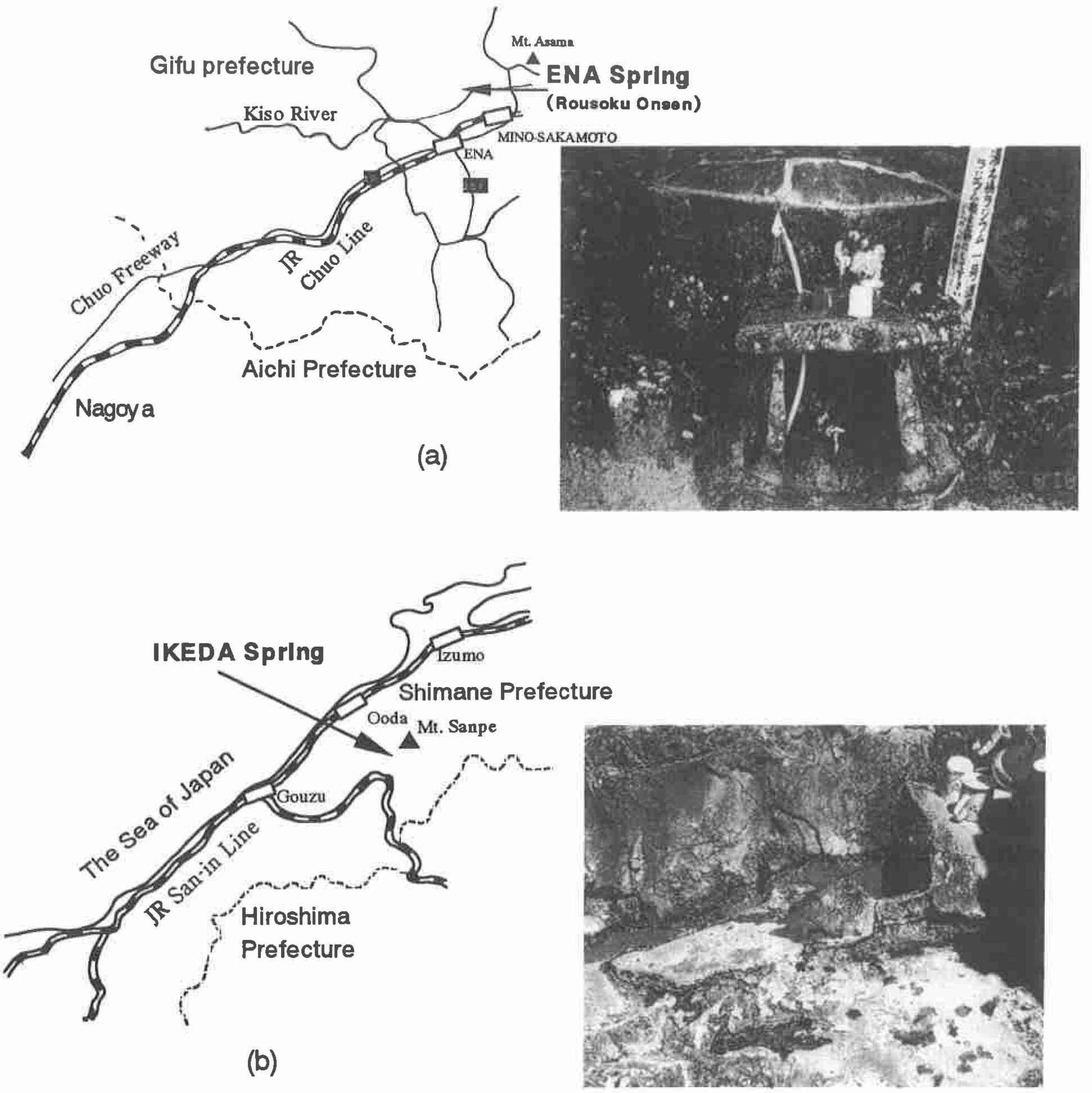
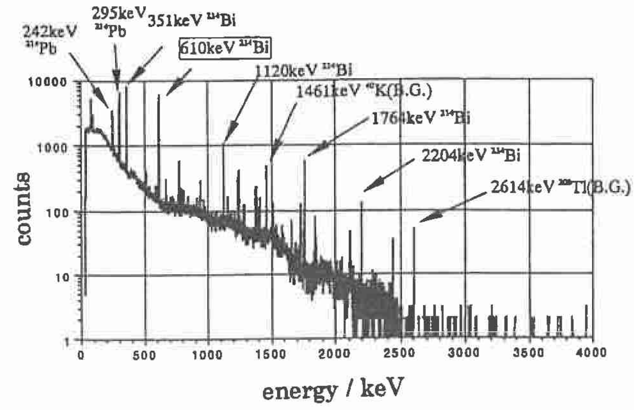
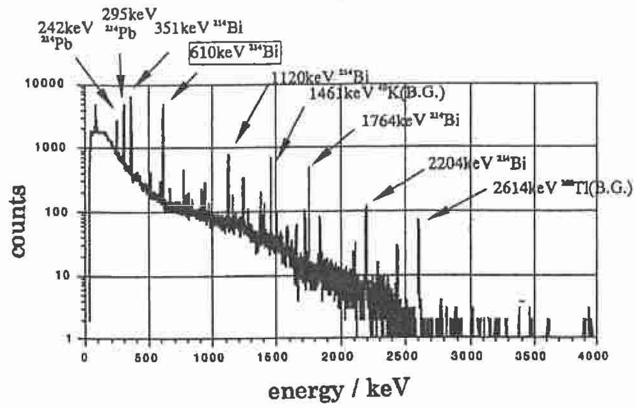


Fig.1 Maps and photos of the sampling sites.
(a)Ena Mineral Spring (b)Ikeda Mineral Spring



(a)

Sample
220mL of Ena spring water
Counting Time
20000 sec
Detector
EG & G ORTEC GEM-10175



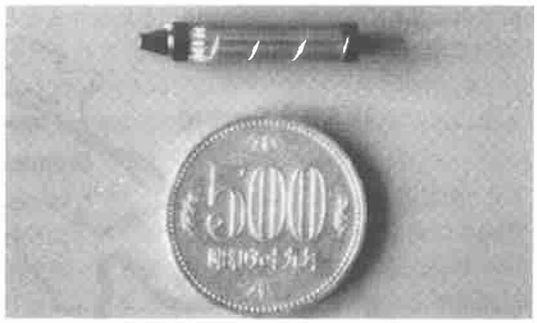
(b)

Sample
280mL of Ikeda spring water
Counting Time
20000 sec
Detector
EG & G ORTEC GEM-10175

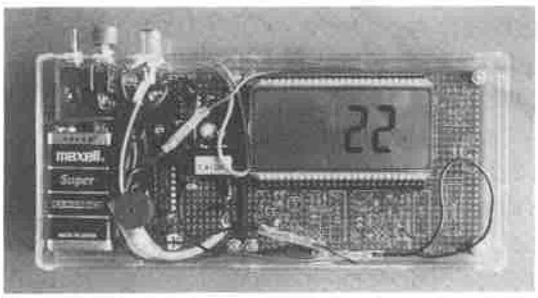
Fig.2 Gamma spectrum and measuring condition
(a) Ena spring water (b) Ikeda spring water

2.2 Measuring device (GM counter)

A GM counter used in this work is sold from Akizuki Denshi Tuusho (http://www.tomakomai.or.jp/akizuki/) as a do-it-yourself kit at the price of 10,000 yen (less than 100 dollars). A GM tube used in it is HAMAMATSU D3372 which consists of a cylinder-shaped cathode (5mm in diameter, 24mm in length) and is designed for the detection of gamma rays and high-energy beta ray which is larger than 0.5MeV. Since only ^{214}Bi emits high energy beta ray with large emitting ratio among daughter species of ^{222}Rn, this tube is suited to measuring the radioactivity of ^{214}Bi settled radiochemically out of Ena or Ikeda spring water. The outside appearance of the GM tube and assembled kit is presented in Fig.3.



(a)



(b)

Fig.3 Outside appearance of GM counter
(a) HAMAMATSU D3372
(b) Assembled kit

2.3 Educational experiments to measure the activity of ^{214}Bi

Following three experiments were designed and conducted.

Experiment 1.:
To precipitate ^{214}Pb and ^{214}Bi together out of the spring water and to measure the radioactivity of ^{214}Bi in the precipitate.

Experiment 2. :
To precipitate ^{214}Bi out of the spring water while leaving ^{214}Pb in water phase and to measure the radioactivity of ^{214}Bi in the precipitate.

Experiment 3:
.To precipitate ^{214}Pb out of the spring water while leaving ^{214}Bi in water phase and to measure the radioactivity of ^{214}Bi in the precipitate that is generated from ^{214}Pb in it.

Flowcharts of these experiments are illustrated in Fig.4

The precipitate containing ^{214}Pb and/or ^{214}Bi is gathered on Kiriyama filter paper with the diameter of 21mm, covered with thin polyethylene film, and fixed around the GM counter tube as illustrated in Fig.5. Counting rates (cpm) were calculated every 10 minutes using the counts accumulated during that period.

Add 10mL of HNO_3 and 100mg of $Bi(NO_3)_3 \cdot 5H_2O$ to 80mL of the spring water and stir for 5min.

↓

Precipitate $Bi(OH)_3$ by adding $(NH_3)_{aq}$ until pH exceeds 10

(a) Experiment 1

Add 10mL of HNO_3, 100mg of $Bi(NO_3)_3 \cdot 5H_2O$ and 100mg of $Pb(NO_3)_2$ to 80mL of the spring water and stir for 5min.

↓

Precipitate $Bi(OH)_3$ by adding NaOH (8-9g) until $[OH^-]$ is approximately equal to 1mol.

(b)Experiment 2

Add 10mL of HNO_3, 100mg of $Bi(NO_3)_3 \cdot 5H_2O$ and 250mg of $Pb(NO_3)_2$ to 160mL of the spring water and stir for 5min.

↓

Precipitate $PbSO_4$ by adding 6.5g of Na_2SO_4.

(c)Experiment 3

Fig.4 Flow charts of experimental procedure

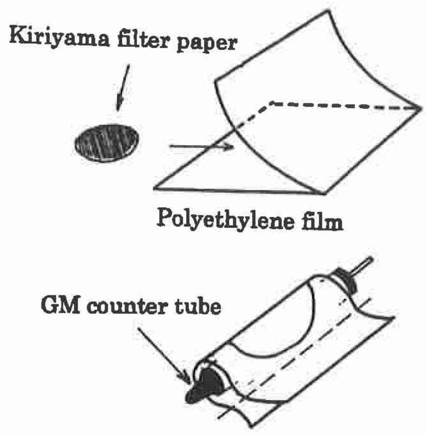


Fig.5 The way of holding the sample around GM tube

3.Results and Discussion

The typical results of Experiment1,2,3 are presented in Fig6. The vertical axis of each graph presents a counting rate of the GM counter and the horizontal axis presents time from precipitation of ^{214}Pb and/or ^{214}Bi.

The counting rate, or emitting rate of beta ray from ^{214}Bi, is proportional to the number of ^{214}Bi, N_2, which can be calculated as;

$$N_2=\{\lambda_1/(\lambda_2-\lambda_1)\}N_{10}\{\exp(-\lambda_1 t)-\exp(-\lambda_2 t)\}+(\lambda_1/\lambda_2)N_{10}\exp(-\lambda_2 t) \quad (1)$$

in case of Experiment1,

$$N_2=N_{20}\exp(-\lambda_2 t) \quad (2)$$

in case of Experiment 2, and

$$N_2=\{\lambda_1/(\lambda_2-\lambda_1)\}N_{10}\{\exp(-\lambda_1 t)-\exp(-\lambda_2 t)\} \quad (3)$$

in case of Experiment 3,

where λ_1 and λ_2 denote decay constant(s^{-1}) of ^{214}Pb and ^{214}Bi respectively; N_{10} and N_{20} denote the numbers of ^{214}Pb and ^{214}Bi at t=0 respectively.

These three equations were derived from following two differential equations;

$$dN_1/dt=-\lambda_1 N_1 \quad (4)$$

$$dN_2/dt=\lambda_1 N_1-\lambda_2 N_2 \quad (5)$$

under the initial conditions of

$$N_1=N_{10},\ \lambda_1 N_1=\lambda_2 N_2 \quad \text{at } t=0 \quad (6)$$

in case of Experiment1,

$$N_1=0,\ N_2=N_{20} \quad \text{at } t=0 \quad (7)$$

in case of Experiment2,

$$N_1=N_{10},\ N_2=0 \quad \text{at } t=0 \quad (8)$$

in case of Experiment3.

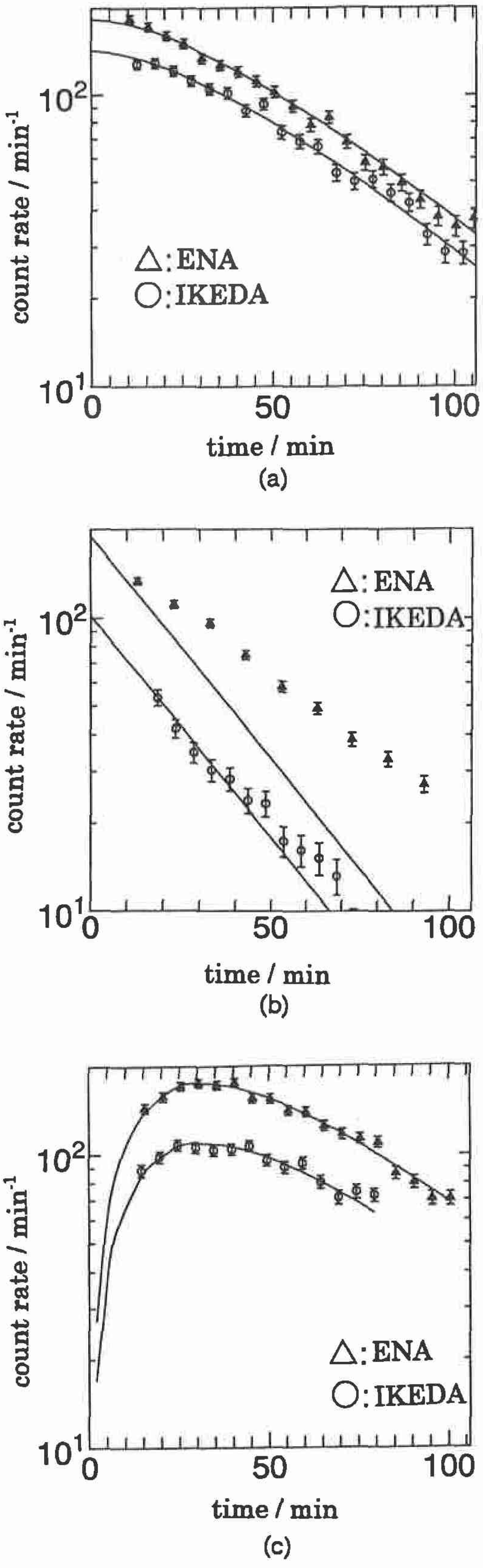


Fig.6 Typical results of (a)Experiment 1 (b)Experiment 2 (c)Experiment 3

The theoretical values calculated from eqs(1-3) are presented in solid lines in Fig.6, where the value of N_{10} or N_{20} was determined arbitrarily.

Through Experiment 1 to 3, measured values is considered to be coincident with calculated ones within statistical error in case of Ikeda spring water. In case of Ena spring water, there exists a wide difference between measured values and calculated ones in Experiment 2. The half-life derived from the measured values was close to half life of ^{214}Pb (27min) rather than half life of ^{214}Bi (19.9min). This means precipitates of Experiment 2 was contaminated with ^{214}Pb from unknown reason.

When measured values in Fig6 (a) were extraporated to t=0, counting rates at t=0 were $182min^{-1}=3.03s^{-1}$ and $143min^{-1}=2.38s^{-1}$ for Ena spring water and Ikeda spring water, respectively. By dividing these values with 0.029, counting efficiency of the GM counter, the radioactivity (Bq) of ^{214}Bi can be calculated as 3.03/0.029=104Bq in case of Ena spring water and 2.38/0.029=82Bq in case of Ikeda spring water. Since the ^{214}Bi in 80mL of Ena spring water and that of Ikeda spring water were turned out to be 192Bq and 129Bq 2.21days after sampling based on the gamma spectroscopic analysis, yield of the Experiment 1 is 0.54 and 0.64,respectively.

4.Conclusion

It was made clear that safe and inexpensive experiment was possible using hot spring water of Ena and Ikeda. The results obtained are quantitative enough for educational purposes, nevertheless no special facility nor special technique were necessary. By using natural radioactivity, learners are expected to recognize that radioactivity/radiation is not something special isolated from their daily lives.

Although there exists strict regulation against the usage of radioactive materials in Japan, it should be noted here that these educational experiment mentioned above are free from any regulation because the amount of the radioactivity is extremely small.

Acknowledgement

Special appreciation is presented here to kind cooperation of every staff in Ikeda spring and Ena spring (Rousoku Onsen) spas.

This work was partly supported by the Grand-in-aid for Developmental Scientific Research from the Ministry of Education, Science and Culture (No. 10558077) in 1998-2000.

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3.9 EDUCATIONAL EXPERIMENT FOR STUDENTS USING NATURAL RADIOACTIVITY. II
(Practical Example of Radiochemical Experiment Conducted at Tottori University)

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Abstract

This paper presents a practical example of educational experiment conducted at Tottori University, whose theme is to separate $^{214}Bi(+^{214}Pb)$ from superphosphate of lime or the soil sampled at Ningyo-Touge mountain pass. The results of this experiment are quantitative enough for educational purpose, although the amount of radioactivity is so small that it is free from any regulation in Japan.

1.Introduction

Although the words "radiation" and "radioactivity" are often used in our daily lives, what we learn about these subjects in our school education of science is limited and only very basic part of them is taken up in physics of senior high school in Japan. When it comes to practical work or educational experiment for students to use radiation or radioactivity, the case that they are conducted is very rare even in science courses of a university. The primary reason for this situation is that the regulation against the usage of radiation and radioactivity is very tight and that the measuring apparatus is very expensive in Japan. In order to change this situation, we have developed several kinds of safe and inexpensive experiments using natural radioactivity and a small GM counter(1,2,3).

This paper reports the practical work of radiochemistry that has been conducted at Tottori University since 4 years ago.

2. Practical work of radiochemistry in Tottori University

2.1 Background of the practical work

The practical work of radiochemistry has been conducted for 3rd year students belonging to

Department of Materials Science, Faculty of Engineering in Tottori University. Although they learn many fields of chemistry such as inorganic chemistry, physical chemistry and analytical chemistry through lectures and practical works, they had met almost no chance to learn about radiation/radioactivity before this radiochemical experiment was introduced in their practical work "Experiment for Materials Science II (EMS II)" 4 years ago. The subjects of EMS II are presented in Table 1.

Table 1 Content of EMS II

1.Electrode Potential and Electrode Reaction
2.Radiochemical Analysis
3.Distillation under the Reduced Pressure
4.Catalysis in Decomposition of Hydrogen Peroxide
5.Synthesis of 4,6-di-*tert*-Butylresorcinol
6.Synthesis of 2-nitoro-p-Toluidine
7.Preparation of Triphenylcarbinol

The number of 3rd year students in this department is 80 to 90. They are divided into 6 groups of 14 or 15 students and are engaged in the practical work of radiochemistry group by group. Since the practical work is conducted once or twice in a week, it takes more than 3 weeks to finish all of them. This means that mineral spring water containing ^{222}Rn such as Misasa spring water in Tottori prefecture is not appropriate for a experimental material because the half life of ^{222}Rn is less than 4 days and fresh material has to be prepared every time.

As a substitute for the Misasa spring water, superphosphate of lime as garden fertilizer or the soil sampled at Ningyo-Touge mountain pass in Tottori prefecture has been used, both of which contain radioactive species belonging to uranium decay series. Since superphosphate of lime is produced from rock phosphate which contains uranium, the product contains ^{228}Ra, one of the daughter species of ^{238}U and radioactive equilibrium is considered to be established between ^{226}Ra and ^{214}Po (cf. Fig.1).

	Half-life	Decay
^{238}U ↓	4.47×10^{9}y	α
^{234}Th ↓	24.1d	β
^{234}Pa ↓	1.17m	β
^{234}U ↓	2.45×10^{5}y	α
^{230}Th ↓	7.54×10^{4}y	α
^{226}Ra ↓	1.6×10^{3}y	α
^{222}Rn ↓	3.82d	α
^{218}Po ↓	3.11m	α
^{214}Pb ↓	27m	β
^{214}Bi ↓	19.9m	β
^{214}Po	164μs	α

Fig.1 Uranium decay series

2.2 Method of the experiment

The theme of the experiment is to separate ^{214}Bi(+^{214}Pb) from superphosphate of lime or the solid sample, radiochemically and to measure the decay of ^{214}Bi(+^{214}Pb) using a GM counter or a handy type beta survey meter "HAKARU-KUN II", which Science and Technology Agency lends to schools for free. Their appearances are presented in photo 1 and 2, respectively.

Since superphosphate of lime as garden fertilizer and the soil sample contain many kinds of compounds as impurities, it is not easy to separate very small amount of one particular

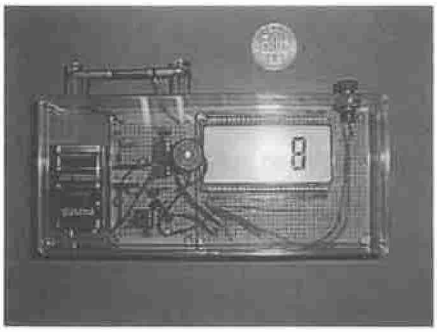


Photo 1

Photo 2

radioactive species, such as ^{214}Bi, chemically from it. In this work, we made use of the fact that only ^{222}Rn is gaseous in uranium decay series as illustrated in Fig.1, and is easily adsorbed onto charcoal activated. This means, if a few grams of charcoal activated is enclosed in a desiccator with 1 or 2 kilograms of superphosphate or the soil sample for one week as shown in Fig.2, ^{222}Rn and its daughter species, such as ^{214}Pb and ^{214}Bi, are accumulated on the charcoal activated. After this charcoal activated is washed in a HNO_3 aqueous solution and these radiochemical species are moved to the liquid phase, it is easy to settle out ^{214}Bi with ^{214}Pb as precipitate of $Bi(OH)_3$. A flow chart of the radiochemical procedure is presented in Fig.3.

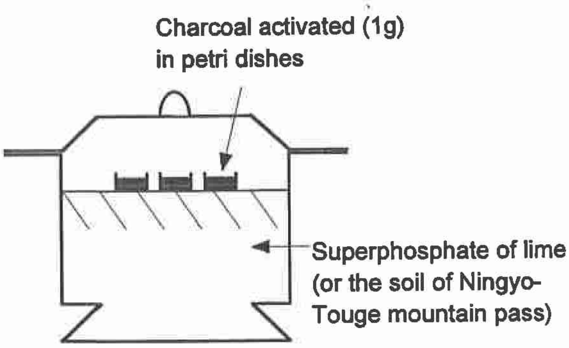


Fig.2 Separation of ^{222}Rn and the daughters from Uranium decay series

Dissolve Bismuth(III) nitrate *($Bi(NO_3)_3 \cdot 5H_2O$, 100mg)* in Nitric acid solution *(HNO_3, 10ml + H_2O, 30ml)*

↓

Add Charcoal activated *(1g)* on which ^{222}Rn is adsorbed and stir for five minutes *(with magnetic stirrer)*

↓

Remove Charcoal activated with a wide-mouthed buchner funnel

↓

Add 25% Ammonia solution until pH exceeds over 10 and precipitate bismuth hydroxide

↓

Gather bismuth hydroxide on Kiriyama filter paper *(21mm in diameter)*

↓

Wrap the filter paper with polyethylene foil and put it around GM counter or under HAKARU-KUN II to measure the β-ray from $^{214}Bi(+^{214}Pb)$

Fig.3 The sequence of the experiment

2.3 Practical Example

A time table of the practical work is illustrated in Fig.4. At the beginning of the practical work, a brief instruction on the experiment is given to the students and they (14～15 students) are divided into smaller groups of two or three. Then as training and as a measurement of background radiation, the students rehearse the experiment using charcoal activated on which no radioactive species are adsorbed. After this rehearsal, or cold run, the actual experiment is carried out. Since the half-life of ^{214}Pb is 27min, swiftness is required. When they finish the chemical procedure, they put the precipitate containing ^{214}Pb+^{214}Bi around a GM counter tube or under a window of HAKARU-KUN II. In case of the GM, the counters are put under an OHC (Over Head Camera) and counts displayed on the scalers are recorded into a video tape. During this measuring time of 70～80minutes, the students clean up the apparatus they used and a small lecture is given to them on radiation and radioactivity. Although some of the students has learned about the basic of this subject in senior high school, most students have not learned (or remembered) it. After the lecture is over, the video tape is played back every 10minutes and they record the counts on their own notebook. They are required to submit their report within a week.

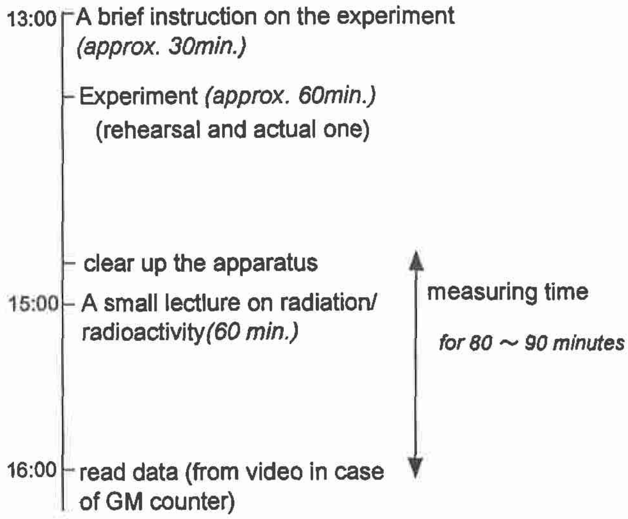


Fig.4 Time table of the practical work

The scenes of this practical work are presented in photo 3.

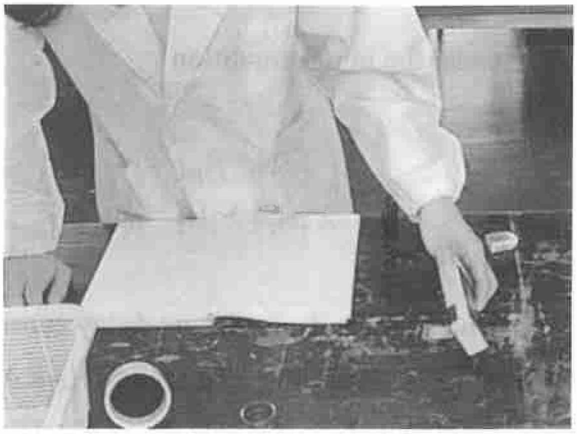
Stir charcoal activated in HNO_3 aq. for five miniutes

Remove charcoal activated

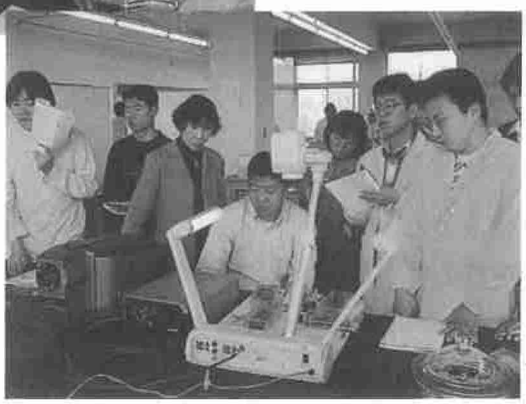
Add 25% ammonia solution

Gather bismuth hydroxide

Fix the Kiriyama filter paper around GM counter



Measure with HAKARU-KUN II



Read recorded data with video

Photo 3 Scenes of the EMS II

4. Experimental results

A typical example of the results obtained using a GM counter is presented in Fig.5. Although only high energy beta ray emitted from ^{214}Bi is detected by the GM counter tube (HAMAMATSU D3372), the slope of decay curve is close to the half life of ^{214}Pb (27min) and this means that ^{214}Pb is also included in the precipitate of $Bi(OH)_3$ with ^{214}Bi, Therefore, the theoretical line in Fig.5 was calculated using

$$N_2=\{\lambda_1/(\lambda_2-\lambda_1)\}N_{10}\{\exp(-\lambda_1 t)-\exp(-\lambda_2 t)\}+(\lambda_1/\lambda_2)N_{10}\exp(-\lambda_2 t) \quad (1)$$

derived from

$$dN_1/dt=\lambda_1 N_1 \quad (2)$$
$$dN_2/dt=\lambda_1 N_1-\lambda_2 N_2 \quad (3)$$

under the initial condition

$$N_1=N_{10},$$
$$\lambda_1 N_1=\lambda_2 N_2 \quad \text{at } t=0 \quad (4),$$

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

The result obtained using "HAKARU-KUN II" is presented in Fig.6. Since this detector is sensible to beta ray with lower energy<0.5MeV or that emitted from ^{214}Pb, the theoretical value is approximately proportional to $\lambda_1 N_1+\lambda_2 N_2$. Thus, the theoretical line in Fig.6 was calculate with eq.1 and

$$N_1=N_{10}\exp(-\lambda_1 t) \quad (5).$$

It should be noted here that the sensitivity of HAKARU-KUN II is far better than a GM tube (HAMAMATSU D3372) and has a function to store every one minute data for 10 hours, which makes the preparation of the practical work much easier.

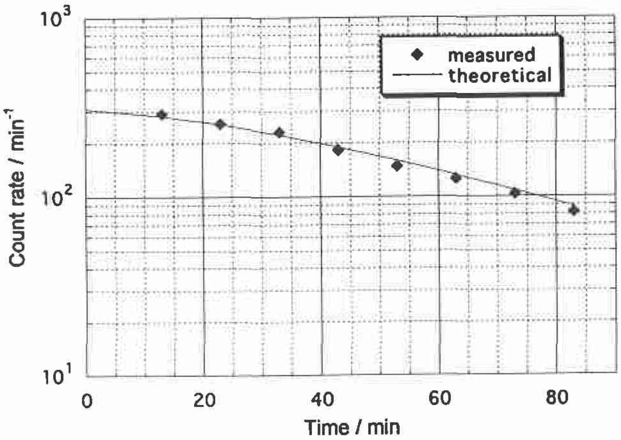


Fig.5 An typical result measured with GM

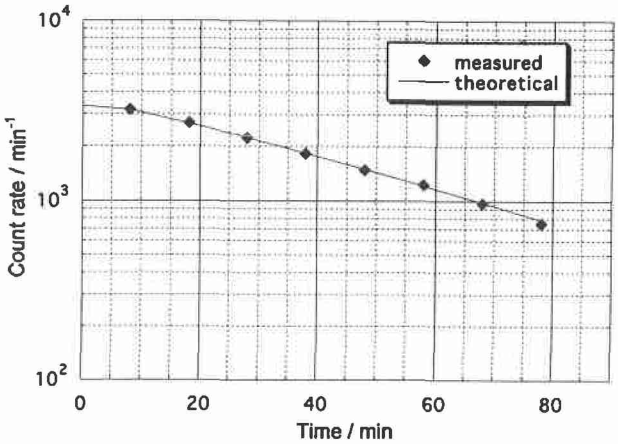


Fig.6 A typical result measured with HAKARU-KUN II

7.Conclusion

Since most students did not have enough knowledge on radiation/radioactivity for this practical work, its educational effect must be considered to be limited. However, it can be expected that students has got a valuable chance to study radiation/radioactivity based on their own experience and they may change their too negative attitude toward radiation/radioactivity usage.

Since neither special apparatus nor special technique is needed in this experiment, this experiment is suited for high school students as a theme of their club activity.

Acknowledgement

This work was partly supported by the Grand-in-aid for Developmental Scientific Research from the Ministry of Education, Science and Culture (No.10558077) in 1998-2000.

Reference

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 and T. Esaka, "Radiochemical Experiment with Natural Radioisotope(IV) Radiochemical Analysis of ^{222}Rn Released from Calcium Superphosphate for Gardening and its Daughters(I)", Chemistry and Education (in Japanese), **43**, 588-591(1995).
3. M.Kamata, M.Nakamura and T.Esaka, "Educational Experiment for Students Using Natural Radioactivity.I (Radiochemcal Analysis of ^{214}Bi in ENA and IKEDA Mineral Spring Water)", Proceeding of International Symposium on Radiation on Education (ISRE 98) to be published.

3.10 岐阜県東濃地域の環境放射線測定を通しての放射線教育

RADIATION EDUCATION BY MEANS OF THE MEASUREMENT OF NATURAL ENVIRONMENTAL RADIATION IN TONO REGION, GIFU PREFECTURE

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3 National Institute for Fusion Science, Toki-city, Japan

Abstract

The Tono region is placed in the south-east of Gifu prefecture. In this region, there is a plan of construction of the Research and Education Park. As the center facility of the park, the National Institute for Fusion Science (NIFS) has started their research activities.

The Plasma Research Committee of Toki-city has been organized by the board of education of Toki-city for about 20 years. The committee is mainly composed of science teachers of elementary school, junior high school and high school in the area.

The committee has measured continuously the natural environmental background radiations in cooperation with NIFS. Its activities were started before constructing the NIFS laboratory buildings. Now, the new measuring points in Tajimi-city and Mizunami-city are added to the points in Toki-city area, therefore, some teachers join as the new members of the committee.

In this conference, we present as follows.

(1) Plasma Research Committee of Toki-city; its history, organization and activities.
(2) Obtained data of the natural environmental radiation in Toki-city.
(3) Example lecture taken in natural radiation, its results and the farther issues.

1 はじめに

岐阜県東濃地域は県の東南部に位置して，その丘陵地帯には研究学園都市建設構想があり，その中核としての核融合科学研究所はすでに完成し研究活動を開始している。土岐市教育委員会を世話役として，地域の小,中,高の理科の先生を中心に土岐市プラズマ研究委員会を組織し，この核融合研究所の建設が始まる前から研究所と共同で，20 年ほど地域の環境放射線の測定を継続的に行ってきた。現在は,多治見市,瑞浪市なども測定エリアに入れ関係の先生と核融合研究所との共同研究を深めている。

今回の発表では

(1) これまでの経緯，実施項目，研究会の組織
(2) 環境放射線測定データの紹介（土岐市周辺の測定結果の紹介）
(3) 教育への採り入れ事例とそこでの成果と今後の方向などを紹介する。

2. 土岐地区環境放射線測定研究の歩み
(1980～1998)

1980 土岐市プラズマ研究委員会
名古屋大学プラズマ研究所　共同研究「土岐地区の環境放射能の測定」開始
1981 ・ＧＭ計数器の試作とそれによる測定
・報告書　I （資料とＧＭ計数管による測定）IPPJ-DT-89 (1981)
1982 土岐市プラズマ研究委員会
・NaIを用いた車上測定（土岐市内）　・土壌試料のNaIスペクトル分析
・各種可搬型測定器(Ar電離箱、NaI-DBM、GM計数管、TLD)による同時比較測定（市内巡回）
1983 ・報告書　II （各種測定器による比較測定）IPPJ-DT-105 (1983)
・ＴＬＤによる定点測定（土岐市プラズマ研究委員会側で運営）
・環境トリチウムの測定用試料採取（河川、雨水、井戸、水道、等）（液シン法）
・土壌採取（Ge測定器用試料）　・環境でのガンマ線成分の測定 (U, Th, K-40,Csその他)
・高校理科教育カリキュラムに反映（土岐北高校）
1984 土岐市プラズマ研究委員会
・Ge測定器による現地測定（空間線量）および採取試料測定
1985 ・土岐市がＴＬＤ測定用機器(UD-512P)購入
・報告書　III （昭和58年度の活動）IPPJ-DT-116 (1985)
1986 土岐市プラズマ研究委員会
・チェルノブイリ事故による環境放射能変化の点検
・報告書　IV（昭和59～60年度の活動）IPPJ-DT-130 (1986)
文部省科学研究費を受領（土岐北高校）
1987 ・ＴＬＤの継続的定点観測（3ヶ月値）
・環境トリチウムの継続的測定
1988 土岐市プラズマ研究委員会
・土岐地区環境放射能の分析（プラズマ研究所測定分との比較）
1989 ・報告書　V（昭和61～62年度の活動）IPPJ-DT-146 (1989)
・報告書　VI（昭和63年度の活動）IPPJ-DT-147 (1989)
名古屋大学プラズマ研究所廃止に伴い共同研究中断（測定中断）
核融合科学研究所発足
1990 土岐市プラズマ研究委員会
核融合科学研究所　共同研究「土岐地区の環境放射線の測定」開始
・ＴＬＤ継続測定再開（15点）
1991 ・ＴＬＤ未回収期間を含めてデータ整理・測定点の整備
変化の要因（読み取り機器の調整、設置場所近傍の改変、自然変動、等）
1992 土岐市プラズマ研究委員会
・ＴＬＤ校正測定の重視
・動燃主催による土岐市周辺カーボーン測定に協力（可搬型機器測定）
1993 土岐市プラズマ研究委員会
・Rn測定（カップ法）準備
1994 ・ＧＭ計数管キットによる試作と測定
・核融合研究所放射線モニターシステム
1995 土岐市プラズマ研究委員会
・1991～94の測定値の検討
・ＴＬＤ読み取り機器の不調----修理調整、校正の徹底
・可搬型測定器（Ar電離箱、Ge、NaI とＴＬＤ）による巡回測定（ＴＬＤ測定点6点を巡回）
1996 ・ＴＬＤ測定点の追加（多治見を含む）
・ガラス線量計とＴＬＤとの比較
・Rn測定（カップ法）の開始
1997 土岐市プラズマ研究委員会
・野外巡回測定　測定器「はかるくん」を用いるルート測定と他の可搬型機器による測定
1998

3 環境放射線測定研究の意義と目的

核融合科学研究所およびその前身である名古屋大学プラズマ研究所：

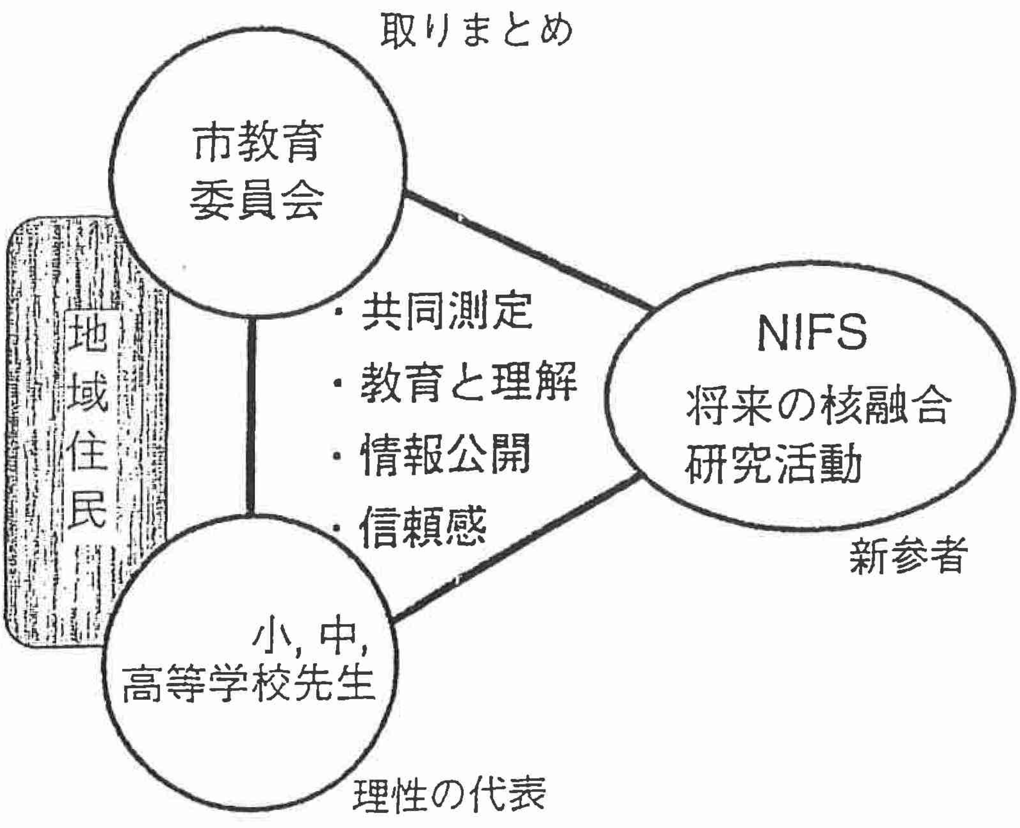
プラズマ核融合の新しい研究施設を建設、運用していく上で
常に念頭に置かれている点：

- 先進的な研究を行う開かれた研究所
- 地域および自然の環境と調和した研究活動
- 共同研究・国際協力・教育効果の重視
- 社会・住民の理解・協力と信頼の確保
- 安全性の十分な確認とそのための管理

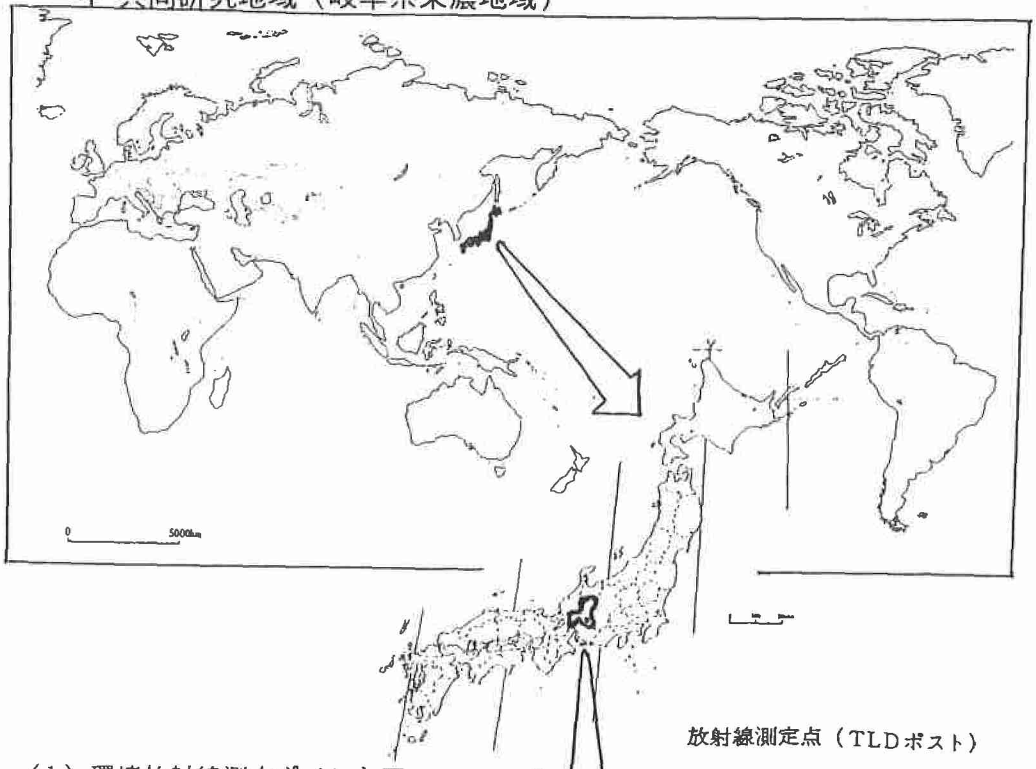
プラズマ核融合装置の大型化に伴う発生放射線の問題：

- 装置運転時の発生放射線が周辺の環境に影響を及ぼさない
- 具体的目標として、敷地境界で年間　50μSv を越えないこと
- 地域の自然放射線の特性の把握が必要
- 監視・評価・確認の手法の確立
- 放射線について住民との共通理解が不可欠

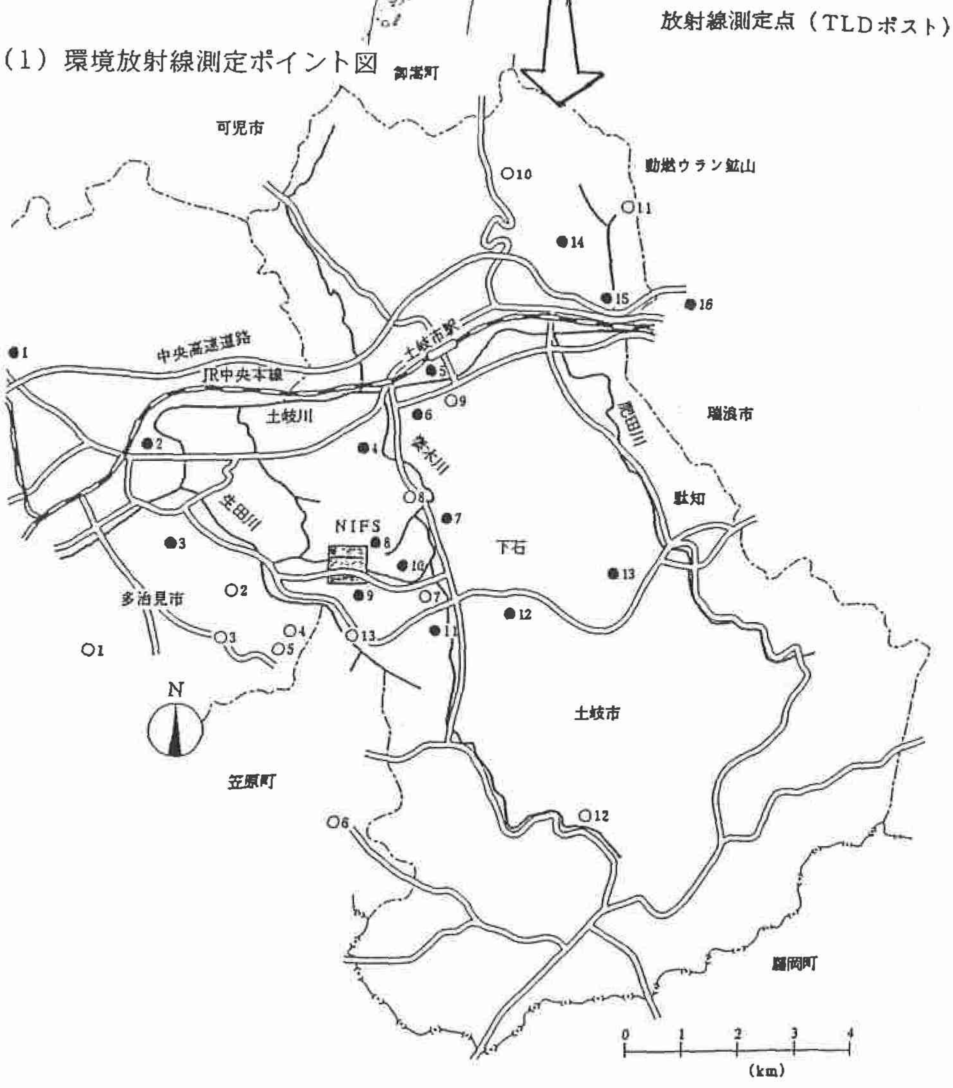
土岐市の側で、核融合プラズマ放射線問題に対応していく組織として
土岐市教育委員会を世話担当とし、高、中、小学校の、理科の先生を中心に
土岐市プラズマ研究委員会
が設置された。



4 共同研究地域（岐阜県東濃地域）



（1）環境放射線測定ポイント図



5 土岐地区環境放射線測定結果

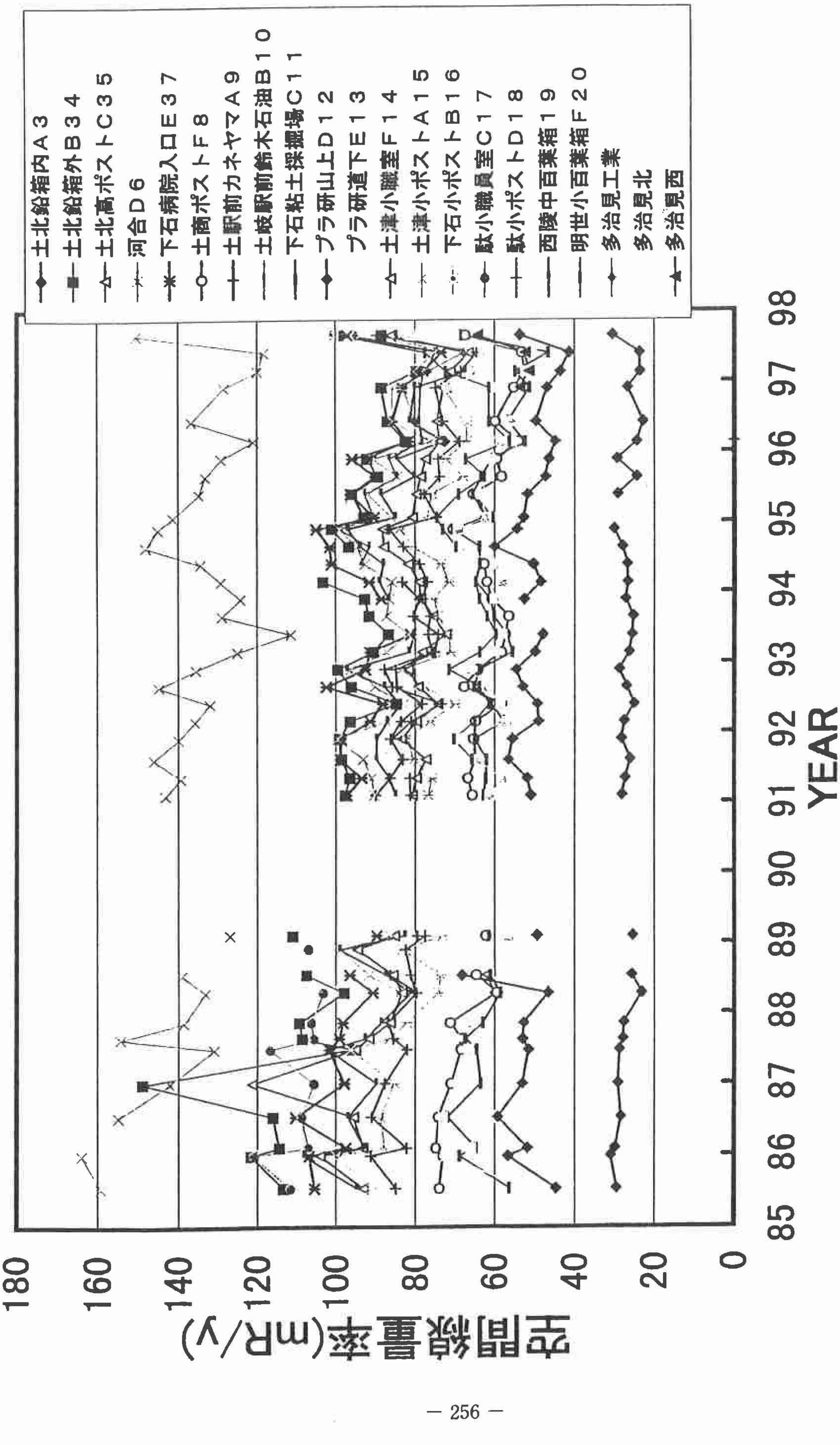
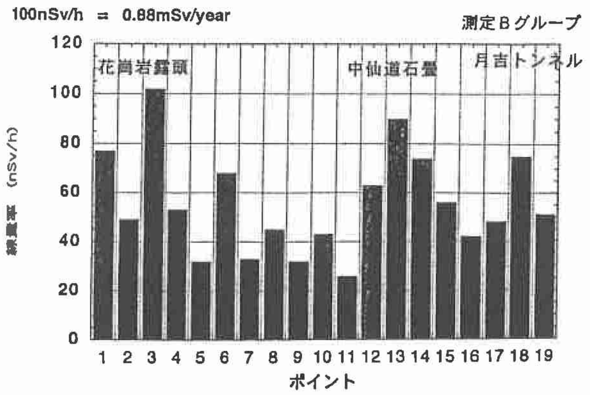


図1 土岐地区環境放射線測定結果　補正なし

6 可搬型測定器(Ar電離箱，Ge，NaIとTLD)による巡回測定
簡易線量計「はかるくん」による移動測定



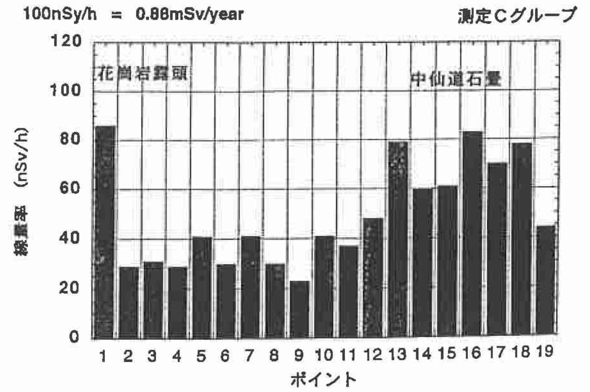


図2 簡易線量計「はかるくん」による移動測定結果

↑
【写真】可搬型測定器による巡回測定

【写真】「はかるくん」による移動測定

7 環境教育活動実践（中学校における実践）

（１）指導計画の概要（ねらい，タイムスケジュールなど）

	タイムスケジュール・活動項目	ねらいと活動内容
４月	○平成９年度活動計画の企画 ○理科環境研究グループの結成	・本年度の環境教育に関する活動計画と環境研究グループを結成する。
５月	○ＪＣﾘﾊﾞｰﾈｯﾄﾜｰｸ(水生生物・水質調査に参加) ○選択理科の環境調査計画	・地域の環境活動として,積極的に参加する。選択理科をｸﾞﾙｰﾌﾟに加える。
６月	○環境研究の研究内容検討 ○ＪＣﾘﾊﾞｰﾈｯﾄﾜｰｸ環境サミットに参加	・環境研究の情報を収集する。 ・身近な環境問題を考える。
７月	○環境テーマ研究の計画と実施 ○環境テーマ研究の資料収集	・環境研究の具体的準備をはじめる。 ・環境研究に実際に取り組む。
８月	○環境テーマ研究の実施 ○実験・観察・調査・ファイルまとめ	・環境テーマ研究を通して,環境問題を考えたり,対応する力をつける。
９月	○インターネットホームページの開設 ○郡上郡科学作品展に出品	・学校のホームﾍﾟｰｼﾞを開設する。 ・郡科学作品展出品準備をする。
10月	○後期の活動計画　○鍾乳洞見学 ○全国小学校中学校環境教育賞参加	・鍾乳洞見学で,自然の大切さを学ぶ。 ・環境研究ｸﾞﾙｰﾌﾟの研究を応募する。
11月	○地域環境調査(酸性雨測定，気温，気圧など) ○ｲﾝﾀｰﾈｯﾄﾎｰﾑﾍﾟｰｼﾞに環境教育のページ開設	・秋から冬の環境調査し,季節の違いと環境について考える。
12月	○冬の環境調査（降雪，夏と冬との違いなど） ○環境に関する研究の情報発信,情報収集	・環境に関する研究をｲﾝﾀｰﾈｯﾄ上に載せ情報発信する。
１月	○降雪調査（雪の結晶,気温,積雪量,ｐＨなど） ○ｲﾝﾀｰﾈｯﾄﾎｰﾑﾍﾟｰｼﾞの作成と活用	・冬の気候,雪に関する調査により,環境問題を考え,研究につなぐ。
２月	○理科環境研究冊子づくり ○環境調査・観察・実験のまとめ	・１年間のまとめとして,環境研究冊子の作成にとりかかる。
３月	○環境調査研究グループ１年間の総合まとめ ○環境研究冊子の完成と来年度の計画	・環境研究のまとめを作成する中で,研究を積み上げ来年度につなぐ。

（２）生徒の取り上げた，研究テーマとそのポイント

学年	研究テーマ	環境の視点	備考
1年生	合成洗剤が環境におよぼす影響	各種洗剤・小松菜・イースト菌・めだか	☆☆☆
1年生	私の鬼谷川の環境調査：水中の生物から	水生生物による川の環境調査	☆☆
1年生	デンプンの謎	デンプンの分解・体・環境との関連	☆☆
1年生	アリの生態と住みやすい環境	アリは，どんな環境で生活しているか	☆
1年生	はずみところがりに関する研究	運動エネルギー・エネルギーと環境	☆
2年生	身の回りの水の環境	西和良地区４ヵ所・名古屋ｐＨ・ＣＯＤの調査	☆
3年生	太陽エネルギーの利用	熱と光についてパソコン分析・クリーンな環境	☆☆☆
3年生	地中の保水性・吸水性の追究	水のモデル実験・森林環境問題への提言	☆☆
3年生	西和良の酸性雨	酸性雨の測定・自動車排気ガスへの実験分析	☆☆
3年生	木と水と自然について	木の役割・水の大切さ・環境を守る方法	☆☆
3年生	土の中の小動物	小動物の環境問題・どこにどんな生物がいるか	
3年生	西和良の天気	気象環境調査・標高さ（３００ｍ・温度変化）	

1年生	身の回りの水質調査	飲料水，川，生活に関わる水のpH，CODなどの調査	☆☆
1年生	川の生きものと住みやすい環境	地域の鬼谷川の水生生物を通して，環境を調べる	☆
1年生	光の進み方の不思議	光についての基礎実験を実施し，光の利用につなぐ	☆☆
1年生	自作プロペラの研究	さまざまな自作プロペラを作り，風力発電をめざす	☆☆☆☆
1年生	水の性質を探ろう	水の実験を通し，水の大切さについてまとめる	☆
1年生	色と太陽の光の関係を調べよう	様々な色と太陽熱の関係（温度上昇，燃え方など）	☆☆
2年生	生活排水が環境におよぼす影響	生活排水のおよぼす影響を調べ，浄化装置の開発	☆☆☆
2年生	熱エネルギーの利用	省エネルギーはどうあるべきか，実験でさぐる	☆☆☆☆
2年生	水質汚染と生物の関わり	水質汚濁を考え，浄化装置の開発と提言	☆☆☆
2年生	本当に消化は進んでいるのか	人体の環境：消化の原理と，消化の度合いの検討	☆☆☆
3年生	酸性雨が自然に与える影響	西和良に酸性雨が降っていることを測定実験で検証	☆☆
3年生	音の性質を調べ，騒音問題を考える	音をパソコンで実験，調査・騒音問題に対して提言	☆☆☆

学年	研究テーマ	環境の視点	備考
1年生	ゴミをよりよい環境で処理しよう	ゴミ（ゴミの分別，処理，自然の戻す）の処理の仕方	☆☆
1年生	生活排水をよりよい環境にしよう	生活排水や水の性質，雨の性質を調べる。よりよい環境	☆
1年生	鍾乳洞と環境	地域の鍾乳洞を観察，調査と環境(気温，水，大気の状態)	☆
1年生	生活用品の処理の仕方	生活用品をどう処理したらよいか，大気汚染と環境	☆
2年生	つりと川の環境	自然な川と人間の手の入った川を比較し，つりとの関係	☆
2年生	自然エネルギーの活用	自然のエネルギー太陽光発電と風力発電について	☆☆☆
2年生	水を汚さずにどれだけ生活できるか	よごれがとれ方，洗剤，洗剤なし，アクリルたわしの効果	☆☆
3年生	廃棄物処理の環境におよぼす影響	廃棄物を燃やした時，人体や植物におよぼす影響	☆☆
3年生	人間はどれだけ省エネができるか	生活エネルギー節約(ｴﾈﾙｷﾞｰﾀﾞｲｴｯﾄ，CO2ﾀﾞｲｴｯﾄ)と省エネ	☆☆☆
3年生	生活排水の浄化とよりよい環境を求めて	自作浄化装置の効果，水質汚濁と生物との関わり	☆☆☆☆
3年生	人間の五感と人間生活の環境	五感(視覚，聴覚，味覚，嗅覚，皮膚感覚)について	☆☆

備考：作品展→ ☆☆☆☆最優秀賞（中日賞）(県出品)　☆☆☆優秀賞（中日賞）　☆☆優良賞　☆努力賞

（３）環境教育に関する具体的実践

①選択理科における環境教育

《気象観測調査，酸性雨調査》

○理科実験を環境問題と結び付けながら活動する。

○パソコンを活用した，実験・観測などの方法を取得する。

インターネットによる観測に参加

②サンパークランド美山鍾乳洞の見学（３年生：理科授業）

○地域（八幡町美山）にある，郡上八幡サンパークランド美山鍾乳洞の見学を，理科環境学習として実施した。(関連単元：大地の変化)

③ＪＣリバーネットワーク水生生物・水質調査，環境サミットに積極的参加（２０名）

○ＪＣリバーネットワークの意味を理解させ，自発的に参加できるようにした。

○水生生物調査を環境学習，理科環境研究につなぐように助言した

④簡易線量計「はかるくん」による放射線の測定

○「はかるくん」を利用して,学校を中心に地域の放射線を調べた。

⑤リサイクル用品の作製（２年生：技術，選択技術）→郡上郡創意工夫展に出品

○「手軽にできるリサイクル用品」を，ペットボトルや牛乳パックを利用して作製した。

・環境にやさしい。費用￥０。実用的。

（４）地域・他機関と連携した実践の場合は連携の仕方

○水生生物・水質調査，環境サミット（郡上青年会議所主催の事業に参加)

○鍾乳洞見学（校区内：サンパークランド美山鍾乳洞との連携参加）

（５）現在までの成果

○理科環境テーマ研究の実施と郡上郡科学作品展に出品参加

・科学作品展（環境と結び付けたテーマ研究をまとめる。継続研究）

○郡上八幡ｻﾝﾊﾟｰｸﾗﾝﾄﾞ美山鍾乳洞の見学・観察と感想文の交流

○JCﾘﾊﾞｰﾈｯﾄﾜｰｸ水生生物調査，環境サミットに参加，環境テーマ研究との連携

○インターネットホームﾍﾟｰｼﾞ開設，環境教育のページの作成

○選択理科における酸性雨測定

（６）今後の課題

○実地資料やデーターに基づく，地域の自然・環境調査地図の作成を検討していく。

○環境学習を盛り込んだ授業のあり方について検討し，授業実践を深めていく。

○放射線測定や酸性雨の測定など，環境調査研究を年間通して継続していく必要がある。

○　インターネットなどで情報収集や情報発信，メール交換などを押し進める。

3.11 大気吸入式正負イオン密度測定器について

薩谷　泰資（イオン情報研究所・神戸電波株式会社）
戸谷　佳武（神戸電波株式会社）

1. はじめに

現在放射線、放射能関係の測定器による測定データーは、それらの強度により環境大気中に生成されるイオン密度（正イオン、負イオン）が正確に測定されていない。

今回は放射線強度に対する小イオン（電気移動度、0.4cm²／V・sec以上）の正イオン密度、負イオン密度の変化を測定したので報告する。

2. 測定方法

放射線を測定する測定器としては（財）放射線計測協会が貸し出している「はかるくん」を使用した。

その強度変化に対する小イオン密度は開発商品化されている大気吸入式のKST－900型で測定した。

放射線強度を変化させる試料としては放射線を放出する直径約10mm程度のセラミックボールを使用。

測定場所は鉄筋5階建の3階の室内（温度約22℃、湿度約43％）である。

3. 測定結果

a). 室内における放射線強度と正負イオン密度の測定

b). セラミックボール1個の放射線強度と正負イオン密度の測定

c). セラミックボール3個の放射線強度と正負イオン密度の測定

d). セラミックボール7個の放射線強度と正負イオン密度の測定

以上の事例について測定したので、それらの結果の平均値を表1に示す。

表1. 放射線強度と生成正負イオン密度

	放射線強度 (μSv/h)	小イオン密度（コ/ml）		イオン比
		正	負	正/負
室内 a)	0.054	123	77	1.59
ボール1個 b)	0.300	415	361	1.14
ボール3個 c)	0.581	661	628	1.05
ボール7個 d)	0.924	1070	1045	1.02

図1は事例C). の正負イオン密度等の実測データ。表2, 表3はそれらの1秒毎のイオン密度である。

放射線強度に対する生成イオン密度は正負イオン密度共に増加するが、負イオン密度の方が多い。すなわちイオン比が1.59から1.02に変化している。一方放射線強度の増加割合よりも生成イオン密度増加は小さい。

4. おわりに

放射線強度変化による環境大気中に生成される小イオンにおける正イオン密度、負イオン密度変化を測定した。このようなイオン密度変化が「低線量放射線の健康への影響」の研究に役立ば幸いである。

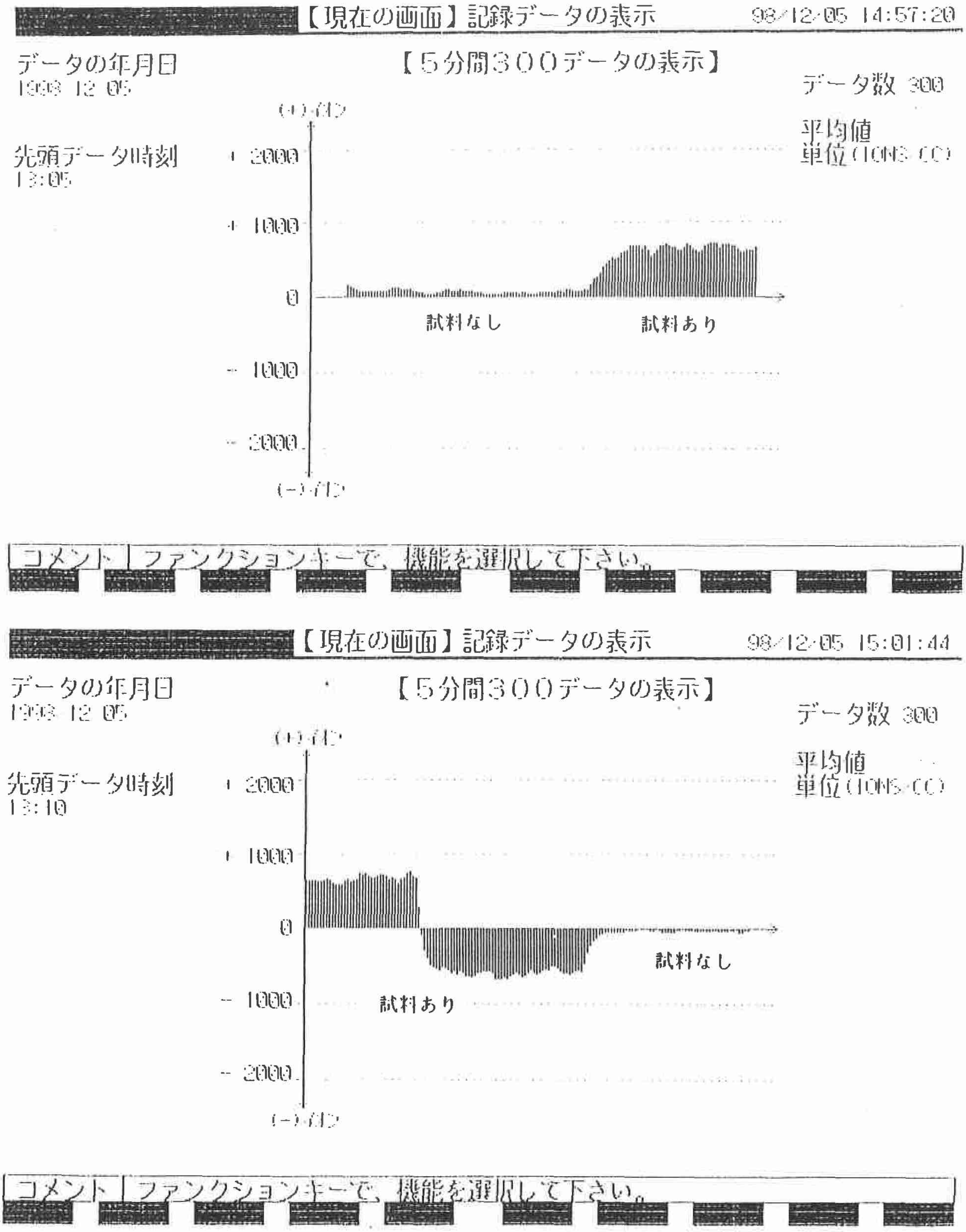


図1. 事例C). の正負イオン密度等の実測データ

表2. 事例C). の1秒毎の正イオン密度等

イオンデータ（単位 IONS/CC)
1998/12/05 13:05

(+)	-	1	(+)	-	1	(+)	-	1	(+)	-	1	(+)	+	0	(+)	-	1
(+)	-	1	(+)	+	1	(+)	-	1	(+)	-	1	(+)	-	1	(+)	+	0
(+)	+	0	(+)	+	0	(+)	+	1	(+)	+	0	(+)	+	0	(+)	+	0
(+)	-	1	(+)	+	0	(+)	-	1	(+)	+	1	(+)	+	20	(+)	+	141
(+)	+	167	(+)	+	158	(+)	+	147	(+)	+	138	(+)	+	136	(+)	+	127
(+)	+	116	(+)	+	104	(+)	+	98	(+)	+	96	(+)	+	91	(+)	+	87
(+)	+	84	(+)	+	86	(+)	+	83	(+)	+	83	(+)	+	81	(+)	+	83
(+)	+	92	(+)	+	95	(+)	+	97	(+)	+	93	(+)	+	87	(+)	+	86
(+)	+	89	(+)	+	96	(+)	+	96	(+)	+	98	(+)	+	102	(+)	+	106
(+)	+	123	(+)	+	142	(+)	+	136	(+)	+	123	(+)	+	120	(+)	+	123
(+)	+	118	(+)	+	108	(+)	+	106	(+)	+	105	(+)	+	107	(+)	+	107
(+)	+	110	(+)	+	102	(+)	+	93	(+)	+	91	(+)	+	81	(+)	+	80
(+)	+	78	(+)	+	72	(+)	+	67	(+)	+	62	(+)	+	59	(+)	+	50
(+)	+	54	(+)	+	52	(+)	+	54	(+)	+	50	(+)	+	58	(+)	+	68
(+)	+	71	(+)	+	74	(+)	+	76	(+)	+	76	(+)	+	86	(+)	+	96
(+)	+	109	(+)	+	108	(+)	+	102	(+)	+	99	(+)	+	92	(+)	+	87
(+)	+	87	(+)	+	93	(+)	+	98	(+)	+	102	(+)	+	101	(+)	+	96
(+)	+	87	(+)	+	87	(+)	+	86	(+)	+	84	(+)	+	82	(+)	+	81
(+)	+	80	(+)	+	73	(+)	+	76	(+)	+	73	(+)	+	70	(+)	+	67
(+)	+	63	(+)	+	59	(+)	+	54	(+)	+	52	(+)	+	52	(+)	+	44
(+)	+	44	(+)	+	44	(+)	+	44	(+)	+	44	(+)	+	48	(+)	+	40
(+)	+	40	(+)	+	48	(+)	+	50	(+)	+	58	(+)	+	62	(+)	+	65
(+)	+	68	(+)	+	74	(+)	+	68	(+)	+	65	(+)	+	63	(+)	+	63
(+)	+	60	(+)	+	56	(+)	+	54	(+)	+	56	(+)	+	60	(+)	+	60
(+)	+	61	(+)	+	64	(+)	+	58	(+)	+	54	(+)	+	54	(+)	+	52
(+)	+	52	(+)	+	50	(+)	+	56	(+)	+	59	(+)	+	66	(+)	+	68
(+)	+	71	(+)	+	75	(+)	+	72	(+)	+	68	(+)	+	64	(+)	+	64
(+)	+	63	(+)	+	67	(+)	+	72	(+)	+	86	(+)	+	88	(+)	+	86
(+)	+	84	(+)	+	80	(+)	+	79	(+)	+	100	(+)	+	110	(+)	+	104
(+)	+	103	(+)	+	97	(+)	+	89	(+)	+	87	(+)	+	87	(+)	+	88
(+)	+	92	(+)	+	92	(+)	+	97	(+)	+	103	(+)	+	106	(+)	+	102
(+)	+	109	(+)	+	123	(+)	+	172	(+)	+	223	(+)	+	247	(+)	+	262
(+)	+	277	(+)	+	297	(+)	+	327	(+)	+	367	(+)	+	408	(+)	+	436
(+)	+	444	(+)	+	458	(+)	+	497	(+)	+	529	(+)	+	536	(+)	+	518
(+)	+	505	(+)	+	516	(+)	+	533	(+)	+	553	(+)	+	582	(+)	+	607
(+)	+	606	(+)	+	605	(+)	+	622	(+)	+	658	(+)	+	696	(+)	+	701
(+)	+	683	(+)	+	691	(+)	+	699	(+)	+	698	(+)	+	696	(+)	+	677
(+)	+	658	(+)	+	682	(+)	+	688	(+)	+	659	(+)	+	627	(+)	+	577
(+)	+	549	(+)	+	573	(+)	+	587	(+)	+	598	(+)	+	630	(+)	+	657
(+)	+	686	(+)	+	680	(+)	+	693	(+)	+	719	(+)	+	703	(+)	+	708
(+)	+	691	(+)	+	669	(+)	+	673	(+)	+	667	(+)	+	665	(+)	+	653
(+)	+	622	(+)	+	601	(+)	+	632	(+)	+	651	(+)	+	666	(+)	+	701
(+)	+	714	(+)	+	706	(+)	+	690	(+)	+	679	(+)	+	656	(+)	+	630
(+)	+	623	(+)	+	624	(+)	+	618	(+)	+	610	(+)	+	636	(+)	+	656
(+)	+	686	(+)	+	718	(+)	+	712	(+)	+	728	(+)	+	733	(+)	+	718
(+)	+	739	(+)	+	747	(+)	+	739	(+)	+	708	(+)	+	677	(+)	+	690
(+)	+	708	(+)	+	719	(+)	+	717	(+)	+	708	(+)	+	701	(+)	+	696
(+)	+	694	(+)	+	690	(+)	+	682	(+)	+	663	(+)	+	646	(+)	+	624
(+)	+	607	(+)	+	601	(+)	+	607	(+)	+	630	(+)	+	635	(+)	+	657
(+)	+	634	(+)	+	623	(+)	+	623	(+)	+	648	(+)	+	670	(+)	+	647

時間 ——————>

表3. 事例C). の1秒毎の正負イオン密度等

イオンデータ（単位 IONS/CC)
1998/12/05 13:10

(+) +	653	(+) +	657	(+) +	651	(+) +	641	(+) +	643	(+) +	651
(+) +	653	(+) +	644	(+) +	630	(+) +	609	(+) +	624	(+) +	634
(+) +	640	(+) +	637	(+) +	666	(+) +	658	(+) +	646	(+) +	631
(+) +	609	(+) +	598	(+) +	599	(+) +	600	(+) +	596	(+) +	599
(+) +	596	(+) +	592	(+) +	642	(+) +	663	(+) +	667	(+) +	643
(+) +	630	(+) +	644	(+) +	659	(+) +	651	(+) +	669	(+) +	711
(+) +	746	(+) +	730	(+) +	731	(+) +	733	(+) +	748	(+) +	732
(+) +	708	(+) +	694	(+) +	687	(+) +	693	(+) +	694	(+) +	698
(+) +	716	(+) +	727	(+) +	727	(+) +	732	(+) +	726	(+) +	717
(+) +	703	(+) +	692	(+) +	678	(+) +	687	(+) +	689	(+) +	673
(+) +	666	(+) +	632	(+) +	608	(+) +	640	(+) +	667	(+) +	690
(+) +	686	(+) +	711	(+) +	750	(+) +	777	(+) +	761	(+) +	738
(+) +	718	(+) +	713	(+) +	698	(+) +	686	(-) +	292	(-) +	53
(-) -	108	(-) -	218	(-) -	300	(-) -	362	(-) -	411	(-) -	461
(-) -	504	(-) -	522	(-) -	530	(-) -	529	(-) -	541	(-) -	558
(-) -	565	(-) -	545	(-) -	534	(-) -	533	(-) -	548	(-) -	542
(-) -	565	(-) -	593	(-) -	600	(-) -	601	(-) -	599	(-) -	621
(-) -	629	(-) -	616	(-) -	581	(-) -	571	(-) -	601	(-) -	631
(-) -	652	(-) -	670	(-) -	654	(-) -	647	(-) -	669	(-) -	659
(-) -	649	(-) -	629	(-) -	612	(-) -	608	(-) -	609	(-) -	595
(-) -	595	(-) -	590	(-) -	590	(-) -	595	(-) -	585	(-) -	587
(-) -	609	(-) -	654	(-) -	683	(-) -	681	(-) -	686	(-) -	695
(-) -	695	(-) -	687	(-) -	679	(-) -	674	(-) -	683	(-) -	684
(-) -	659	(-) -	644	(-) -	631	(-) -	621	(-) -	608	(-) -	605
(-) -	635	(-) -	652	(-) -	660	(-) -	658	(-) -	654	(-) -	622
(-) -	604	(-) -	585	(-) -	570	(-) -	587	(-) -	614	(-) -	633
(-) -	630	(-) -	606	(-) -	602	(-) -	596	(-) -	587	(-) -	570
(-) -	564	(-) -	574	(-) -	564	(-) -	534	(-) -	537	(-) -	536
(-) -	529	(-) -	528	(-) -	548	(-) -	581	(-) -	598	(-) -	600
(-) -	606	(-) -	603	(-) -	600	(-) -	610	(-) -	628	(-) -	621
(-) -	611	(-) -	603	(-) -	586	(-) -	571	(-) -	563	(-) -	587
(-) -	596	(-) -	569	(-) -	494	(-) -	423	(-) -	355	(-) -	296
(-) -	251	(-) -	214	(-) -	188	(-) -	170	(-) -	148	(-) -	127
(-) -	113	(-) -	104	(-) -	93	(-) -	85	(-) -	79	(-) -	74
(-) -	70	(-) -	65	(-) -	62	(-) -	61	(-) -	65	(-) -	67
(-) -	66	(-) -	68	(-) -	61	(-) -	64	(-) -	61	(-) -	61
(-) -	54	(-) -	50	(-) -	54	(-) -	58	(-) -	54	(-) -	48
(-) -	42	(-) -	38	(-) -	38	(-) -	38	(-) -	36	(-) -	36
(-) -	38	(-) -	36	(-) -	35	(-) -	33	(-) -	42	(-) -	48
(-) -	46	(-) -	40	(-) -	36	(-) -	38	(-) -	46	(-) -	54
(-) -	62	(-) -	61	(-) -	62	(-) -	65	(-) -	70	(-) -	69
(-) -	66	(-) -	64	(-) -	62	(-) -	61	(-) -	56	(-) -	52
(-) -	46	(-) -	42	(-) -	38	(-) -	40	(-) -	42	(-) -	50
(-) -	46	(-) -	48	(-) -	54	(-) -	60	(-) -	50	(-) -	46
(-) -	54	(-) -	52	(-) -	50	(-) -	48	(-) -	48	(-) -	48
(-) -	46	(-) -	42	(-) -	46	(-) -	46	(-) -	48	(-) -	50
(-) -	54	(-) -	60	(-) -	59	(-) -	56	(-) -	52	(-) -	52
(-) -	50	(-) -	42	(-) -	44	(-) -	46	(-) -	42	(-) -	44
(-) -	44	(-) -	48	(-) -	50	(-) -	62	(-) -	64	(-) -	64
(-) -	69	(-) -	65	(-) -	58	(-) -	50	(-) -	42	(-) -	38

時間 ———▷

3.12 高校現場における放射線教育の実験事例と実情の報告

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要趣

現行の高校教育課程の中で、今後、国民的なレベルで必要とされる放射線教育が現場の理科教育で実践する状況にはほとんどない。高校生の物理の履修率が20%にも届かない現状にあって、物理離れとともに理科離れが進んでいる。本校では1996年より選択履修で文系に大学進学する生徒にとっても、より理解しやすく、また、実験中心に進める講座として自然科学実験講座という名称で物理、化学、生物、地学を含めた総合講座の形式で開講した。1998年には高校２年と高校３年にそれぞれ２講座ずつ設けられている。この講座のカリキュラムの中に放射線教育を取り入れて実践した内容を紹介します。

１．はじめに

私たち身の回りには沢山の放射線がある。放射線というと生徒に危険な物というイメージが強い。わが国は原子爆弾の世界最初の被爆国である。生徒にとって放射線教育はいろいろな問題を含んでいる。しかし、昔から自然の放射線は存在していたのである。自然に存在する放射線のことをバックグラウンド放射線と呼び、次の２つに大別している。１つは、宇宙線と言われ空から降り注いでくる。その発生源は太陽であったり、宇宙に存在する他の天体からのものであろうと推定されてる。もう１つは、地球に存在しているもので、地面の中にあるウランやトリウム、ラドンなどをごくわずかに含む鉱物から出る放射線、植物や建物にある放射性物質から出る自然の放射線などがある。

このような自然の放射線に対して人工的な放射線がある。それは１９世紀の終り頃、ドイツの科学者レントンゲンによって発見されたX線や、原子炉などで作られる各種の放射線同位元素（ラジオアイソトープ）、原子爆弾や水素爆弾による各種の放射性物質など、人間が作り出したものである。こうした人工的に作り出された放射線は、身体にとって危険性が多いので取扱いには十分な注意が必要である。しかし、これらの人口放射線も科学的に安全に取り扱えば私たちの日常生活の中で有効に活用されるものもある。例えば医療用に使用したり、新しい製品開発のためにβ線などが使用されている。もちろん、発電にも原子力発電が使用されており、様々な課題を含みながらも原子力発電に依存しなければならない現状である。

こうした身近な放射線について、科学的に正しく理解することが重要であり、下記に示すような実践事例を紹介する。

2．授業活動のねらい

自然放射線の科学的な理解を深め、放射線そのものが身の回りに存在することを認識させる。高校理科教育の自然科学実験の授業のねらいとして下記のような放射線教育の目標を立てた。

①私たちの身の回りにある自然放射線を簡易放射線探知機や、簡易型霧箱を用いて、α線、β線、γ線などを観察し、その違いについて観察する。自然放射線にはいろいろな種類があることを理解する。

②放射線探知機と電子線計測器とを組み合わせて、自然の放射線の定量測定をすることにより、日常的に放射線が飛来していることを認識する。

③放射能、放射線、放射線量などの用語を正確に理解する。

④放射性元素がα崩壊、β崩壊を繰り返して一定の周期で質量が半減されていく現象を模擬実験で検証する。

⑤人工放射線の実験例として、ソフテックス（軟Ｘ線装置）用いて生徒の持ち物などをＸ線撮影する。Ｘ線の透過力の強いことの危険性について認識し、放射線の実験で被爆した研究者の写真や、広島、長崎などに原子爆弾が投下された写真などを観察し、人口放射線のに対する認識を科学的に正確に理解させる。

以上の実験や観察を実施することにより、放射線の科学的な理解と認識を深めるとともに原子力利用の実情などを紹介する。放射線は危険なものであり、しかし、扱い方によっては安全であり、人類にとって今後、研究し、開発していかなければならない大きな課題であることを認識する。

3．実験方法と事例

(1).私たちの身の回りにある自然放射能探知機と実験用簡易放射線源セットを用いて、放射線を観測する。市販されている実験用簡易放射線源セットは、次のようなものがある。

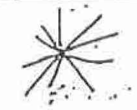
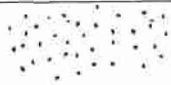
ポロニウム（Ｐｏ－210）α線、0.1 μＣｉ、半減期138 日、ストロンチュウム（Ｓｒ－90）β線、0.1 μＣｉ、半減期28.6年、コバルト（Ｃｏ－60）γ線、0.1 μＣｉ、半減期5.27年などがありプラスチックケース入りで取扱い免許の必要はないとされている。

①. 簡易放射線探知機を使用して自然放射線を測定し、下記の表に記入する。ただし、飛行機などの測定は、その様な機会があった時に測定する。

＜バックグラウンド放射線の測定結果＞

測定場所	μＳv／10min（放射線カウント数）					
	１回	２回	３回	４回	５回	平均
屋　内						
コンクリート建物						
木造建築						
トンネル内						
池、湖、海						
飛行機						

また、簡易型霧箱を用いて、α線、β線、γ線などを観察し、その違いについて観察する。自然放射線にはいろいろな種類があることを理解する。その違いは、下記の図のように霧箱の中で観察することができる。

放射線の種類	霧箱の飛跡の様子	飛跡の図	イオン化能力	透過能力
α線	たこ糸のように太く短い		大	小
β線	蜘蛛の糸のようで細く曲がっている		中	中
γ線	点状に広がる		小	大

②放射線探知機と電子線計測器とを組み合わせて、自然の放射線の定量測定をすることにより、日常的に放射線が飛来していることを認識する。

地学標本の岩石の中にウランの鉱石が数種類ある。これらを用いて測定する。ほかに上記に示した市販されている実験用簡易放射線源セットなどを用いて、放射線源を定量的にカウントする。単位時間当たりどれだけのカウントされたかをそれぞれについて表にまとめて考察をする。また、自然放射線の飛来してくるものをカウントしてその比較をする。

③放射能、放射線、放射線量などの用語を正確に理解する。下図のような絵をえがき、黒板用磁石で固定し、上記の用語を正確に理解する。

放射能、放射線、放射線量の違いと単位

左図のように放射能、放射線を光に例えると、放射線は光で、放射能は光を出す能力である。放射能をもつ物質が放射性物質で、光源に相当する。

〈放射線の単位〉

1．放射能（崩壊の強さ）：ベクレル（Bq）

　1ベクレルは1秒間に1個の原子核が崩壊する放射能の強さ

　　1 Bq＝1崩壊／秒　1 Ci＝3.7×10^{10}Bq

2．吸収線量（D）：グレイ（Gy）

　物質1 kgに、放射線によって与えられるエネルギーが1ジュールになる放射線の量

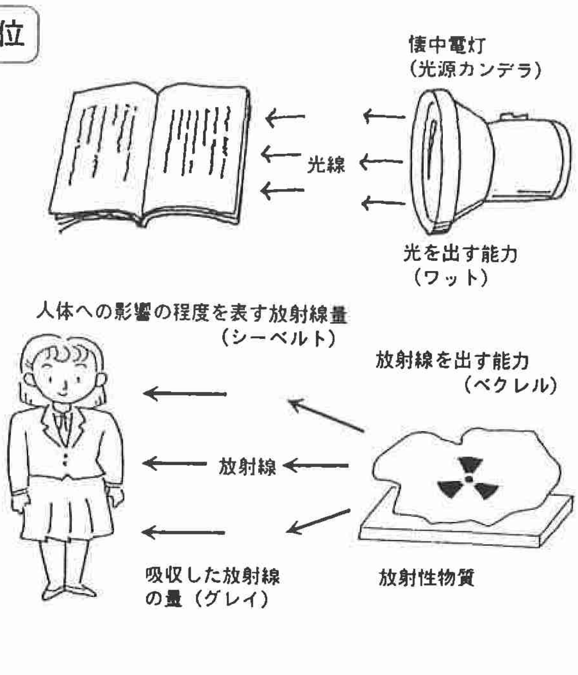
　　1 Gy＝1 J／kg＝100rad（ラド）

3．線量当量（H）：シーベルト（Sv）

　放射線の吸収量に、人体に対する影響の現れ方を補正した線量

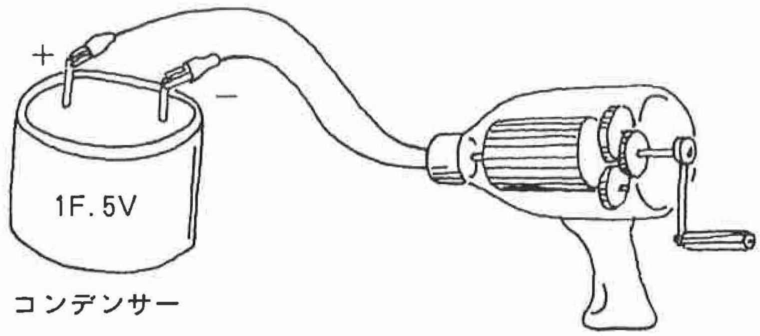
　　H＝D×Q　1 Sv＝100rem（レム）

　　Q；線質係数



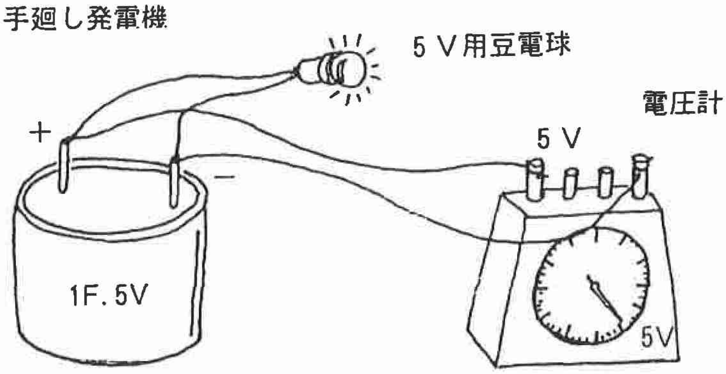
④放射性元素がα崩壊、β崩壊を繰り返して一定の周期で質量が半減されていく現象を模擬実験で検証する。
（ア）コンデンサー（容量、耐電圧それぞれ１Ｆ、５Ｖ）に、手巻き発電機を用いて、電圧、５Ｖまで充電する。
（イ）充電したコンデンサーに５Ｖ用豆電球を接続し、放電時間を１０秒間ずつとりこの時の降下電圧を測定してグラフにする。
（ウ）下図のようなグラフが描くことができる。これは放射性物質の質量の半減期の様子に似ていることから半減期の公式を検証することができる。

手廻し発電機による充電



コンデンサー

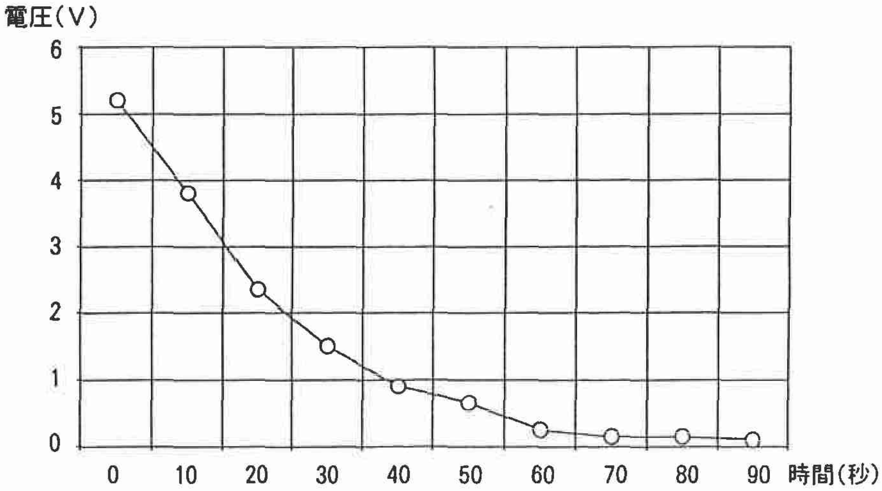
手廻し発電機



コンデンサー

コンデンサーに豆電球を接続した放電現象

放射性物質の半減期減少をコンデンサーの放電によって表わすグラフ



⑤人工放射線の実験例として、ソフテックス（軟Ｘ線装置）用いて生徒の持ち物などをＸ線撮影する。

（ア）ソフテックスＸ線照射口の下５cmのところに、大きさ３cm×４cmの歯科用のデンタルフィルムを不透明なビニール袋に封入されたまま、白い面を上に向けて置く。

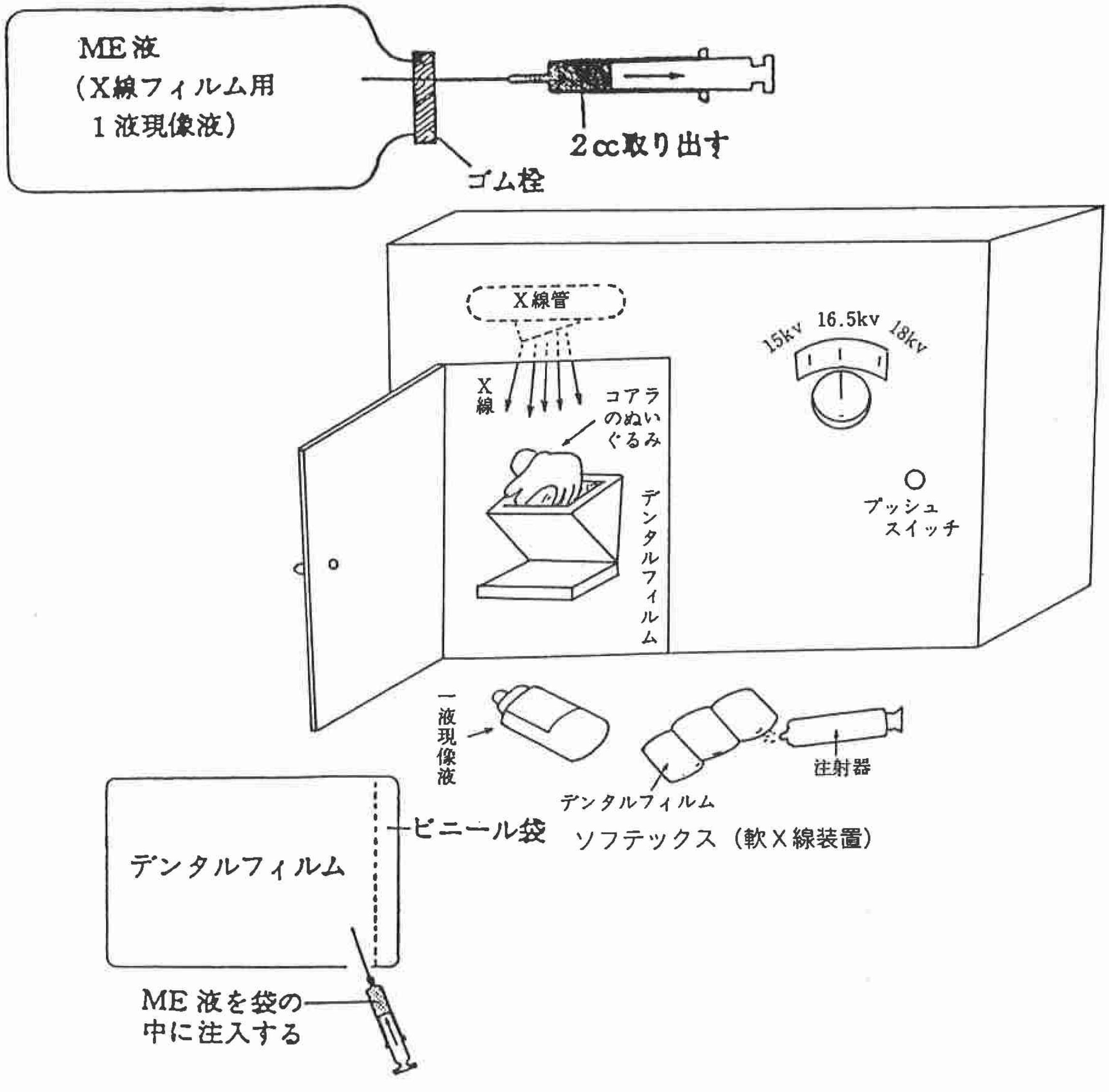
（イ）そのフィルムの上に、例えば生徒の持ち物のコアラの人形など載せ、取りだし口を閉める。これでＸ線を照射しても漏れることはない。

（ウ）プッシュスイッチを押してＸ線を５秒間照射し、照射後フィルムの入ったままのビニール袋を外に出す。

（エ）Ｘ線フィルム用１液を（ＭＥ液）の入ったポリ容器のゴム栓の中に注射器の針を差し込みＭＥ液を２ccほど取り出す。

（オ）Ｘ線を照射したデンタルフィルムのビニール袋の中に注射器の針を差し込み、２ccのＭＥ液を注入する。現像時間、１分後、はさみでビニールの端を切り取って、開封し、中のフィルムを取り出して水洗いする。

（カ）数分間水洗い後、風通しのよい所でフィルムを乾燥する。完成である。



４．実情報告

①．本校の場合、自然科学実験法という講座が選択科目で履修できるカリキュラムになっている。ここで放射線教育を６時間から８時間の時間帯で学習できる。

②．この実験・実習をとおして生徒は自然放射線の実態を体験することから、安全性について理解することができた。

３．将来、生徒たちにとって放射線に関する学問や実践の場で活動することに危険なイメージを拭うことができた。

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3.13 Natural Radioactivity Distribution Images and Their Educational Uses

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Distribution images of natural radioactivities in vegetables, meat and porcelain works were obtained by use of Imaging Plate with very high sensitivity to radiations. A brochure titled "Natural Radiations through Naked Eyes" was published in both Japanese and English which included the images mentioned above. In this paper, the method to obtain the distribution images of extremely low level natural radioactivity, the content of the brochure and the effect of it to the public are described.

1. Introduction

Potassium is always contained in living cells and it contains 0.0119% of radioactive potassium K-40 which emits beta-rays with the maximum energy of 1.33MeV. Although the radioactivity in food or meat is only 0.02-1Bq/g, if we use Imaging Plate (IP) [1] which was developed by Fuji Photo Film Co. Ltd. and has very high sensitivity of more than 100 times compared with conventional X-ray films it might be possible to obtain the images of the natural radioactivity distribution. If so, we thought that such images would be effective to let the public understand through their eyes that radioactivity and radiations are naturally present even in food or in our own bodies. This was the beginning of this work.

Rough estimation revealed that almost one month would be necessary to obtain the distribution images of natural radiations from vegetables, meat etc. in a shielding box for the reduction of background radiations. We finally obtained some new images [2,3,4] of vegetables, meat, porcelain wares, glass wares etc.

Then we published a brochure titled "Natural Radiations through Naked Eyes" including the new images and have distributed them in public meetings.

2. Reduction of natural background radiations

Since the radioactivity contents in vegetables and meat are almost same or sometimes smaller than those in environmental natural materials, it is necessary to reduce background radiation intensity to obtain the images. Figure 1 shows the background radiation intensity as a function of a thickness of the wall of a shielding box measured with IP by exposing it for 10 hours in the box. A lead box or iron box whose inner side was lined with Cd 1mm, Cu 1mm, and acrylic resin 1cm, so to speak a graded shielding box, showed a reduction of background radiations to about 1/30 [5].

3. Specimen exposure, image reading and radioactivity determination

The exposure time of vegetables and meat on IP in the shielding box is very long over about one month. We had to antisepticize such specimens to prevent from rotting. The specimens were

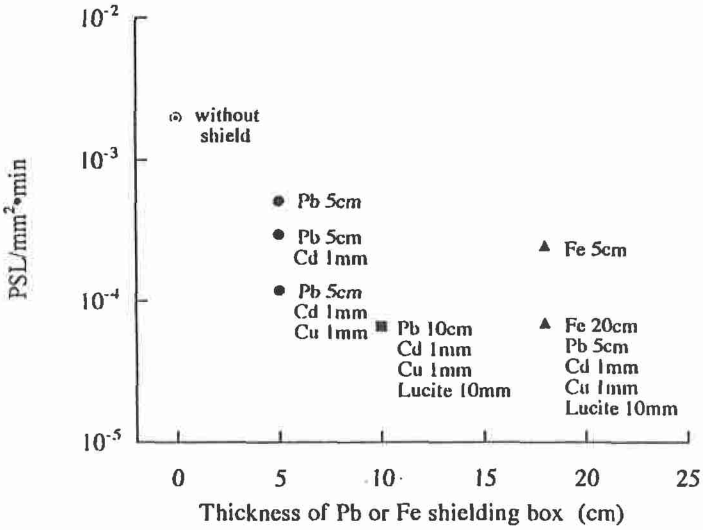

Fig.1 Reduction of background radiations with shielding box

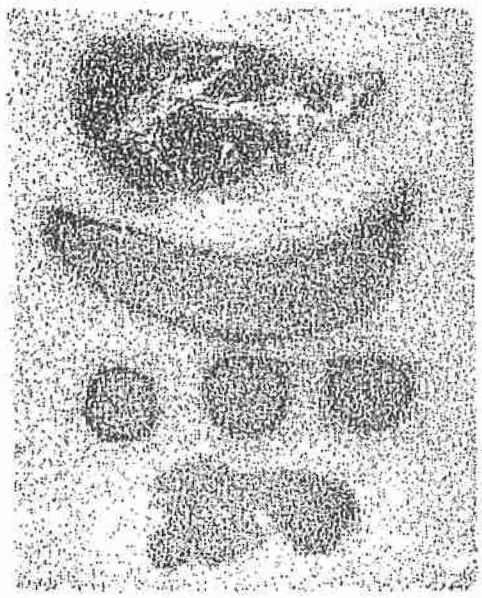

Fig.2 Radioactivity distribution images of pork, banana and ginger

wrapped up with a thin polythene film. After the exposure, the IP must be quickly read out, otherwise the accumulation of background radiations deteriorates the image clarity.

Figure 2 shows the natural radioactivity images of pork, banana and ginger. It can be seen that the part of fat in pork does not show radiation intensity. In the case of vegetables and meat, the contribution of radionuclide to making images is K-40 and the contribution of other nuclides such as C-14 and H-3 is less than 1% because of their low energy beta-rays and low concentration.

Figure 3 shows natural radioactivity distribution images of three pairs of glasses. The radiation intensity largely depends on the difference of glass material. The intensity from the glasses shown at the bottom in the figure was estimated by calculation that they will bring radiation exposure dose to the eyes wearing them about 2-3mSv/y, which is very small and included in the difference of background radiation intensities depending on the district.

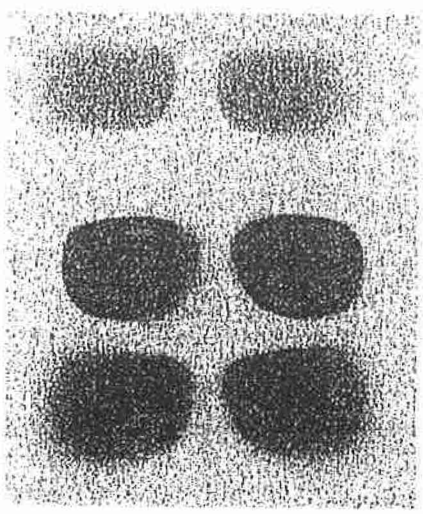

Fig.3 Radioactivity distribution images of glasses

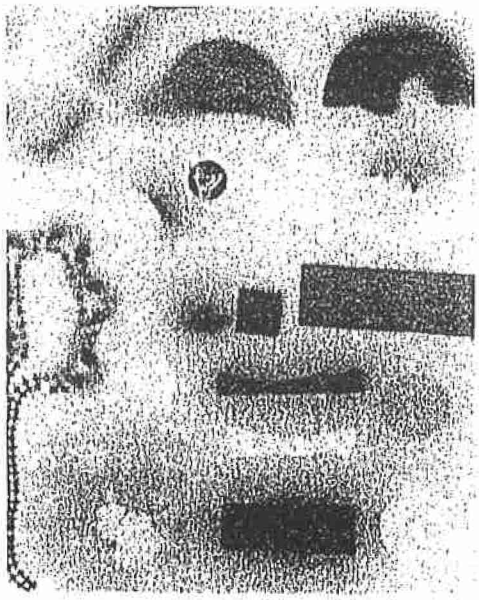

Fig.4 Radioactivity distribution images of personal ornaments made of glass and ceramics

Figure 4 shows some images of personal ornaments. Some brooches made of porcelain and some others including necklace made of glass contain some amount of radioactivity of mainly K-40 and of small amount of other nuclides in uranium and thorium series.

A known weight of KCl was dissolved in distilled water. The amount of K-40 was determined from the natural abundance (0.0119%) of K-40. The solution was poured into a vessel and put on a high purity Ge detector in a graded shielding box. The gamma-ray energy spectrum was obtained. Vegetables was then ground and the same amount of it to the KCl solution was put into the vessel. The intensity of gamma-rays (1.46MeV) from K-40 in the vegetable was compared with that of KCl and K-40 radioactivities were determined as shown in Fig.5 which coincides with published data [6].

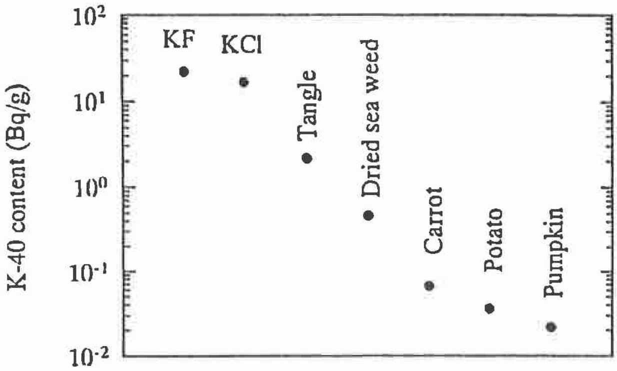

Fig.5 Radioactivities contained in some specimens measured with HP Ge detector

3. Publication of brochures

Since we obtained some new images of natural radioisotope distributions, we considered that they might be helpful to visually inform the figure of the nature as it is to the public. We prepared a brochure [7] as shown in Fig. 6 which includes various natural radiation images: natural radioactivity images of vegetables as shown in the cover paper, Prof. Roentgen's X-ray images although X-rays are not natural ones, Prof. Becqerel's gamma- and beta-ray image from uranium ore, polar light caused by cosmic radiations, Sun's flare caused by nuclear fusion, traces of radiations in stones, paths of radiations in cloud chamber, Cerencov radiation, natural radioactivity distribution images of porcelain paint, etc. Both Japanese and English versions were published. They have been used for three years in public meetings and sometimes in radiation education classes for high school students and even in university students. English version was distributed in foreign countries, Canada, Australia, USA, Korea and other countries.

Fig.6 Cover page of the brochure showing lotus root, sweet potato, potato, ginger and pumpkin. The title of English version is "Natural Radiations through Naked Eyes"

Another brochure titled "Environmental radiations through figures" was published in Japanese, which also has been widely distributed. When we use these brochures with explanation on the content, we sometimes make inquiries about the effect of the brochures. Most of the audience reply that they had rather strong impression on the images of natural radioactivity in food and consequently in their own bodies.

4. Conclusion

The images of the distribution of natural radioactivity in vegetables, meat etc. were first obtained in the world by using Imaging Plate. Brochures including them were published and widely distributed in public meetings or school classes. Fairly large proportion of the public people first understood that natural radioactivity was included in food and even their own bodies.

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3.14 40KVナロービームX線の吸収線量

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要旨

最近ナロウビームXγ線が放射線治療と診断に利用されている。そして、治療用には4MV以上の高エネルギーX線と^{60}Coγ線を使用し、診断用には150KV以下の低エネルギーX線が用いられている。しかし自由空気電離箱を線量標準とした平行ビーム光子の校正場の概念で構成されている照射線量体系ではナロービームの吸収線量測定は不能である。

われわれは、X線エネルギーを40KVに限定して、PMMA(PMMAはポリメチルメタクリレートの略号) 厚板ファントムを媒質に用いた零外挿式電離箱の一次元空洞の比電離電荷 q_n/dx とその分布特性から吸収線量の評価を試みた。

その結果、3mmφと300x300mmのコリメータを通過したナロービームとブロードビームのX線を比較すると、ナロービームの吸収線量はブロードビームに対してて0.336倍の値を示した。またこれらのX線ビームの分布特性は、いずれも正規分布に近似して比較することができた。また衝突阻止能との関係から一次元空洞:dx(cm)・S(cm^2)の吸収線量は特定した電子の飛程数:T_nとdE/dXρ^{-1}の積で表す事ができた。

1．はじめに

要旨でも述べた PMMA 厚板ファントムを媒質に指定したγ線用の零外挿式電離箱が開発[1)]されている。基本的にβ線の吸収線量測定器と同じであるが、β線用の測定器は人体胴部を想定したファントム効果が小さくγ線吸収線量の評価には不適当と考えられている。一般に用いられている軸長:Lと直径:D_Cで電離容積:V_Cが決まる円筒形電離箱の電離電荷量はV_Pに比例するが、二次電子の放射体としての壁:W_Cの面積とは比例関係をもたない。これが単位容積(V_P/cm^3)当たりの電離電荷量:q_Eにのみ注目する照射線量:Xの概念である。

吸収線量:D_d は光子の相互作用で生成する壁:W_Pの転換電子e_Kと散乱電子e_Sとの電離:e_{KS}の単位質量当たりのエネルギー量:J_d/gに注目するから、e_{KS}の電離電荷:q_n はW_Pの面積Sと電離容積:V_P に比例関係係を持つ平面空洞が必要になる。

比電離電荷:q_n/dxを求める零外挿式電離箱は入射媒質に正対する集電極面積:S(cm^2)までの長さ:dx(cm)を変数として電離容積:V(cm^3)が決まる(1)式の1項が示す一元空洞:dx・Sである。図1. 参照

いま入射媒質から集電極に向って通過するe_{KS}が一様な分布で放出されていれば、一次元空洞の電離電荷:q_nは平坦分布を示す。このエネルギー吸収量は(1)式の2項からJ_d(erg/g)で表される。

$$J_d = \frac{q_n(C)}{dx(cm)\cdot S(cm^2)} \times \frac{33.97(eV)\times 1.59\cdot 10^{-12}(erg/eV)}{1.293\cdot 10^{-3}(g\cdot cm^{-3})\times 1.602\cdot 10^{-19}(C)} \quad \text{------}(1)$$

入射媒質の厚さ:dを指定した吸収線量:D_d(Gy)は$J_d\cdot 10^4$を媒質:PMMAの阻止能比:$_GS_M$で補正すれば決まる。最近、^{137}Csと^{60}Coγ線のe_Kの阻止能分布が零外挿式電離箱で測定[2]された。この結果からq_n/dxを転換電子:e_Cの減速過程の電離:e_K と電離ポテンシャル:Iを越えるが飛程の短い散乱電子の電離:e_Sとの混在電離:e_{KS}の比電離電荷q_{KS}/dxと表せば電離の仕組みを更に詳述できる。

一次元空洞の電離電荷:q_Pが正規分布近似[3]を示す照射断面積:A/S<Aのナロービーム X線では、J_dの検出に長さ:dxと集電極面積:Sを変数に必要とするがS が固定されているからJ_dが成立しない。そこでS の面積内に収まるq_Pの分布特性からエネルギー吸収量:J_Pを検出する方法を試みた。

2. 零外挿式電離箱とX線装置

X線装置と零外挿式電離箱の実験配置を図1. に示してある。ここでナロービームX線は3mmφX100mmのPbコリメータを通過して照射される。またブロードビームX線は300X300(mm)の照射野は可変絞りで決められている。Z軸の照射距離はX線装置の上下の移動によつて変えられる。このX線の出力条件は管電圧、管電流、照射時間の各々を40KV, 320mA, 100mSとした。

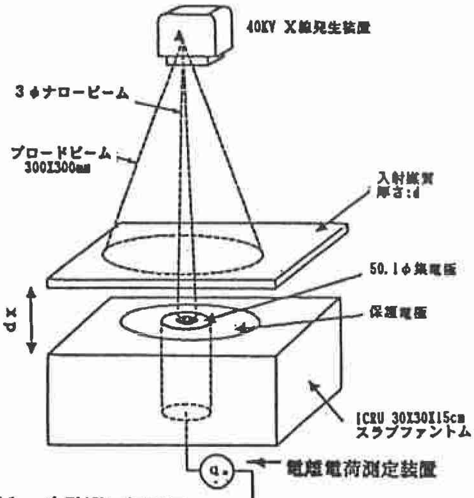

図1. 実験配置概要図

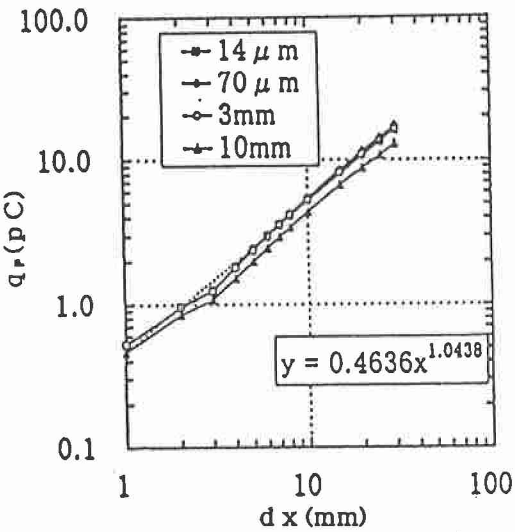

図2. ナロービーム電離電荷特性$q_P\cdot dx$

図1. に描かれた零外挿式電離箱は国際放射線単位・測定委員会(ICRU)が推奨する30X30X15(cm)のPMMA厚板ファントムで作られている。このファンムに支柱を介してグラファイトで導電化した最も薄い入射媒質(14μm厚さのPMMA)が正対して、厚板ファントム中央の50.5mmφ集電極と一次元空洞を構成している。そして目的とする媒質の厚さ:dはこの入射媒質の上に重ねて置かれる。また一次元空洞のdxは支柱の長さを変更して求める。この零外挿式電離箱は電離電荷:q_Pの分布特性を測定するためX線ビームの中心に位置するX-X'、Y-Y'の2 軸水平移動架台に据えられている。

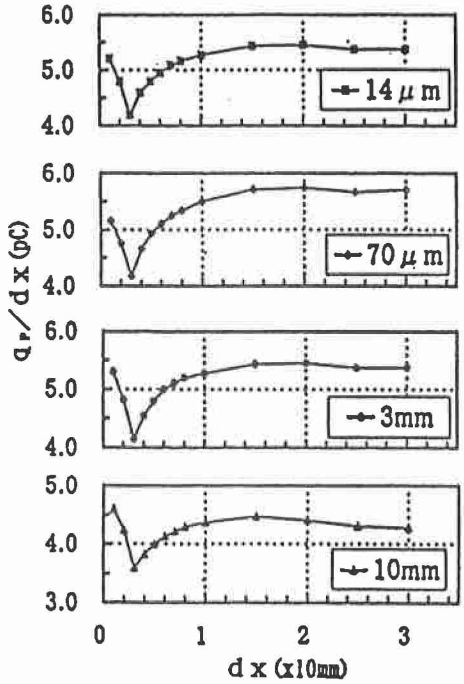

図3. 比電離電荷特性:Kqi

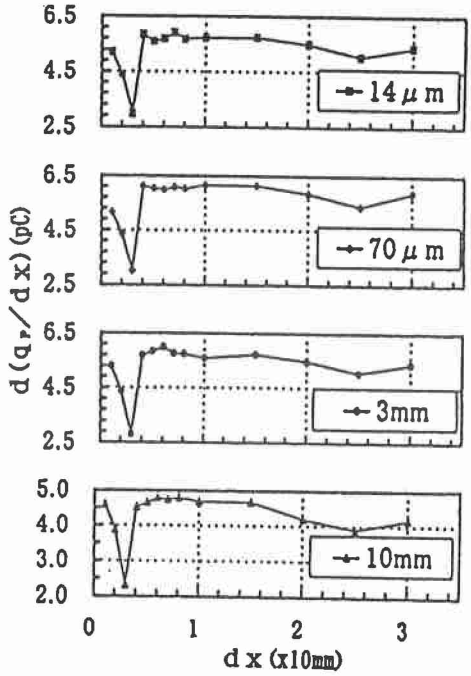

図4. 微分比電離電荷特性:Kqd

3. 比電離電荷測定

入射媒質の厚さ:d(厚さは各々14μm, 70μm, 3mm, 1cm)をパラメータに採り、dxを1mmから30mmまで変えて測定したナロービームの電離電荷特性:q_P・dxを図2. に示す。図3. にq_P/dxの比電離電荷特性:Kqiが示してある。このKq_iはdに拘らずdxが3mmで最小値を示すが、これは入射媒質が放出するe_{KS}のエネルギーが低くて、飛程の短いことに起因する。従ってq_P/dxの最大:q_iはdxの零外挿から求めるが、統計誤差の大さが問題になる。dxが3mm以上になるとX線の光子が空気と相互作用を起こしている。ここでは信頼性の高いq_iが得られる。しかしKq_iの最小値を含む平均値であるから、$q_P+\Delta q_P$とq_P の差分の最大として $q_d=d(q_P/dx)$ を採る微分比電離電荷特性:Kq_dで修正すれば$q_i=q_d$の関係から信頼性は向上する。

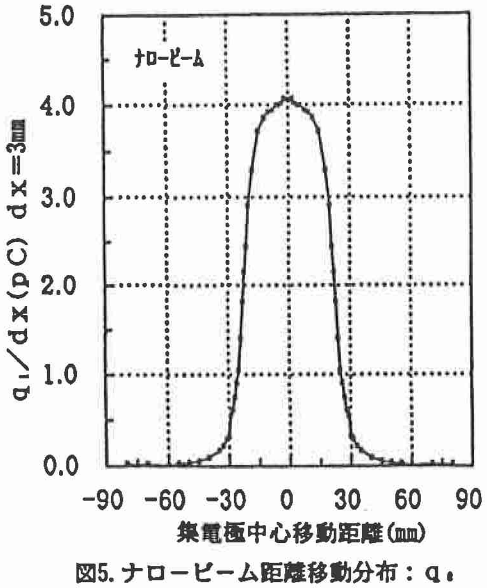

図5. ナロービーム距離移動分布：q_e

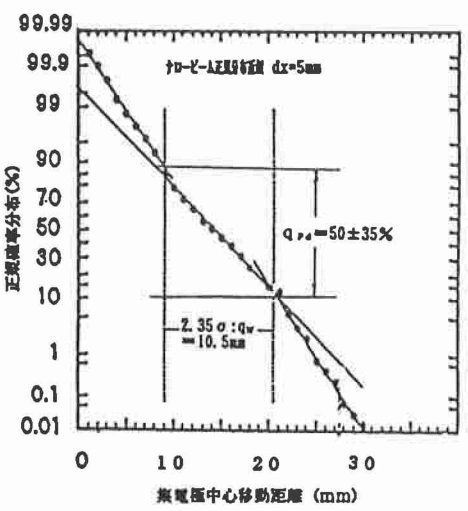

図6. ナロービームの正規分布近似 dx=5mm

4. 正規分布近似

X線装置から60cm離れた直径:Dが50.5mmの集電極中心:0に向けて入射媒質d:70μmを通過するナロービームX線は、一次元空洞にKq_dで修正した q_i=6.18pC を生成した。この中心0をX方向に移動した 図5. の q_i の移動距離分布:q_eを微分すれば電離電荷分布:q_{Pd}が求まるが、微分法は統計変動を増幅するので大きな誤差を与える。正規分布近似は図6. の正規確率紙にq_eの百分率を点描して、q_{Pd}の高さ 50±37.5% に対する 幅2.35σ:q_W を規格する手法で q_Wは移動距離から、また分布乖離度は百分率直線性から直読できる。しかし、一次元空洞のe_{ks} が半径方向に起こす散乱のため、dxの次数でq_W の値が異なるから入射媒質内の電離分布:e_Pはdxを変数とした零外挿値:$q_W=q_P/dx\rightarrow0$ になる。表1. に一次元空洞の $q_P/dx\rightarrow0$=6.4mm と、X線フイルムで求めた相対黒化度分布:F_PのX-X' 面分布:F_Xの2.35σ:$W_{1/2}$=5.6mm が示してある。図7. に示してあるF_Pの信頼性は確立しているからフイルム組成が入射媒質に等しいとすれば、$e_P=F_P$

ナロービーム 入射媒質厚さ70μm		
dx mm	q_W mm	$q_i≒q_d=d(q_P/dx)$ pC
30	17.2	5.82
20	15.4	6.18
10	13.5	6.18
5	10.1	6.02
2	7.8	6.1
$q_P/dx\rightarrow0$	6.4	6.18
フイルム$W_{1/2}$	5.6mm	

表1. 一次元空洞と写真黒化度の2.35σ巾(mm)

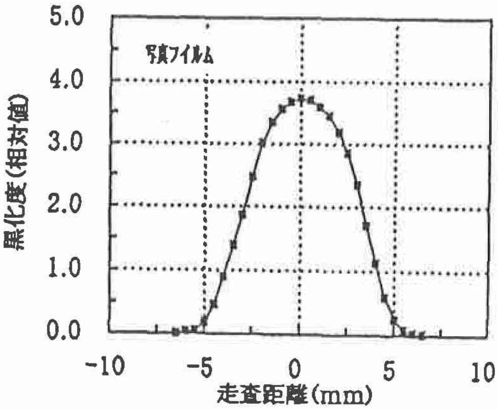

図7. 写真フイルムX-X'軸の黒化度分布

になる。このF_Xにq_i:6.18pCを0.5mm巾で按分して、頂点:m_Xを中心とした0.5mm巾の分布スライスに占めるq_X=0.43pC を求めた。さらに分布スライスの Y-Y' 面の分布:F_Yの半値巾:$W_{1/2}$ を5.6mmとして0.5mm幅で0.43pCの按分をすれば、F_Yの頂点:m_Yとm_Xが交差する面積:$S_d=2.5\cdot10^{-3}cm^2$の電離電荷:q_{XY}=0.03pC が求まる。F_xとF_yの分布の概念を図8. に示してある。ナロービームに対するこのq_{xy}/S_d の照射立体角:σ_nは(3)式

$$\sigma_n=2.35\sigma\cdot S_d^{0.5}/5.6(W_{1/2})$$
$$=0.21\sigma \text{ ---------------- (3)}$$

である。このσ_nの収斂係数:Kσは正規分布表から1.022を求めた。$K\sigma\cdot q_{xy}/dx\cdot S_d$は 平坦分布電離電荷:$q_n$に等価であるから $q_{xy}/S_d=12.26\cdot10^{-12}C/cm^3$ を(1)式の1項に代入した(4)式

$$J_p=12.26\cdot10^{-12}C/cm^3 X 2.598\cdot10^{11}erg/g\cdot cm^{-3}$$
$$=3.186erg/g \text{ ------------------------ (4)}$$

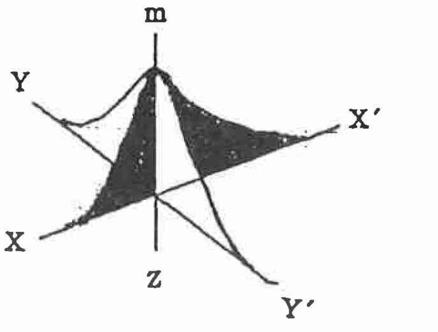

図8. 分布スライスの概念図
面積:S_dはmからzを見たX−X′、Y−Y′の重なり部分で、概念図とは異なり各々のmはオフセットしている。

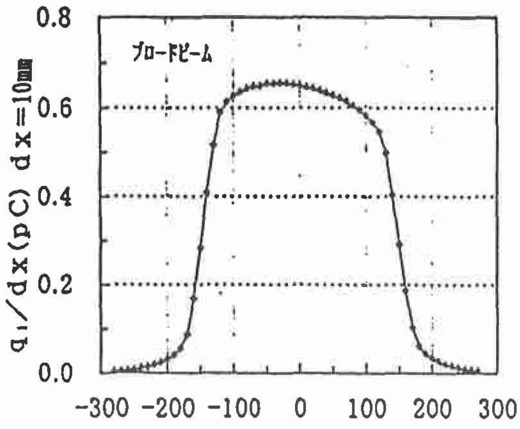

図9. ブロードビームの距離移動分布:q_i

で近似される。

一様な照射野を目的とするブロードビームX線はd:70μmを通過して集電極中心:0にq_iとして653.5pC/dx_{1cm} を生成した。図9.に示す距離移動分布:q_iから求めた q_wは208mmになる。また直径:Dが50.1mmの集電極の照射野立体角σ_bを(5)式に示す。

$$\sigma_b = 2.35\sigma \cdot D/q_w$$
$$= 0.566\sigma \quad \text{-------}(5)$$

このσ_bの収斂係数:$K\sigma$は1.121になる。そして$K\sigma \cdot q_i$は一次元空洞の平坦分布電離電荷:q_nに相当するから平面に対するJ_dが成立する。直径50.5mmの面に与えるJ_dは　$K\sigma \cdot q_i/dx \cdot S = 32.63 \cdot 10^{-12}C/cm^3$ を(1)式1項に代入した結果の(6)式

$$J_d = 9.502 erg/g \text{-----}(6)$$

で近似できる。

測定共通条件　照射距離:60cm　入射媒質厚さ:70μm		
X線共通条件　管電圧:40KV　管電流:320mA　出力時間:100mS		
ビームモード	ナロー	ブロード
コリメータ(cm)	0.3φ	30X30
検出面積(cm²)	$2.5 \cdot 10^{-3}$	20.03
σ_n	0.21*1	0.556*2
$K\sigma$	1.022	1.121
q_n(pC/cm)	0.0307*3	732.6*4
$erg/g \cdot cm^{-3}$	3.186	9.502
Gy*5	$3.162 \cdot 10^{-4}$	$9.419 \cdot 10^{-4}$

表2. 吸収線量線のビームモード比較

表2.にナローとブロードの40KVX線の測定結果を示し、内容の補足説明を下記に述べてある。

*1：照射断面積:Aと集電極面積:Sの関係がA/S<Sであるから図5.で中心 0 から(+)の領域の100分率が図6.の正規分布近似に相当する。

*2：ここでは、A/S>S であるから(−)から(+)の全領域の積分値の100分率が図6.の正規分布近似に相当している。$d(q_P/dx)$の修正はない。

*3：$K\sigma$の補正で検出面積に対して平坦な電離電荷分布：q_nを適用する。

*4：*3に同じ。

*5：${}_GS_M$=1.13を使って入射媒質のGyに換算した。

5.むすび

周辺が空気壁で構成された一次元空洞:dx・S の比電離電荷:q_n/dx が一様分布である場合が J_d/g の成立条件として40KVのナロービームX線とブロードビームX線のPMMA厚板ファントム吸収線量：D_dを測定した。その結果ナロー、ブロードの両ビームとも 一次元空洞の転換電子：e_Kと散乱電子：e_Sとの合成電子：e_{KS}が垂直方向と直角方向に特定分布を示すため一様分布に相当する修正を必要とした。垂直方向では空気飛程が3mm以下のe_{KS}の比電離電荷:q_{KS}/dxがJ_dに寄与するから$dx\to 0$の零外挿を必要とした。しかし零外挿のq_iは大きな統計誤差を含むからX線光子と空気の相互作用のe_{KS}による微分電離電荷:q_dで補償することを述べた。光子エネルギーが高くなると空気の相互作用が減少するのでq_d によるq_iの補償は不能であるから、これに替わる統計誤差の補償法が課題となっている。

直角方向はdxの零外挿と更に照射野立体角σ_n、σ_bの補正を必要とした。とくにブロードビームのσ_bが$K\sigma$=1.121を示した。この補正値の精度を実験的に確かめるため集電極直径が10.5mmの零外挿式電離箱のD_dと比較する準備を整ている。そして正規分布近似の方法としての信頼性は異なる$K\sigma$で補正された両方のD_dが一致する事で確立するであろう。

光子の質量エネルギー吸収係数から吸収線量の説明がなされているが、電

表3.Coleの空気とコロジオンに対する飛程とエネルギー損失の測定と計算の結果

電子エネルギー KeV	飛程(測定値) μm(単位密度)	飛程(計算値) μm(単位密度)	dE/dR(測定値) KeV/μm(単位密度)	dE/dX(計算値) KeV/μm(単位密度)	W値 KeV
0.02	0.00096		11		70.08
0.04	0.0026		14		67.82
0.06	0.0038		26		59.43
0.1	0.0054	0.0035	26	29.7	52.14
0.2	0.0094	0.0073	23	24.6	48.19
0.4	0.019	0.017	17	17.9	45.50
0.6	0.032	0.029	14.5	14.5	43.89
1.0	0.061	0.062	10.6	10.6	39.89
2.06	0.192	0.186	6.5	6.6	37.63
4.0	0.63	0.59	3.9	3.9	35.96
6.0	1.25	1.20	2.9	2.9	34.39
10.0	3.1	2.9	2.0	1.97	33.47
20.0	10.0	9.8	1.20	1.16	33.47
40	33.0	33.3	0.71	0.68	33.47
60	65.0	67.5	0.53	0.51	33.47
100		163		0.36	

子飛程の問題を扱わないので電離空洞でのエネルギー吸収の仕組みが解明しなかつた。この問題について電子衝突阻止能:S_{col} MeV cm^2g^{-1} と一次元空洞のq_n/dxの仕組みを下記で考察した。

表3.にCole[1.]が減圧電離箱と20eVから50KeVの単色電子エネルギービームを用いた空気とコロジオンに対する電子の飛程と損失の測定結果と、対応する計算値が示されている。ここには、電子エネルギー(E)KeVに対して飛程(R)をμm(単位密度)、dEをKeV、電子が通過した吸収体の厚さdRをμm当りで表した測定値と、dE/dXの計算値が記してあるが、dEはdRまたはdXで起きるエネルギー損失の平均値である。また、グラフ形式で報告した平均のW値を数値化して記載した。そして測定結果に対して、下記に示すEとRに関係する経験式は20eVから100KeVまでの範囲が概ね10%程度で一致したと報告されている。

$$E=5.9(R+0.007)^{0.565}-0.367$$
$$R=0.0431(E+0.367)^{1.77}-0.007$$
$$dE/dX=10.05(E+0.367)^{-0.771}$$

更にこの測定結果は他の理論計算[2.]とも比較されている。

電子衝突阻止能と一次元空洞:dE/dx・Sの比電離電荷:q_n/dxとの関係の考察をするため、図3.のd:70μmのK_{q1}をq_n/dxに仮定する。またdE(KeV)/dR(μm:単位密度)をdE(KeV)/dX(cm) ρ^{-1} ($1.293\cdot10^{-3}gcm^3$)$=S_{col}$MeV cm^2g^{-1}の空気等価に表示換算しておけば、最小dx=1mmは飛程1.293μmに相当するから表3.の電子エネルギーを6KeV、dE/dR は2.9KeV/μmまたはこのdE/dXρ^{-1} は29 MeV cm^2g^{-1} に近似できる。このq_P/dx が5.4pC/cm で零外挿値が6.18pC/cm であれば

$$29MeV\ cm^2g^{-1}\times5.4pC/cm\div6.18pC/cm=33.19MeV\ cm^2g^{-1}$$

になるからこの値に対応する電子エネルギーとしては表3.の4KeV、3.9KeV/μmの近傍値 5.2KeV、1μmに近似する。またW値を35.33eVに近似した6.18pC/cmの電子エネルギー損失は $5.49\cdot10^4$MeV g^{-1}であるから一次元空洞の単位面積当たりの電子飛程数:T_n

$$T_n=5.06\cdot10^4MeV\ g^{-1}\div\ 33.19\ MeV\ cm^2g^{-1}$$
$$=1.525\cdot10^3cm^{-2}$$

で表せる。従って一次元空洞:dx/S の吸収線量D_dはdx を変数とした電子の平均エネルギーdE/dXρ^{-1}と電子飛程数:T_nとの積が最大になる J_d/gである。しかしこの dE/dX$\rho^{-1}\cdot T_n$ は10KeV以下のW値の信頼性を今後の課題としている。

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3.15 APPLICATION OF RESEARCH REACTORS FOR RADIATION EDUCATION

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ABSTRACT

Nuclear research Reactors are, as well as being necessary for research purposes, indispensable educational tools for a country whose electric power resources are strongly dependent on nuclear energy. Both large and small research reactors are available, but small ones are highly useful from the viewpoint of radiation education. This paper offers a brief review of how small research reactors can, and must, be used for radiation education for high school students, college and graduate students, as well as for the public.

1. EDUCATIONAL RESEARCH REACTORS

Research reactors belonging to universities and colleges have been introduced for education as well as various research purposes. In the United States about 80 educational research reactors were built during the most prosperous period of the atomic energy development. This number has now decreased to less than half, mainly due to the weakening of government support. The beginning of atomic energy development in Japan was delayed about 10 years compared to the leading nations. Furthermore, as the nation that suffered the first atomic bombing, people felt ambivalent toward atomic energy development and the introduction of educational research reactors. Thus the number of the educational research reactors in Japan was limited from the beginning. Nowadays management is confronted with such inner difficulties as aging of facilities and of personnel.

The controversial use of educational research reactors, as is more or less the case in

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*Present address: College of Tourism, Rikkyo University many countries, is seriously questioned by people concerned with college education. Particularly in Japan, which must depend on a substantial fraction of electricity generated by nuclear power, educational research reactors are indispensable for education and for the development of advanced nuclear power technologies. The functions of educational research reactors can be summarized as follows:

1. Cultivation of professional nuclear engineers through college education
2. Education of college students outside nuclear engineering into neutron and nuclear physics, nuclear sciences, radio- and radiation sciences
3. Training and re-education of professional nuclear engineers
4. Education of the public for the understanding of reactors, radioactivity and radiation
5. Study of reactor design and reactor performance
6. Study and development of radioactivity measurements and neutron physics
7. Study of neutron reactions, including production of radioisotopes
8. Various utilization of neutrons for research and practical applications

In all these functions, the importance of the educational research of nuclear reactors lies in its ability to provide opportunities to experience real phenomena, or even accidental occurrences, which cannot be obtained from textbooks, simulators or firmly guarded, non-research orientated nuclear plants.

Watt class reactors are useful for education in nuclear physics, neutron measurements, and the training of reactor operation. 100kW class reactors usually have irradiation facilities, which are useful for radioisotope production. Direct educational use of reactors larger than 1MW is limited but, nevertheless, they are effectively used through research activities of post-graduate students.

2. RADIATION EDUCATION FOR COLLEGE STUDENTS AND TEACHERS USING RESEARCH REACTORS

Normally students enter college without much knowledge of radiation, or with a misguided understanding of the danger of nuclear energy. Students must be encouraged to explore this vital area open-mindedly.

1) Students in nuclear science and technology;

Needless to say, the knowledge of radiation is a professional necessity for this group of students. Commonly detailed educational courses on radiation are programmed both by lectures and by laboratory experiments. But normally little opportunity is given to students to spend time in a research reactor facility. On the average, these students spend less than 1 week at such a facility during their undergraduate years. It is necessary to give them more opportunity to work with research reactors.

2) Non-nuclear, science and engineering students

All the students of science and engineering should be educated to deal with radiation and radioisotopes properly. This appears to be completely ignored in Japanese colleges. It is not easy to establish programs in every faculty or department. A practical solution would be to make use of nearly research reactors. These students should be required to do an internship, several days in duration, at least one once during their undergraduate years.

3) Students in human sciences

Students in human sciences should also be given a reasonable education in the field of radiation. The invaluable experience of visiting a research reactor should be incorporated into their education requirements.

4) Professors

Many professors lack competency in the field of radiation and nuclear sciences. Any trial to educate students would not be very fruitful if educating professors is ignored. A countermeasure for this would be to plan a projective program for college professors. Junior and secondary high-school teachers may also be included in this plan.

5) Post-graduate students

Many post-graduate students in science and engineering are given frequent chances to visit nuclear or radiation facilities, nuclear reactors, accelerators, photon factories and so on, as a part of their research activities. Since the users are obligated to attend a special guidance course in radiation protection in many radiation facilities, radiation safety is firmly insured. But proper understanding of radiation treatment is not sufficient. For example, at many radiation facilities, both post-graduate students and the teachers think that radiation is dangerous entity that should be strictly avoided. Since such misconceptions cause inefficiency and unnecessary care and cost, a stronger effort should be made to reassure people of the safety of the safety of radiation research and useful recognition about radiation. It would be advisable to create professional course on radiation for this group of students.

3. RADIATION EDUCATION FOR HIGH SCHOOL STUDENTS

Students in junior and senior high schools are taught about “matter” through their study of physics and chemistry. It should not be difficult to make them understand that radiation or radioactivity is a particular activated state of a substance. For this purpose research reactors provide various, but most simple, nuclear reactions: degradation of neutron energy, nuclear reactions induced by neutrons, neutron absorption, nuclear fission, nuclear transformations and the production of radioisotopes. High school students need not understand the details of all these processes, but it would suffice for them to see these amazing natural phenomena during a half-day visit of a research reactor.

4. EDUCATIONAL ITEMS OF SMALL SCALE RESEARCH REACTORS IN CONJUNCTION WITH RADIATION

The characteristics of small research reactors (below ca 300 kW) in conjunction with radiation education are as follows:

(1) The reactor core can be observed during operation.

(2) Radioisotopes of various half-lives can be produced without the danger of excessive activity.

(3) Neutron beam is used easily and can be applied to neutron measurements and radiography.

Considering the above characteristics, the following educational subjects can be programmed.

1) For elementary school pupils

a) Cerenkov radiation

Cerenkov radiation is the light that is emitted when a charged particle, which in the case of reactors is the electron ejected by gamma-ray bombardment of water, passes through a substance with a velocity larger than that of photons in it. This light, being different from normal light emission in origin and mystically blue in color, is of intriguing scientific interest.

b) Radiation Level

There are various radiation levels around the reactor. Measurements and analysis of these radiation levels are useful for understanding the nature of radiation. It is also valuable to know the radiation level is not at a dangerous level in the reactor room even when the reactor in operation. Pupils must be given the chance to manipulate radiation detectors to experience radiation by themselves. It would be useful to compare the radiation level around the reactor site with that, for example, near their homes.

c) Radioactivity

Any material put into a reactor is activated normally. The activity can be measured immediately after irradiation, and on-site experience of how fast the activity decays and how a part of the activity remains a long time may be given. This must be presented together with a demonstration that the activity is not very dangerous when it is dealt with properly and carefully.

2) For high school students

The items described above should be included in the educational program of high school students, too. In addition, a more familiar and quantitative experience with radiation and activated substances must be given. Brief qualitative understanding of activity (dps), count rate (cps), fluence and exposure, absorption dose (Gy), and effective dose (Sv) may be given. The concept of "exposure" may also be taken up in conjunction with time, distance, and shielding. For this purpose demonstrational experiments of activation using reactors are highly educational.

3) For college students

The understandings expected for high school students as described above must be elevated to a more quantitative level. College students of science and engineering course must be able to calculate quantities related to radioactivity and radiation. College students of nuclear science must be able to calculate the stopping power of a substance toward ionizing radiation, attenuation, absorption doses, and shielding effects. This may well be done through designing their own experimental set-ups and/or conditions.

4) For the public

Education of the public is highly important at this time since radiation education for adults has been largely ignored. Because free access to reactor sites is usually forbidden to the general public at the present time, reactor facilities must be made more available to the public. A well conceived short course for teachers, from elementary school teachers to high school teachers, will also be important.

5. CONCLUSION

Although research reactors are highly useful for radiation education of people of various generations, they are not used to their full effectiveness. Many research reactors from time to time open their facilities for the public to visit, often with some exhibitions. This, however, is usually done on a voluntarily and irregular basis. Since research reactors are the educational property of society , they should be given proper support for their educational and research potential.

Recently, problems regarding the existing research reactors in Japan have become the focus of the attention. Some associations have started an urgent examination of management and operation of research reactors, aimed at promoting more extensive use of them. It is not without reason that the social movement for research reactors is in accordance with that of the radiation education.

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3.16 科学館における放射線関連の展示

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要旨

放射線教育における博物館の有効利用及びその推進を目的とし、関東・東北地方を中心に50館の博物館（PR館を含む）における放射線の展示を1996年4月から1998年11月にかけて調査した。調査内容は、放射線の展示（例えば、宇宙線の展示やX線の展示など）の有無と、その展示背景についてである。調査対象のうち、放射線についての展示がある館は30館、原子力についての展示がある館は25館、いずれかについての展示がある館は39館あった。私立の館については、電力会社関係の館が多かったため、ほとんどの館に放射線及び原子力に関する展示が存在した。スパークチェンバーは12館、霧箱は4館に存在し、両方とも存在する館は2館である。X線を実際に使用した展示は4館にあった。

放射線の展示の種類は決して十分とは言えず、内容にも大きな偏りが見られ、多くの館にあるものは「環境に少量の放射線と放射能が常に存在すること」についての展示であり、他の展示は少ない。全体的に放射線の展示は印象が薄くなりがちなハンズオフであったり、仕組みや原理がブラックボックス的であったりすることが多い。現在の博物館において、放射線教育の効果を考えた場合、展示が十分でないことから、成果が確認できない可能性が高い。博物館で放射線教育の効果を狙うためには、科学史的な観点から展示している館に対しては寄贈のシステムを整える、サイエンスセンター型の館に対してはハンズオンの展示の開発するなどの対策が考えられる。ハンズオンの展示として実際の測定の他、数種類の展示があるが、現在展示されていない放射線の他の面についても分かりやすくするための展示の工夫が必要である。

1．はじめに

放射線やラジオアイソトープは、理化学の研究の他、医療や工業・農業など広い分野で利用されている。また、原子力も総発電量の約35％を占めるにいたっている。これに対し、一般的な知識・教養として放射線は認識されておらず、そのうえ不正確な知識による誤解も多い。

現在、放射線・放射能教育について様々な教育普及活動を行っている団体は、学校における放射線教育が中心としているところが多いが、学校の範囲を超えた活動も不可欠であると考えられる。その理由の一つとして、仮に2000年に高校生への放射線教育を必修とした場合でも、この教育を受けた人が有権者として過半数を超えるためには30年以上かかるということがある（図１）。もう一

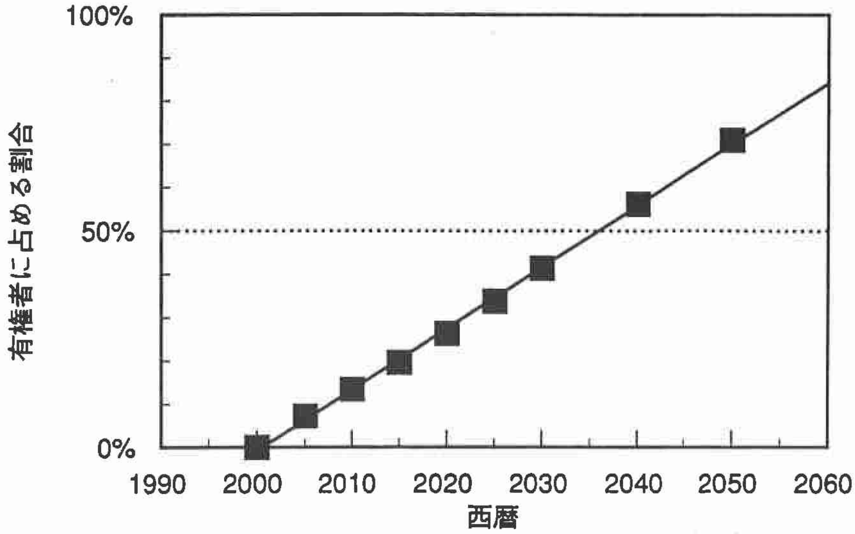

図１：全有権者に対する放射線教育を受けた人の割合
（2000年から放射線教育を義務づけた場合）
（高校進学率を100%、死亡率は変化しないと仮定し日本の統計[1]をもとに計算した）

つの理由としては、学校で獲得した知識は必ずしもそのまま保持されるわけではないため、卒業後に記憶の保持に対する何らかの補佐を行う必要があるということがある。

渡辺ら[2]の報告によれば、生徒が調査や自習を行う場合、博物館・展示館を利用すると答えた生徒はほぼ半数になる。卒業してもその傾向は続くと考えられ、博物館は教育の一端を担うと考えられる。成人は博物館で見た事実や知識をほとんど記憶していないということがいわれているが、想起法で自由に述べさせるといくつかの展示については覚えており、それは事前の知識と事後の経験により影響されるとされている[3]。そのため、博物館だけによる知識の普及は難しいものの、他のメディアや学校教育との供用により、博物館が放射線の新しい知識を提供することや、既に獲得した知識の保持の一端を担うこと、放射線に興味を持たせること（動機づけ）は可能である。

しかし、放射線に関して、博物館・展示館で何をどのように展示され、来館者にどのように利用されているのか分かっていないことが多い。

本調査では、放射線教育における博物館の有効利用及びその推進を目的として、東日本を中心に博物館における放射線の展示を調査した。

調査内容は松浦[4]の「最低限度必要な基本知識」を基準としたが、放射線についての知識は放射線そのものの知識のほかに利用についての知識もあることや、放射線への理解には、放射線の基本的な知識が必要であるが、その動機づ

けには「どのように利用されているか」ということの理解も必要であると考えられることからも、放射線の利用についても展示の調査を行った。

2. 調査内容及び方法

2.1. 調査対象

東日本を中心に、理工系の展示を持つ館及びPR館の中から50館選び、調査対象とした。調査は、1996年4月から1998年11月にかけて行った（表1）。

表1 今回見学を行った博物館・展示館の数

	国公立			法人	私立	合計
	国立	都道府県立	市町村立		企業	
館数	3	3	28	6	10	50

2.2. 調査方法

実際に見学を行い、実物展示を中心に展示内容の記録を取った。

その結果を元に、松浦[4]の「最低限度必要な基本知識」を基準に展示されている情報の有無をまとめた。また、放射線の利用等その他の知識についても傾向ごとにまとめた。尚、最低限度必要な基本知識（松浦[2]による）とは

1. 環境に少量の放射線と放射能が常に存在すること
2. 近くに放射線を放出する放射性物質が存在してもそれから安全に身を守ることができる3つの基本的方法（線源から距離を取って遠ざかる、線源と身体との間に遮蔽体を置く、線源から近い距離にいる時間を短くする）
3. すべての放射性物質が固有の半減期に従ってひとりでに消滅していく
4. 放射性物質が体内に入ったとき「生物学的半減期」により体内から排出される

である。

3 調査結果及び考察

今回調査を行った館のうち、放射線についての展示がある館は30館、原子力についての展示がある館は25館、いずれかについての展示がある館は39館あった。私立の館については、電力会社関係の館が多かったため、ほとんどの館に

表2-調査結果（抜粋）

	内容		展示物	国公立	法人	私立
基本的事項	環境に少量の放射線と放射能が常に存在すること		スパークチェンバー	8	2	2
			サンプル等の放射線の測定	0	3	3
			霧箱	1	2	1
	近くに放射線を放出する放射性物質が存在してもそれから安全に身を守ることができる3つの基本的方法	線源から距離を取って遠ざかる	アトムカー[a]	0	0	1
		線源と身体との間に遮蔽体を置く	アトムカー[a]	0	0	1
			放射線防護服[b]	1	0	1
			放射線の特徴[c]	0	2	0
		線源から近い距離にいる時間を短くする	無し（1館のみパネルで存在）	0	0 (1)	0
	全ての放射性物質が固有の半減期に従ってひとりでに消滅していく		無し（1館のみパネルで存在）	0	0 (1)	0
	放射性物質が体内に入った時「生物学的半減期」により体内から排出される。		無し	0	0	0
放射線の利用に関する展示	医学利用		X線によるレントゲン(hands onのみ)	3	1	0
			アトム号[d]	0	1	0
			器具の滅菌	0	1	0
			X線CT	0	0	1
	理工学的利用		コッククロフト・ウォルトン型加速器	1	0	0
			加速器の原理-コロガリトロン[e]	0	1	0
			蛍光X線分析装置、及びその実演[f]	1	0	0
			装飾品の着色／架橋・分解	0	1	1
			空港での荷物検査に用いられるX線	0	1	0

a)アトムカー（電車）を走らせて、駅に止めるというゲームであるが、アトムカーのジオラマの下にある検出器の放射線量をその検出器とそばにある放射線の線源の模型の距離をハンドルで調整したり、遮蔽体を置くことにより変化させ、それとともに速度を調整することができるようになっている。

b)放射線防護服-厚さ5cm分の鉛程度の防御ができると説明されているが、単なる衣服の機能を説明する例として取り上げているため、「何故この服は、放射線防護の機能を持つのか」ということに関して詳しい説明がない。

c) α 、 β 、 γ の線源と検出器の間に紙や、アクリル板、鉛等をおいて、どの程度遮蔽されるかを示す展示

d)映像に合わせて客席も揺れるようになっている装置。内容は「放医研のHIMAC」に関したものであり、自分が重粒子とともに行動し、ガン細胞を叩くという話になっている

e)レールの上の金属球を粒子に見立て、加速させるゲーム。レールには2個所の枠があり、枠の中を通過するタイミングに合わせてボタンを押すと電流が通り、加速できるようになっている。

f)蛍光X線分析装置-実物が存在し、原理をパネルや映像で説明するほかに、来館者が持ってきたものを実際に測定することができる（一日2回）

放射線及び原子力に関する展示が存在した。結果の一部を表2に示す。

3.1. 放射線に関する基本的な知識について

「環境に少量の放射線と放射能が常に存在すること」に関する展示の中で一番多いのはスパークチェンバーの展示である。私立の館の場合、原子力の展示とともに置かれている例が多いが、公立の館では宇宙線を「宇宙や自然を理解するための道具」として扱い宇宙や環境に関するコーナーに置かれていることが多い（表3）。また、オブジェとして出入り口近くに置いている館もあった。来館者はパネルをあまり読まないことや、物理的なコンテキストで展示物を理解することを考慮すると公立の館の配置で環境放射線が存在することを理解させることは、難しいと考えられる。

表3 実物展示の所在（展示物毎に）

展示物	展示場所	館数		
		公立	法人	私立
スパークチェンバー	宇宙	4	-	-
	原子力	-	1	4
	光	1	-	-
	環境	1	-	-
	（オブジェとして）	2	-	-
X線	光	3	-	-
	原子力・放射線	-	2	-

但し、「天文、宇宙、地球の科学」に対しては学習関心調査報告[5]から潜在的関心が他の科学分野よりも高いことから、「放射線についての知識があれば宇宙や天文への理解がより深まること」を示唆できればスパークチェンバーは放射線への理解のきっかけとして使うことができる。

また、宇宙の展示は入り口に近い所に置かれていることが多い（4館中3館）。このため、身体的にも疲労が少なく、心的飽和状態（展示物を見ることに飽きてくる状態）になっていないことから比較的じっくりと見てもらえる可能性が高い。さらに2館では展示会場が暗くなっており、解説が読みづらいという難はあるものの、光を放つスパークチェンバーは人の光指向から考えても注目度

が高いと考えられる。

しかし、今後の展示の傾向を考えると、ハンズオフの展示は好まれない傾向があるため、ほとんどがハンズオフの展示であるスパークチェンバーは、展示が敬遠される可能性もある。公立の館の中には、スパークチェンバーの一部に空間をつくり、その中に手を入れることにより宇宙線が体を透過することを理解させるという工夫をし、ハンズオンに近い展示を行っている館もある。また、スパークチェンバーの持つ芸術性を高めるため、鏡やスライドを組み合わせて独特の雰囲気を作っている館もある。

自然の中にある物質を実際に検出器を用いて測定させるという展示は電力関係のPR館に多く公立の館ではあまり見られなかった。測定させるものとして「コンブ」「湯の花」「肥料」「土」等が一般的に用いられており、館による変化があまり見られない。この展示は、ハンズオンであるが、変化に乏しいため注目を高めさせるための工夫も必要である。また、検出器はある意味でBlack Boxであるため、この仕組みでなぜ放射線が測定できるのか理解させる展示も今後開発する必要がでてくるであろう。

自然史の科学館では放射線を出す鉱石として検出器を近付けて音の変化を見せている館もある。この場合は、「そんな性質をもつ石がある」というのを見せているだけなので放射線に関する教育効果は期待できない。

「線源から距離を取って遠ざかる」には線源と検出器の距離を離させることにより、線量が次第に低下していくのを確認させているものがある。「線源と身体との間に遮蔽体を置く」では、「遮蔽体について展示」や「放射線防護服」の展示がある。遮蔽体については線源と検出器との間に遮蔽体を挿入させ、計測器のメーターが下がるのを確認させる展示が多い。実際に遮るものとしては紙、アルミ、ガラス、鉛、コンクリート等から幾つかが選ばれている。放射線防護服を展示するのは、放射線防護の理由を認識しづらいが防護服が普段見ることができない変わったものであるため関心を引きやすいと考えられる。

それらに対し「線源から近い距離にいる時間を短くする」に関しては展示がほとんど無かった。同様に、「半減期」、「内部照射」についての展示もほとんど無かった。視覚化し、なおかつ来館者の興味を引くようにすることは難しいためであると考えられる。

以上のことから、放射線についての展示はあるものの、松浦の「必要な知識」から考察すると、内容に大きな偏りがあるといえる。また、全体を通してみても、放射線は実際に見ることができないこともあり、展示物の仕組みや原理が

ブラックボックス的なものが多い。現在の博物館において、放射線教育の効果を考えた場合、展示が十分でないことから、成果が確認できない可能性が高い。

3.2. 放射線の利用

「博物館」は本来ものを収集し、研究し、展示し、保管するということを目的としている。この目的に沿った館では、収集や展示を行いやすい利用についての知識のほうが展示されやすいと考えられる。

X線は検診などのようにかなり身近なものとして利用されているが、X線についての展示は私立の電力関係の館ではほとんど見られなかった（表3）。公立の館の中にはX線の医学利用を豊富な写真を用いて、有益性を紹介しているところもある。

X線の展示は実際に持参したものを透過させて見ることができるハンズオンの展示として良く使われている。レントゲン撮影をはじめとして割合と身近でよく知られているものの解説のため、どの館でも興味を持って接している子供が良く見られた。

今後、ガン治療をはじめとする医学での放射線利用はますます増えると考えられるうえ、インフォームド・コンセントが重視される中、放射線の医学利用の知識の提供は必要になると考えられる。また、X線の他に加速器や、蛍光X線装置（化学分析の一例として）を展示している館もある。これらの展示には放射線の性質そのものよりもどのような原理で行われるのかや、どのような成果を挙げられるかについてパネルなどで説明されている。

現在のバイオテクノロジーの基礎となる部分は、トレーサー利用により解明された部分も多く、また、X線によるタンパク質や核酸の結晶解析も様々な役割を果たしているが、生物学への応用に関する展示は少ない。また、厚さ計、着色等のように工業的な利用例も、多いとは言えない。科学技術の発展に対する放射線の貢献についての展示は功績に比べて少なすぎるといえる。

3.3. 博物館に放射線の展示を受け入れてもらうためには

現在のところ放射線を展示するということは科学館に必ずしも要求とされているわけではない。そのため、科学館が受け入れやすいような体制を作っていく必要がある。

新規に建設される館や展示替えをしている館では良い展示方法があれば受け入れられやすい。例えばエクスプロラトリアムの展示方法はハンズ・オンの展

示があるほとんどの館で、「調和水槽」等も、環境に関する展示を最近開始した所では必ずといっていいほど置かれている。また、サイエンスセンター型[6]の科学館が増えることにより、ハンズ・オフの展示より、ハンズ・オンの展示が増加が考えられる。このようなことを考慮すると、放射線の新しい展示方法（できうるかぎり五感を使う参加型、またはオブジェとしての使用に堪えられるような芸術性の高いもの）を開発する必要もあると思われる。

館の数は少ないが、科学史の展示も行っている館もある。このような館では、収集資料の質や量が展示の質も決めてしまうため、大学や研究所で放射線に関する実験器具で不要になったものを寄贈しやすいようにする等の体制を整える必要がある。

なお本調査は私的に実施したものである。

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3.17 "RADIATION FAIR" FOR 15 YEARS IN OSAKA, JAPAN, AND SURVEY OF THE PARTICIPANTS' ATTITUDE TOWARD RADIATION

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ABSTRACT

We have been successfully operating "Radiation Fair -- The relationship between daily life and radiation --" during summer vacation season in August every year for 15 years in Osaka, the largest city of western Japan. The purpose of this event is radiation education of public including school kids through efficient information transfer of radiation and radiation-related technology. Currently we set up the space of it on a floor of Kintetsu Department Store, one of the major department stores in downtown Osaka and display various irradiated products available in our daily life together with explanatory panels. We have been devising various attractions as efficient information transfer media so that even elementary-school kids understand the basic knowledge of radiation and irradiation technologies. The number of participants has increased year by year until more than 20,000 in recent years. We distributed questionnaires to the visitors for recent 3 years to inquire their status toward radiation and irradiated products as well as impression toward the displays. The survey results suggest that school education may contribute to establish the public image toward "radiation" as well as mass media.

1. INTRODUCTION

Although radiations, which always exist in our environment, are utilized in various fields of our daily life, it is hard to say that they are well understood. In order to find a way out of such a situation, information transfer activities have become more important. In case of food irradiation, for example, test marketing has been successful in gaining efficient information transfer to those who have little knowledge specialized for radiation and radiation-related technology. As a result, in a large survey of over 1,000 people in the United States, the Gallop organization determined that 73% have heard something about food irradiation; and 24% have some knowledge of the food irradiation process. 54% stated that they would be likely to purchase irradiated foods over non-irradiated foods when they learned of the benefits and organizations that endorse the process[1]. We have been held "RADIATION FAIR, -- The relationship between daily life and radiation --" for 15 years in Osaka, the largest city of western Japan, for the purpose of public education and information transfer of radiation, radioisotopes, and radiation-related technology to citizens including school kids. We have also been conducting a questionnaire study toward the visitor of the Fair for 3 years to inquire public knowledge and feeling toward radiation and irradiation technology as well as the impression of this event. knowledge of them

In this paper, we introduce the outline of our activity and the survey results of the feeling toward radiation and the route of cognition of the word, "radiation".

2. OUTLINE OF "RADIATION FAIR"

We organize the Executive Committee for "relationship between radiation and our daily life" with other associations supporting and promoting the use of radioisotopes, irradiation technologies, and atomic energies in Osaka area. They are Osaka Nuclear Sciences Association, Inc., Japan Radioisotope Association, Inc., Japan Atomic Industrial Forum, Inc., Association of Radiation Engineers in Osaka Prefecture, Inc., Atomic Energy Society of Japan, Inc., Electron Sciences Research Institute, Japan Atomic Energy Relations Organization, Japan Atomic Energy Research Institute, and us. We have been holding "RADIATION FAIR, the exhibition of radiations related with our daily life" annually in summer vacation season for 15 years. The scale of the exhibition expanded year by year until 1990. Since then, we have been set up the space on a floor of Kintetsu Department Store, one of the major department stores in downtown Osaka (*see* Photo).

Various "irradiation-treated" products available in our daily life have been displayed, including irradiated potatoes, EB-treated Styrofoam products, tires, golf balls, etc. together with explanatory panels. We have been devising efficient information transfer media, such as games, quizzes, street performances, and handicrafts as well as explanatory panels so that even elementary-school kids can understand the basic knowledge of radiation and irradiation technologies. We invite professional actors and street performers playing characters of famous historic radiation scientist providing science quizzes related to radiation sciences and games and acrobatics using irradiated products. We have also provided "Experience corner" where the participants could experience the existence of the radiation through observation of cosmic rays by a cloud chamber and radiation measurement of soils and stones. Free medical clinic and bone densitometry service has provided for adult visitors (*see* Photo). The number of participants has increased year by year until more than 20,000 in recent years (*see* Fig. 1).

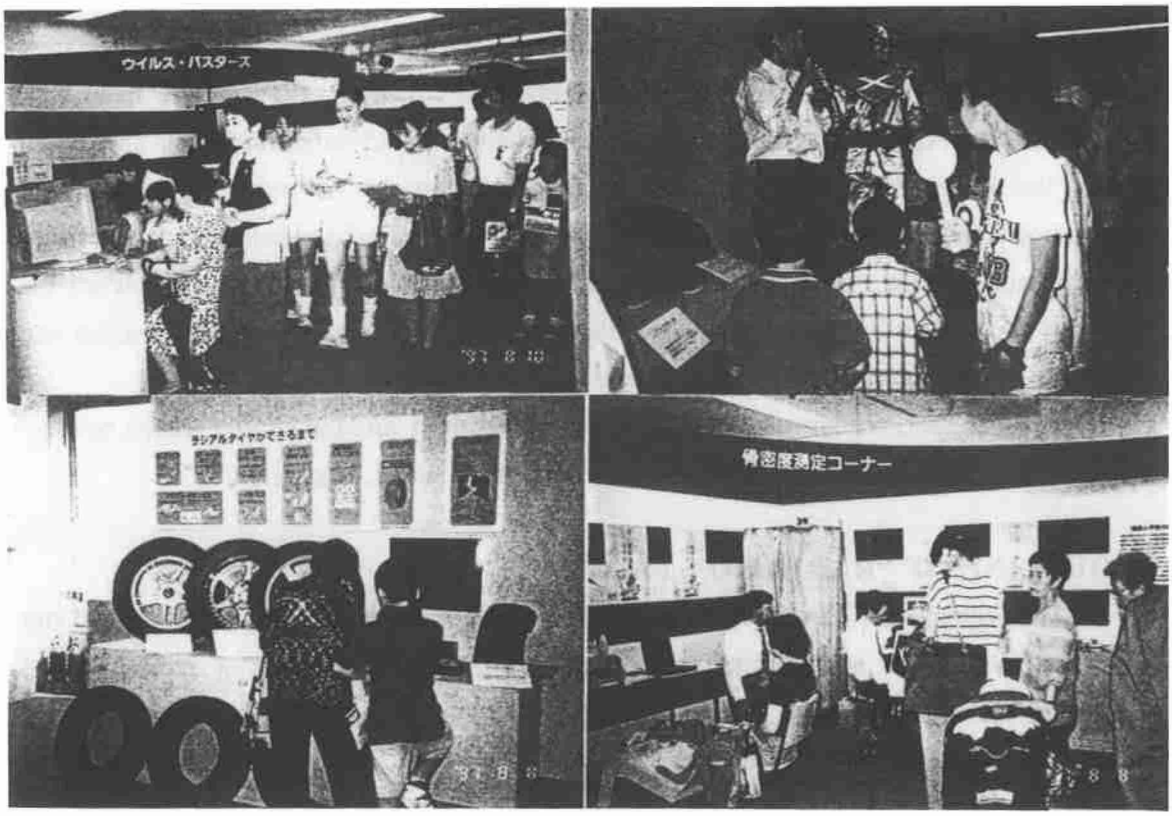

Photo: Various events at "Radiation Fair" on the floor of Kintetsu Department Store in Downtown Osaka.

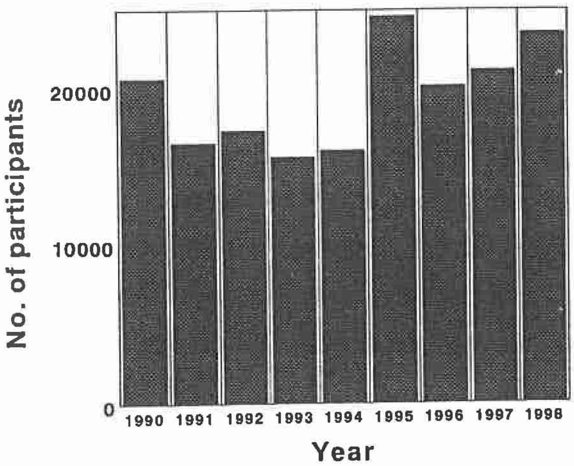

Fig. 1. The increase of participants in the "Radiation Fair".

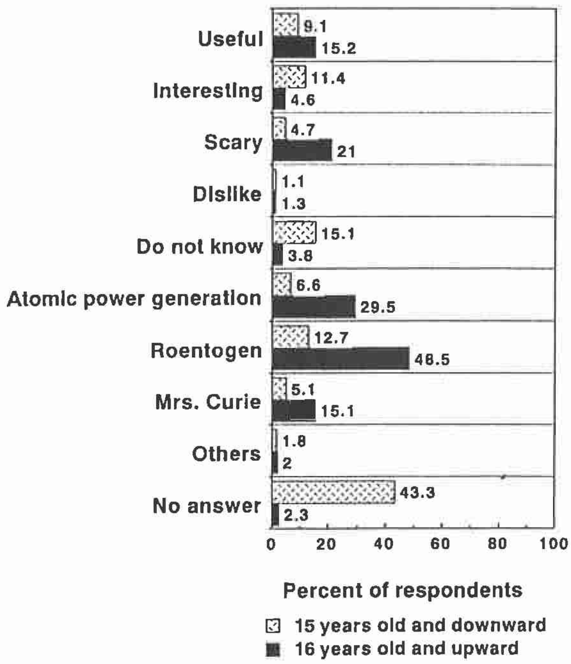

Fig. 2. Closest Images associated with "radiation".

3. QUESTIONNAIRE PROCEDURES

We designed two questionnaires for kids (under 16 years old) and grown-ups (16 years and upward), separately. The both ones contain questions about the knowledge of radiations and the impression toward the various activities of our event. as well as the demographic questions, such as sex, age, companions, and information source of the Fair. We added detail questions about the time and place of recognition of the word "radiation" together with knowledge of natural radiations and irradiated products including irradiated potatoes and other food safety issues to the questionnaire intended for the grown-ups. We distributed the questionnaire sheets to the visitors at the entrance and collected the answered sheets at the "Questionnaire collecting corner" beside the exit.

4. QUESTIONNAIRE RESULTS

We obtained 3568, 2136, and 2320 answers in 1996, 1997, and 1998 surveys, respectively. Most kid visitors were accompanied by their mothers. More than 50% of the visitors occasionally recognized this event when they stopped at the department store . Each survey revealed that the ratio of visitors who had heard something about radiation increased with increasing age and reached over 90% at junior high school ages (13-15 years old).

In 1996 survey, "Roentgen" standing for X-ray radiography in Japan, and "atomic power generation" were the closest words associated with "radiation" chosen by grown-up participants. In contrast, more than 40% of kid participants chose "no answer". Interestingly, the ratio of "scary" chosen by grown-ups as the closest word with "radiation is approximately 4 times higher than kids (*see* Fig. 2). Fifty six point nine percent and 37.7% of the grown-up participants indicated "rather bad" image of "radiation" in 1997 and 1998 surveys, respectively, when they heard of the word (*see* Fig. 4). These ratios were the largest among the 5 choices including "very good", "rather good", "average", "rather bad, and "very bad" in each survey. The ratio (59.6%) of the answers, either "rather bad", "bad", or "very bad" from the grown-up participants for the image of the 1st encounter of the word "radiation" became approximately 4 times as much as those from kid participants. Fortunately half of the participants answered that the image became better after their first encounter with "radiaiton". More than 70% of the kid participant answered that they understand the "radiation" after browsing the Fair. The same ratio of the grown-up participants also noted that their visit of "Radiation Fair" was a good chance of improvement of their image toward radiation, indicating that our event is effective for public acceptance of radiations and radiation-related technology.

1996 survey for grown-up visitors also revealed that 59.1% of participants recognized the word of "radiation" when they were at elementary school and the most significant sources of this information were school lessons and mass media (*see* Fig. 3). 1997 and 1998 surveys also indicated similar results.

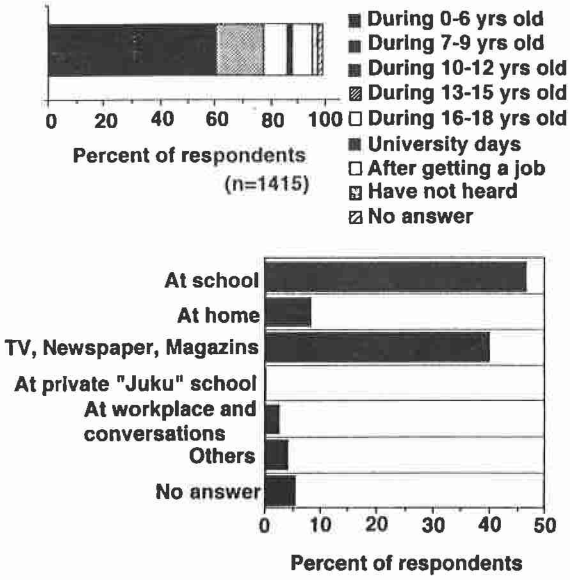

Fig. 3. Distribution of the recognition time (Top) and sources (Bottom) of "radiation"by 16-year old and upward participants.

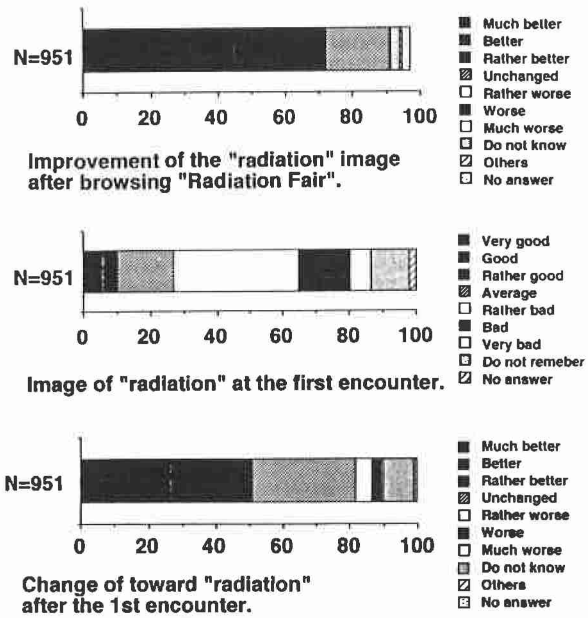

Fig. 4. Difference of the image toward "radiation" before and after the visit of the "Radiation Fair"

5. DISCUSSIONS

These survey results indicated that worse images toward radiation would be formed after junior high school days while the word, "radiation" is initially recognized during elementary school days according to Figs 2 and 4. "Radiation fair" was shown to be very helpful not only as an introduction of radiation science and radiation-related technology to elementary school kids but also as an media to improve the image of radiation and atomic power-related technology toward older people. From these viewpoints, if we transfer the correct information about radiation sciences and technology at the right stage of education, we could improve consumer's image toward radiation.

The survey results also showed that school education is an important recognition route of the word, "radiation" as well as the mass media. Therefore, we should watch the school curriculum. Although several radiation- and atomic power-related topics are appeared in authorized textbooks including science and social studies for school education in Japan, many mistakes have been pointed out in the context of the description of each topic by several radiation scientists groups. Thus we should check the current teaching materials and plans in order to make radiation-related information transfer in school more effective. To do this, we are planning more detailed survey to reveal actual status of "radiation education" at school and food irradiation among consumers.

ACKNOWLEDGMENT

We thank the members of the specialized subcommittee of "Relationship between radiation and our daily life" Executive Committee for valuable discussions to develop the questionnaire. We also thank I &S Inc. for technical assistance.

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3.18 IONIZING RADIATION – ONE OF THE MOST IMPORTANT LINK OF THE ENERGETIC CHAIN IN BIOLOGICAL CELL

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ABSTRACT

High (large) and low (small) doses of ionizing radiation consistently induce opposite physiologic effects in biological systems. The effects of low doses cannot be inferred by interpolation between the result from groups exposed to high doses and controls irradiated only by Natural Background Radiation. Stimulation („bio-positive") effects by low-level doses of ionizing radiation are called radiation hormesis. It is still controversial idea, however it was found that some biological objects (yeast, seeds, animals) after gamma irradiation by low-level doses (10-50 times more NBR) can increase their development.

The result of present researches demonstrate that the excitation of living system by gamma quanta (high energy) initiates prolonged secondary emission that influences biota and activates many important processes in biological systems. According to the excitation theory of bio-molecules the author suggests that gamma irradiation in low-level doses excites such molecules as DNA and proteins, and this being followed by a long-termed secondary coherent radiation. The spectral analysis of this secondary emission confirmed the contribution of the UV component to the total emission.

The data obtaining by using SPC method (single photon counting) make possible a partial understanding of the radiation hormesis phenomenon and suggest closer relationship to UV emission from biological systems during mitotic processes.

The experiments with humic acid (high doses) and glycine (low doses) confirm the author hypothesis that gamma-irradiated organic compounds are capable to emit secondary radiation This secondary radiation probably plays very significant role in the intercellular communication inside the living systems.

In conclusion the author proposed de-excitation processes in bio-molecules as a common denominator of UV and ionizing radiation interacting with living cells.

Finally he refers to the Cerenkov radiation which is created inside the biological cells. Because the Cerenkov radiation is totally absorbed, consequently these photons must be play very important part in energetic balance in living organism. The author expects that Cerenkov radiation may converse - like ionizing radiation - into UV photons and effects as a "bio-positive" factor (Cerenkov Hormesis).

1.INTRODUCTION

A great deal of scientific researches confirmed that high and low doses of IR consistently induce opposite physiologic effects in biological systems. Stimulation (bio-positive effect) by low-level doses of any agent is called **hormesis**. Luckey[1,2] in his works transferred this notation to IR and defined radiation hormesis (RH) as a bio-positive effect of low-level doses of IR. What does it mean low-level dose of IR? This dose is defined as a value from of more than ten times of Natural Background Radiation (NBR) to 1/100 LD (lethal dose); i.e.40-50 mGy.

The data show increased or accelerated respiration, germination, growth, development and maturation, reproduction, resistance to disease and sub-sequent irradiation and average longevity. Under the irradiation of gamma rays the increasing of mitosis index is observed.

Hormesis evokes increased vigor and strength in individuals subjected to sub-optimum conditions[1,2,3].
The hormetic dose varies with subject, conditions, physiologic function measured, dose rate and total exposure. The type of radiation seems to be less important than the rate at which it is administrated. Next, the dose rate is probably more significant than the total dose in radiation damages. The same total dose irradiated in long or short time effects differently in living organisms.
RH following whole-body irradiation was established in animals for growth and development, fecundity, immune competence, decrease mortality rates from infection and average life span. RH is regularly noted in independent microbes such as bacteria, yeast and algae. RH is found in plants and both vertebrate and invertebrate animals[3].
Whole-body human exposure to low-level doses of IR consistently results in decreased cancer death rates[1,2].
Man appears to be one of the most radiosensitive species. The magnitude of LD_{50}^{30} for man equals to about 2.6 Sv and this value is at least one order of magnitude smaller than the corresponding value for other living organisms Tab.1. We can realistically estimated total dose, which a man is exposed to equals about 1 mGy/y. But there are some regions of the Earth, where the NBR is much higher than so-called normal level. For example: in Brazil, beaches of Guarapari - 263 mGy/y, Guapara 10-18 mGy/y and Apaxi 35 mGy/y; Iran, Ramasari 7-480 mGy/y; India - Kerela coast - 4-23 mGy/y; several thousand people in Espirito Santos - 30 mGy/y; Caucasus and Himalayan mountaineers - 35 mGy/y – Tab.2[2].

Subject	Sv
Man	2.5-3.0
Dog	2.6
Monkey	5.0
Rat	8.0
Fish	8.5
Chicken	10
Bat	150
Snail	200
Snake	800
Wasp	1000
Ameba	1000
virus	5000

Tab.1.

Place	[mGy/y]
United States	2.6
Nile Delta	3.5
Exposed workers	3.6
Jet air flyers	5.0
Kerala, India	4-23
Guapara, Brazil	10-18
Apaxi, Brazil	35
Optimum	100
Ramasari, Iran	243
Guarapari, Brazil	263
Maximum safe level	10000
Proposed person allowance	5.0

Tab.2.

People from Nagasaki or Hiroshima who during A-bomb explosion received doses of 60 to 700 mGy appear to live longer than those who received either higher dose or none[1,2].

Till 1990 the information about RH in scientific literature had only little meaning however a great deal of data shown that high and low-level doses induced opposite results in microbes, plants, a variety of invertebrates and many mammals, including humans. The effects of low-level doses cannot be inferred by interpolation between the result from samples exposed to high doses and controls irradiated only by NBR.
The development of A-bombs and political situation in the World ("cold war", existing of two opposite political and military systems) led to extensive researches only on the damaging effects of high-level doses and forced the concept that all doses of IR are harmful. Harm

dominated the last half-century of radiobiological research. Even today RH hypothesis is still controversial.

2.IR AND SECONDARY UV - TWO LINKS OF THE SAME ENERGETIC CHAIN

In my opinion there is close relationship between IR and secondary UV emission from the cell. I postulate the above hypothesis based on the principal biological fact - the process of cell division (mitosis) is conditioned by two factors, namely: by metabolic processes which lead cells to dividing stand-by, and by "impulse" (stimulant) which starts division, proliferation and mitosis processes[4,5].

I suggest that the IR can create this so-called „starting impulse". Even low intensity of short electromagnetic waves (180-220 nm) or a few quanta can start mitosis. On the other hand under the irradiation of gamma rays the increasing of mitosis index is observed[6,7].

2.a. PROBABLE SOURCE OF PHOTON EMISSION FROM THE CELL

Konev[8,9] has carried out the pioneering work on photon emission and cell cycle. He was the first to employ the UV sensitive photomultiplier tube to detect UV photon emission from living organisms, using synchronized cultures of *Candida utilis*. Spectral analysis indicated that the wavelength range was 250-380 nm. The most extensive investigations on photon emission in the cell have been performed in meiosis during pollen grain formation in the anther of *Larix europea*[10] and in mitosis of yeast *Saccharomyces cerevisiae*[11].

First a biochemical reaction has been looked for that is based on a physiological process of general nature. Mainly Russian[12] investigators have been successful in finding some distinct correlation between low level luminescence and radical reactivity, originating essentially from lipoxygenaese reaction.

Guided by the photon storage hypothesis, Popp[13] suggested that only DNA can work as the coherent biological photon store. In order to examine whether DNA really works as a photon store[15] performed a basic experiment by using ethidium bromide as a probe. At least Van Wijk[15] experiments have confirmed that a considerable part of biological photon emission originates from DNA.

Li and Popp[16] have proposed a physical explanation of photon storage of DNA on a molecular level, but only a very general approach to the mechanism has been suggested. They postulated that exciplex (exciton-) states of the DNA base pairs are responsible for this effect.

In the latter experiments, photon emission was measured as a function of the cell-division cycle. The research has shown that photon emission - for instance - in yeast follows a characteristic pattern in the course of the cell-division cycle, increasing in the late S phase to the G2 phase[11,17]. The estimated photon spectrum is continuous, with maximum in the UV and blue region.

The source from which the emission from yeast originates is not known. It has been suggested that the UV component arise from excited tryptophan[18,19] . I have tried irradiated this compound but till now with repulse. Exciting tryptophan by ionizing radiation is difficult.

2.b. CERENKOV RADIATION – CERENKOV HORMESIS CH

It is well known that all living systems contain some natural radioisotopes and all are under the constant cosmic ray irradiation. Any charged particle that moves at a velocity higher than the phase velocity of light in a medium produces Cerenkov radiation. Quickenden[20] reported that the exposure of pure water to cosmic or NBR (for example -^{14}C,^{32}P,^{40}K) leads to the excitation of UV and visible emission in addition to Cerenkov radiation. The excitation of bacterial and yeast suspensions by the Cerenkov rays from ^{32}P results in fluorescence with a spectral distribution similar to that of MR. Barenboim and Domanski[21,22] have studied such important molecules as tryptophan, lysozyme, DNA and RNA and have found that these compounds are similarly excited by ^{32}P and ^{40}K to produce their characteristic fluorescence. Because Cerenkov radiation is totally absorbed inside cells, consequently these photons must play very important part in energetic balance in living organism.

3.EXPERIMENTS AND RESULTS

As we know from radiation chemistry the formation of H_2 and H_2O_2 are equally possible in aqueous solutions irradiated by ionizing radiation. The primary ionization of the water molecule is followed by the recombination and fast dissociation: $H_2O \rightarrow H_2O^+ + e^- \rightarrow H_2O^\bullet$. Part of the excited water molecules dissociates into radicals: $H_2O^\bullet \rightarrow H^\bullet + OH^\bullet$. Molecular products form through the recombination radicals: $H^\bullet + H^\bullet \rightarrow H_2$ and $HO^\bullet + OH^\bullet \rightarrow H_2O_2$. The above combination processes take place at the beginning of the life the clouds when the local radical concentrations are still high.

Therefore, when the water solution was irradiated, as the product of radiolisis some concentration of hydrogen peroxide has been received. This chemically aggressive compound effects on another bio-important compounds.

3.a. EXPERIMENTS WITH GLYCINE

I took into consideration glycine - the simplest amino acid (endogennic), an element of proteins. The influence of hydrogen peroxide on glycine has been examine. Hydrogen peroxide produced may in turn continue oxidation:

$$H_2NCHR - COOH \xrightarrow{H_2O_2, NH_3} O = CR - COOH + h\nu$$

During this process some secondary emission has been detected (Figure 1). The fact that quartz rather than glass permeable for this radiation indicates that the latter emission belongs to the UV range of spectrum. It was interesting to investigate for how long time it is possible to reveal this secondary radiation. The results presented in Figure 2 show that the effect was quite high within 20-30 minutes for the beginning of the experiment (after adding NH_3). Then it decreased by the next 1 hour (23).

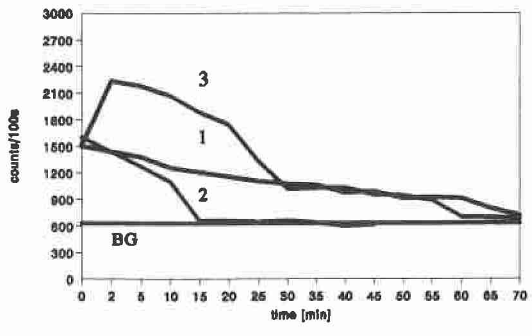

Fig.1. Secondary emission from Gly (different ammonia concentration)
1:Gly-0.87M,hyd.per-0.7M,amm-0.7M
2:Gly-0.87M,hyd.per-1.125M,amm-0.875M
3:Gly-0.9M,hyd.per-0.9M,amm-0.7M

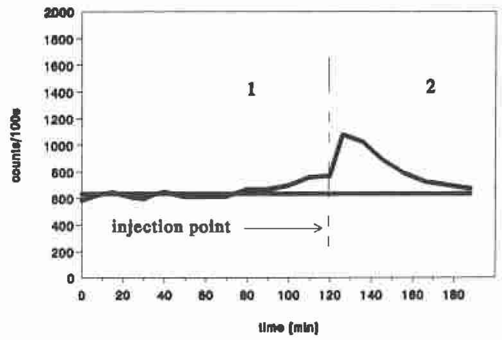

Fig.2. Gly emission as a function of Ammonia concentration.
1:Gly-0.87M,hyd.per-0.7M,amm-0.35M
2:Gly-0.8M,hyd.per-0.67M,amm-0.67M

If water solution of glycine was irradiated by gamma rays we received the following :

$$\gamma + H_2NCHR - COOH \xrightarrow{H_2O, NH_3} O = CR - COOH + h\nu$$

I conclude that this UV quantum is nothing else as the hypothetical Gurwitsch mitogenetic radiation.

3.b. EXPERIMENTS WITH HUMIC ACID

Humic substances (HS) belong to the most widespread biopolymers. However exact structure of HS is unknown it suggests that these compounds could be treated as a rich source of energy, carbon and nitrogen for soil microorganisms. From the energy point of view, the transformation process of plants' or animals' materials into humic substances, is exergonic one. The degradation of humic acids (HA) by ionizing radiation (IR) influence certain physical and chemical properties of soil and aquatic environment..

As the consequence of HA' degradation the following processes are observed:

- direct stimulation or inhibition of soil's and plants' microorganisms by products of HA degradation;
- influence on the soil structure through changing sorptive, chelate, oxido-reduction properties and organic substance mineralization;
- sensibilized degradation and activation of organic compounds contained in superficial soil layer (especially pesticides).

Ionizing radiation in biopolimers is known to cause the following chemical processes:

- chemical compounds decomposition (for example : di-sulfide, hydrogen and peptide, deamination and decarboxylation), which caused biopolimers degradation;
- creation of non-specific chemical bounds in biopolimers (covalence, hydrogen, ionic) which caused polymerization and aggregation of molecules and incorporation of atoms and small molecules;
- other modification of aminoacids residuum (changing electrical charge, for example).

On the other hand the specified chemical changing can create next changes of physical and chemical properties, such as: spectral characteristics, viscosity, constant of sedimentation, molecular mass, isotopic exchange ability and so on.

More often biological influence of IR is indirect, based on the secondary ionization (it refers to hydrated habitats generally).

Because processes of the oxidative degradation are exergonic, we can experimentally observe some energetical stages, which conditioned creation of excited molecules. As the consequence chemiluminescence (CL) emission is measured.

In my experiments HA (SERVA) has been examined. The solution of HA (200 mg HA in 1000 cm^3 of 0.1 N Na_2CO_3) was irradiated in Russian RChM-gamma-20 (Co-60) equipment in the following absorbed doses (1 kGy, 2 kGy, 5 kGy, 19 kGy, 40 kGy, 50 kGy, 60 kGy and 90 kGy) has been.

RESULTS

After absorption of high doses of IR by HA some degradation processes have been observed. The secondary chemiluminescence accompanied to this process. Only HA in a dried HA form irradiated was even at 90 kGy stable,. After irradiation HA changed its color from dark-brown to straw-colored. For higher absorbed dose the effect of colors' changing was more visible (described by the absorbancy or transmittance, at $\lambda = 254$ nm) and the intensity of CL is higher. Furthermore, relation between intensity of chemiluminescence and absorbed dose rate (Fig.3) and between transmittance and absorbed dose rate (Fig.4) has been found.

CONCLUSIONS

All experiments leads to the following conclusions – after the process of HA irradiation in high doses we observed :

- oxidative degradation; it caused creation of low molecular products with increased amount of COOH, i.e. class of fulvic acids;
- polymerization of HA and its fragments caused creation of high molecular products (humins).

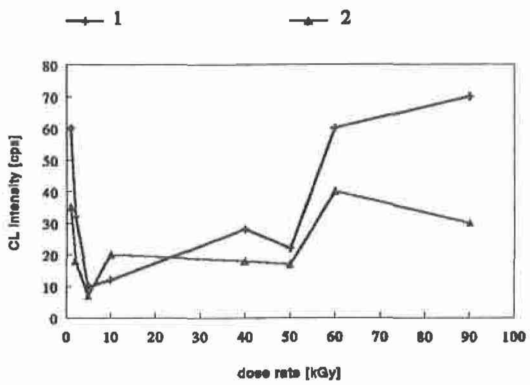

Fig.3.Intensity of chemiluminescence and absorbed dose rate of gamma irradiation ^{60}Co (1-immediate measurement,2-delayed 40min)

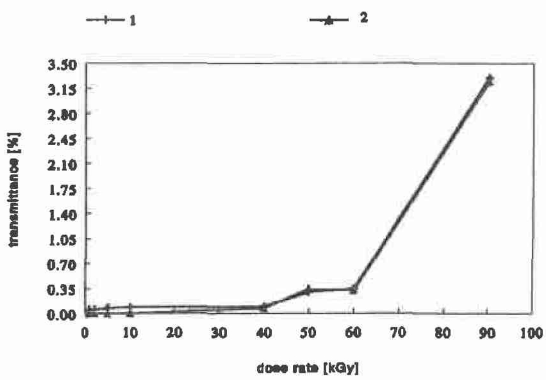

Fig.4 Relations between transmittance and absorbed dose rate gamma irradiation ^{60}Co for λ =254 nm (1-immediate measurement,2-delayed 40min)

For the absorbed dose higher than 50 kGy the process of HA radio-degradation was strongest.

There is almost no published research on the influence of ionizing radiation on HS. What would be the fate of this the most important and vital component of soils and waters in the case of an nuclear accident?

4.a. HOW TO EXPLAIN CREATION OF SECONDARY UV EMISSION AFTER IRRADIATION OF IR?

If we irradiate some living objects with low doses of IR macromolecules of DNA, RNA, proteins will probably turn to excited states. As a result of these processes the polaritons are created. Polaritons create the subsequent coherent emission from DNA. This secondary radiation (the so-called DNA fluorescence) has much longer wavelength than primary radiation, which excited DNA molecules. This secondary radiation with a wavelength in UV region is analogous to postulate by Gurwitsch mitogenetic radiation MR.

Therefore, I deduce that IR can create secondary UV. On the other hand, only IR without excessive reduction can penetrate a deep region of a microorganism, because UV is easily absorbed by biological tissue.

4.b. MEDICAL ASPECT OF RADIATION HORMESIS RH AND CERENKOV HORMESIS CH.

We know epidemiological evidence which showing that human cancer mortality rates are lower in areas of high NBR than in low-level radiation regions. Some physicians postulated that low-level doses of whole-body irradiation may reduce cancer induction - see UNSCEAR 1994 Report[24]. This hormetic phenomenon appears in this respect as a possible new method of therapy. Maybe in the near future we will irradiate our children like now we are inoculating them. It is surprising proposal but if we remember how vaccine works in human organism we understand easily the idea of hormetic therapy. ***Based on the experiments and epidemiological evidences the following doses are recommended: 20 mGy/y for selected organs and 100 mGy/y for whole-body chronicle irradiation.***

As I mentioned before Cerenkov radiation is totally absorbed inside cells. Consequently these photons must be play very important part in energetic balance in living organism.

I postulate that Cerenkov radiation may converse - like IR - into UV photons. In my opinion this is very important problem because the simple calculation shown that for ^{40}K about 10 Cerenkov photons will be created during 1 second in 1mm of water's layer. Consequently for adult (70 kg) we should measure more than 10^8 Cerenkov photons per 1 sec. For phosphorus ^{32}P and carbon ^{14}C less but still very high number - Tab.3.

Element	Atom's number	Disintegration/sec
T-3	$1.7*10^9$	3
C-14	$8.1*10^{14}$	$3.1*10^3$
K-40	$1.2*10^{21}$	$4*10^7$

Tab.3

I think research on the influence of Cerenkov or natural background radiation on living systems should be advanced. Maybe this is among the other important factors not only in the evolution of biological systems but in the creation of Earth's life in general.

I proposed deexcitation processes in biomolecules as a common denominator of UV and ionizing radiation interacting with living cells, underlying both radiation hormesis and creation the secondary UV, which can be identify with postulated by Gurwitsch mitogenetic radiation MR.

It is therefore extremely important and interesting for scientists to find out to what extent might the low-level radiation be beneficial to most individuals.

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3.19 EXTENSION LECTURES: THE EFFECTS OF RADIATION FROM ATOMIC BOMBING

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ABSTRACT

About 56,000 A-bomb survivors are living in Nagasaki city even today. Nagasaki citizens, whether they are A-bomb survivors or not, can not live without concerns on the existence of radiation effects. They have fears of any amount of radiation and are afraid that it may harm their life. As results of studies in the university on radiation effects are not familiar to the citizens, we have started extension lectures on "the effects of radiation from A-bombing" to them since 1990. We discuss the problems as well as significance of the extension lectures by reporting the details of the extension lectures which we have managed in the past.

1. Introduction

About 56 thousand A-bomb survivors live in Nagasaki City today, and many people in the city are related to the survivors, including family including the second generation of survivors, relatives and acquaintances. People who have came into the city after a long time of A-bombing and who are not directly related to the A-bombing are also conscious of radiation from A-bombing. Unlike conventional bombing, A-bombing makes survivors, as well as citizens not related to the survivors and live in the city, afraid of its effects. However, studies performed in the university are not always understood by citizen. We have opened the first extension lectures on the effects of A-bombing in Nagasaki in 1990. From 1995 we have been planning the extension lectures every year.

2. Opening of Lectures

Following 6 sessions were held since 1990 to 1998.

(1) September, 1990: 5-day course of 1 hour 45 minutes on Friday
(2) July, 1995: 3-day course of 3 hours on Friday
(3) August, 1996: 1-day course of 4 hours
(4) August, 1997, 1-day course of 3 hours

(5) August, 1998, 1-day course of 3 hours
(6) December, 1998, 1-day course of 2 hours and 15 minutes

3. Contents of Lectures

Following contents were included in the extension lectures performed in the past.

(1) Character of Radiation:
- Power of A-bombing
- Radiation from A-bombing
- Radiation and radioactivity
- Radiation and active oxygen
- Measurement of radiation: practice

(2) Effects of Radiation on Human Beings:
- Radiation and human cells
- Radiation injury
- A-bomb syndrome
- Early effects of Nagasaki A-bombing
- Late effects of Nagasaki A-bombing
- A-bombing on Nagasaki and cancer
- Fifty years of study on leukemia induced by A-bombing
- Cellular damages induced by radiation and its defense mechanism

(3) Health Control:
- Medical data base of A-bomb survivors
- Medical examination of A-bomb survivors and its benefit
- Health control of A-bomb survivors
- Health of aged persons

(4) Application of Radiation:
- Clinical application of radiation and radioisotopes
- Radiation diagnosis and radiation therapy
- Radiation for leukemia treatment
- Application of radiation and radioisotope in life science

(5) Effects of Accident of Chernobyl Atomic Power Station:
- Situation of accident of Chernobyl atomic power station
- Health problems of Chernobyl accident

4. Discussion

To make clear the problems and solution of the extension lectures, questions are proposed and answers to them are presented in the followings.

(1) What idea do the citizens have on radiation?

a: They have feeling of fears of radiation without reliable reasons.

b: They think that even a very small dose of radiation induces injury.

(2) What don't they know?

a: They don't know that people living on the earth are exposed by natural radiation.

b: They don't know that they contain radioactive ^{40}K in their body.

c: They don't know that low level radiation induces no injury.

d: They don't know well that radiation and radioisotopes are applied in medical treatments.

(3) What should we consider for the extension lectures?

a: We should try to make the citizens understand scientifically and medically what they don't know.

b: We should try to use words which they use in their daily life, not technical terms.

3.20 STUDIES OF RADIOLOGICAL CONSEQUENCES ON THE REPORTS OF CHERNOBYL ACCIDENT

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Summary

1) Relation of radiation related quantities such as radioactivity, exposure, absorbed dose, dose equivalent, effective dose equivalent and radiation protection standards were explained as easy as a beginner could understand. 2) Using published data including IAEA data in the report "One Decade After Chernobyl (Summary of the Conference Results, 1996)" and some reports, outline of explosion, exposure dose and radiation effects which gave to the human body were briefly described and some rational ways for understanding the data were shown.

1. Introduction

It is considered that there are several causes which bring about excessive radiation-phobia in majority of public. These are 1) a human can not recognize the existence of the radiation with five senses of sight, hearing, smell, taste and touch, 2) the straight line relation hypothesis between radiation exposure and its biological consequences would produce misunderstanding in public, as if the relation is a fact and 3) a rational way of understanding radiological consequences may be insufficient in many people.

Here, in connection with the last subject, I attempted to give some rational ways for understanding the radiological consequences written in the reports of the Chernobyl accident which is a matter of great concern to us. It is another reason of choosing the reports of Chernobyl accident to probe a possibility of putting these reports to some use in school education.

2. Radiation related quantities and radiation protection standards.

Before going to the matter of Chernobyl accident, I described about radiation related quantities and radiation protection standards including risk coefficient for a better understanding of matters. For the radiation related units, there are five principal quantities such as radioactivity, exposure, adsorbed dose, dose equivalent, effective dose equivalent and risk coefficient. The former three are physical quantities and the latter three are quantities for radiation protection.

a. Radioactivity (Bq, Ci, dpm and cpm)[1,2]

A quantitative expression of intensity of rdioactive nuclide is the radoactivity, abbreviated by symbol A. The SI unit of radioactivity is the Becquerel (Bq) defined as the number of disintegrations per second (dps): 1 Bq = 1 dps. It is a very small activity and usually multiples of it are used: PBq, TBq, GBq, MBq, kBq. The traditional unit of activity was Curie (Ci). Although the use of the Ci unit is not recommended it is defined to be 1 Ci = 37 GBq = 3.7×10^{10}.

Activity is often characterized by the number of disintegrations per minute (dpm): 1 dpm = 60 Bq; 1 Ci = 2.22×10^{12} dpm. Taking the degree of efficiency of the measurement to be η, we can formulate the following relationship between the counts per minute (cpm) and the activity in dpm: 1 dpm = 1 x $1/\eta$ cpm.

In the following description, I deviate sometimes from the SI recommendations and use Ci (as well as its fractions mCi, μCi and multiples MCi, kCi).

b. Exposure (C/kg and R) and Exposure rate (C/(kg·s) and R/h)[1,3,4]

The electromagnetic radiation (gamma rays or X rays) causes ionization in air. The measure of the interaction is characterized by the exposure abbreviated by symbol X. The SI unit of exposure is coulombs per kilogram of air (C/kg). (amount of 1 kg of air corresponds to the volume of 773 liter of air at temperature of 0 °C and pressure of 1 atm.) The traditional unit of exposure was Roentgen (R): 1 R = 2.58×10^{-4} C/kg; 1 C/kg in air = 38 Gy in water (see section 2.c.). The exposure is called by the name of "radiation dose", too.[4]

Exposure rate is exposure per unit of time, stated as coulombs per kirograms per second (C/(kg·s) or A/kg). The traditional value of 1 R/h is equivalent to 7.167×10^{-8} A/kg.

c. Adsorbed dose (Gy and rad)[2,3,4]

The energy of both corpuscular and electromagnetic radiation is adsorbed during the passage through an organism in the same manner as in any other material, by ionization and excitation of atoms or molecules of the material. In a biological system this ionization causes damage directly by disruption of chemical bonds in the cell. The interaction of the radiation with water both inside and outside cell nucleus produces free radicals which also damage the cell by causing oxidation-reduction reactions.

As a result of interaction between radiation and a material, the amount of energy absorbed in the irradiated material per unit mass is called the absorbed dose abbreviated by symbol D. This applies to all radiations and material. The SI unit for adsorbed dose is Gray (Gy). One

Gray means that one joule of energy absorbed per 1 kilogram of material; the traditional unit of absorbed dose was rad (rad): 1 Gy = 100 rad = 10000 erg/g = 10000000 erg/kg = 1 J/kg.

If radiation dose is 1 R, then absorbed dose will be almost 1 rad. If the value of exposure is estimated in absorbed dose in water, 1 C/kg in air is equivalent to 38 Gy:

$$
\begin{aligned}
1\ \mathrm{C/kg} &= 2.998 \cdot 10^{6}\ \mathrm{esu/g} \\
&= 2.998 \cdot 10^{6}\ \mathrm{esu/g} \times (1/4.803 \cdot 10^{-10}\ \mathrm{esu/ions}) \times 34\ \mathrm{eV/ion} \\
&= 2.122 \cdot 10^{17}\ \mathrm{eV/g} \\
&= 340000\ \mathrm{erg/g} = 34\ \mathrm{Gy\ in\ air} \\
&= 34\ \mathrm{Gy\ in\ air} \times (\text{electron density per gram of water} \\
&\qquad / \text{electron density per gram of air}) \\
&= 38\ \mathrm{Gy\ in\ water}
\end{aligned}
$$

4 Gy of electromagnetic radiation (: 4 Sv) of the adsorption dose (which brings 50 % death) causes 53000 of ionizations per human cell nucleus. In comparison with the number of atoms (: approximately 10^{11} in DNA strand (wt. 5.6 pg) of a human nucleus, the number of ions formed by irradiation is very small. However this quantity of adsorption dose brings about serious biological effects (see section **2.f.**).

d. Dose equivalent (Sv)[1-3]

The degree of biological effect is depend on the kind and energy of the radiation, even in cases where the absorbed dose is the same. In order to take into account the different extent of the biological effects of different radiation, the concept of dose equivalent abbreviated by symbol H was created. The dose equivalent is used only for radiation protection at the low exposure dose. In the estimation of degree of biological effects at high exposure dose, the concept of the relative biological effectiveness (:the RBE value) is used. The dose equivalent can be obtained by multiplying absorbed dose, D, by a quality factor, Q, and modification factor, N : $H = D \cdot Q \cdot N$. The quality factor relates to the radiations of different LET (linear energy transfer). For example, quality foctors of 1 for beta rays (electron rays) and gamma rays (X-rays), and 20 for alpha rays are currently used. The modification factor adjust for differences due to irradiation conditions, such as exposure rate, however, at present, a value of N is taken as 1.

The SI unit of dose equivalent is Sv: 1 Sv = 1 J/kg. The fractions mSv, μSv are also used. The traditional unit of dose equivalent was rem: 100 rem = 1 Sv. If the gamma rays or X-rays are externally exposed to the human body, 1 Gy of adsorbed dose become 1 Sv of dose equivalent; 1 rad likewise become 1 rem: 1 Gy = 1 Sv; 1 rad = 1 rem.

On 1990 ICRP recommendation, the term of "dose equivalent" was renamed to "equivalent dose". Under current Japanese laws and ordinances

(Concerning Prevention of Radiation Hazards), the name of dose equivalent is still used.

e. Effective dose equivalent (Sv)[1,3,5]

Radiation effects on the human body appear in two form: although the relationship between exposure dose and biological effect is still a matter of conjecture, it is now accepted that the probability of occurrence of some late and somatic effects (e.g. cancer) and genetic effects, rather than the severity of the effects, varies with the magnitude of the radiation exposure (: the straight line relationship). Threshold dose can not be assumed below which some harmful effects may not occur. This kind of effects is called stochastic effects. In contrast, the acute and somatic effects (e.g. loss of hair) and some of late and somatic effects (e.g. leukemia) depend on the magnitude of the dose received, and there may be a threshold dose below which no detrimental effects can be observed. These effects are non-stochastic effects. On 1990 ICRP, the term of "non-stochastic effects" was renamed to "deterministic effects", but the old name of "non-stochastic effects" is still accepted in Japanese law.

Within the range of low doses under keeping properly the radiation protection rules, the number of radiation workers or public suffering from a deterministic effects is virtually zero. However there must be serious concern about stochastic effects. For the stochastic effects, the sensitivity to radiation varies with the tissue (or organ). Even if dose equivalent is the same, the probability of occurrence of radiation effects depends on the tissue which is irradiated. In order to assess the total stochastic effect on various tissues throughout the body, effective dose equivalent, abbreviated by the symbol of H_E, is used. To get an effective dose equivalent, tissue dose equivalents, H_T, multiplied by weighting factors for tissues, W_T, (expressing each tissue's sensitivity to radiation) are added together; Unit is Sv (or rem):

$$H_E = \Sigma_T W_T H_T$$

f. Radiation Protection standard[3,5,6]

At an exposure dose of 0.25 Sv or less, no clinical symptoms by non-stochastic effects are recognized. The excess exposure of a whole-body to radiation in one time causes a harmful acute effects. A minimum lethal dose is 2.25 Sv. A dose about 4 Sv brings 50 % death within 30 days. At 7 Sv, the probability of death is 100 %.

The aim of radiation dose limitation in the ICRP (International Commission on Radiological Protection) recommendation is to prevent the stochastic effects of cancer (see section **2.e.**). Although the straight line relationship between radiation exposure and its biological consequences for stochastic effects is assumptive, these error, if anything, is on the side of safety

For a radiation worker, the ICRP, in 1977, recommended the effective dose equivalent limit of 50 mSv (5 rems) per year. For public, in addition to 2.4 mSv, which was estimated as an annual effective dose equivalent due to natural background, a whole-body exposure to radiation was limited to 1 mSv (100 mrem) per year. For the annual dose limit of radiation worker, the value of 50 mSv are still accepted in present Japanese law, although, in 1990, the ICRP recommended new effective dose equivalent limit of 20 mSv/y for a radiation worker.

Risk coefficient[3]: The degree of occurrence of harmful effects induced by exposure is called a risk. The risk does not mean that harmful effects will occur, it is only the probability that they will occur. The degree of risk is represented by a risk coefficient. Present Japanese law was based on the ICRP 1977 recommendations and has accepted a risk coefficient of 1.65×10^{-2}/Sv which is a cumulative value of probability of occurrence of lethal cancer on every tissue and organ.

In 1990 the ICRP recommended new risk coefficient, newly named nominal lethality probability coefficient, of 5.00×10^{-2}/Sv for public including children and 4.00×10^{-2}/Sv for a radiation worker. But author describe with use of the risk coefficient accepted in Japan in the text.

3. Studies of Radiological Consequences on the Chernobyl Accident

3.1. Outline of explosion[7,8,10,11]

At am. 1:23 on 26th April 1986, an accident of explosion of reactor unit occurred at unit 4 of the Chernobyl nuclear power plant (graphite-moderated light-water-cooled reactor; 1000 MW of electric power). 10 km north of Chernobyl, Pripyat having population of 45 thousand is located and 130 km south, Kiev having population of 2.5 million is located. This accident was an occurrence during shutdown of the reactor for routine maintenance. At the time of accident an experiment was carried out and the reactor staff did not keep to the operating rules. The reactor became uncontrollable, causing the increase of output by about 100 times of the rated output with the steepest ascent that resulted in a generation of enormous amounts of steam, an explosion and the ejection of enormous amounts of rdioactive material.

Releases of radioactive materials was as follows: the total activity of all the radioactive materials: around 12×10^{18} Bq including noble gases (^{85}Kr,^{133}Xe etc.) $6\text{-}7 \times 10^{18}$ Bq, ^{131}I $1.3\text{-}1.8 \times 10^{18}$ Bq, ^{137}Cs ca. 0.09×10^{18} Bq, ^{134}Cs ca. 0.05×10^{18} Bq and ^{90}Sr 0.01×10^{18} Bq. About 3-4 %

of used fuel in the reactor as well as up to 100 % of noble gases (Kr,Xe) and 20-60 % of volatile radionuclides (20-40 % of Cs, 50-60% of I) were released at the time of accident. The amount of radioactivity was assumed to be 200 times of radioactivity of both Hiroshima and Nagasaki atomic bombs together.

It is considered that if the 1000 MW nuclear reactor involves a radioactivity of 40×10^8 Ci after 1 day from the time of shutdown, this activity decreases to 10×10^8 Ci after 1 month, to 1×10^8 Ci after 1 year and 1×10^7 Ci after 10 years. [10] Present total activity in the destroyed Chernobyl reactor is estimated to be 700×10^{15} Bq (1.9×10^7 Ci).[7]

3.2. Exposure Dose[1-12]

a. The persons who received exposure to radiation[7]

The response to the accident was carried out by the initial persons having dealt with accident and a large number of specified workers called "liquidators" and so on. The number of persons who received exposure and the individual exposure dose of them are shown in Table 1. The group 1 of several tens persons received a lethal dose of 1000 mSv. The group 4 was the inhabitants having lived within a distance of 30 km

Table 1. The number of persons who received exposure to radiation.

Groups of persons who received exposure to radiation	Number of persons	Exposure dose mSv
1. Initial persons having dealt with accident	several tens	1000 (100 rem)
2. Liquidators (workers such as operators, non-professional personnel, etc on a period of 2 years.)	200,000	100 (10 rem)
3. Persons who were registered as involved in activities relating to the reduce of extent of disaster.	600,000 ～ 800,000	
4. Inhabitants having been evacuated from their home during a period from Apr. 27 to the middle of Aug. '96 in Mogilev and Gomel districts.	116,000 (fewer than 5 % had received doses greater than 100 mSv; fewer than 10 % had received doses greater than 50 mSv)	

(Between 1990 and the end of 1995, furthermore, decisions were taken to resettle the persons of 53,000 in Ukraine, 107,000 in Belarus and 50,000 in Russia.)

from the power plant and having been evacuated; their exposure dose exceed the annual effective dose-equivalent limit of 50 mSv/y (5 rem/y) for radiation worker (formal standard value for enforced evacuation).

b. The exposure dose of inhabitants[9)]

The exposure dose of inhabitants who were evacuated is shown in Table 2. The inhabitants of 135,000, having been evacuated, received a collective effective dose-equivalent of 1.56×10^4 man-rem (the value in Table 2 differ from the value in Table 1 because of difference of cited references.) The number of fatal cancers, being revealed in future, due to the accident was estimated to be 160-230. (Author's note: $1.65\times10^{-2} \times 134.9\times10^3 \times 0.155 = 258$, where 1.65×10^{-2} is a risk coefficient per Sv. The assumed fatality against to the population in question is 0.2 %.) The fatalities of 100-500 was assumed among the persons of 24000 having been exposed to high dose radiation, where the risk coefficient was 0.0125-0.05 /Sv[10)]. (Author's note: 0.0125x24000x0.44 = 132 (fatality = 0.4 %), 0.05X24000X0.44 = 528 (fatality = 2 %))

Table 2. Exposure dose of inhabitants who were evacuated.

Distance from power plant(km)	Persons ($\times10^3$)		Exposure dose (rem)	
Citizen of Prypyat who were evacuated within the 27th Apr.				
3	45		3.3	
Persons who were late for evacuation.				
3 -7	7.0		54	
7-10	9.0	(24000 pers.	46	av.
10-15	8.2	in total)	35	44
15-20	11.6		5.2	
20-25	14.9		6.0	
25-30	39.2		4.6	
	* 135.9 in total		av. 11.5	

* Collective effective dose-equivalent = 135.9×10^3man x 11.5 rem
= $1.56\times10^4$4 man-rem

c. Collective effective dose-equivalent for public[9)]

It was estimated that the people of 74.50 million living in Ukraine (pop. 50 million), Belarus (pop. 10 million) and Russia (pop. 150 million) received 290,000 man-Sv of collective effective dose-equivalent over their lifetimes of 50 years (i.e., per caput effective dose-equivalent was 290,000 / 74.5×10^6 = 0.0039 = 3.9 mSv/person/lifetime). The fatality due to the committed dose was assumed to be 0.006 % ($1.65\times10^{-2} \times 0.0039 = 6.4\times10^{-5}$), which would be impossible to distinguish from the spontaneous mortality due to cancer (26.5 %).

d. Territories with radioactive contamination[11,12]

There are two contaminated territories of 1) central region centerring around the atomic power plant in Chernobyl, Ukrine, and 2) Bryansk-Belarus contaminated region, north of Chernobyl, ranging over Mogilev-Gomel districts in Belarus and Bryansk district in Russia Federation.[11] Chernobyl lies near the north border of Ukrine (600,000 km^2) being contiguous to Belarus (210,000 km^2) and Russia (17070,000 km^2).

Three years after the occurrence of accident, the distribution of ^{137}Cs, whose half life (30 y) is very long and which can be detected easily, in the ground surface was revealed. The contamination density of 37 kBq/m^2(1 Ci/km^2, 0.001 mCi/m^2) - 555 kBq/m^2(15 Ci/km^2, 0.015 mCi/m^2) was measured at the area of about 100,000 km^2, and the activity levels in excess of 555 kBq/m^2 (15 Ci/km^2, 0.015 mCi/m^2) was measured at the area of larger than 100,000 km^2. The contamination areas of high level of 1480 kBq/m^2 (40 Ci/km^2, 0.04 mCi/m^2) and 5200 kBq/m^2 (140 Ci/km^2, 0.14 mCi/m^2) were found in the central region and the Bryansk-Belarus contaminated region respectively. The values of these high contamination densities (ca. 200 Ci/km^2) are understandable, if the ^{137}Cs activity of $2X10^6$ Ci ($0.074X10^{18}$ Bq) that is released came down to cover the ground within 10,000 km^2.

Present author notes in parentheses that the exposure rate at the distance of 1 m from a point radiation source of ^{137}Cs of 1 mCi can be calculated to be 0.35 mR/h (: external exposure dose rate of 3.5 μ Sv/h). Using this value being the case for a point radiation source, the annual external exposure dose are tentatively estimated to be 1.23 mSv/y and 4.4 mSv/y for the radiation source of 1480 kBq and 5200 kBq which existed on the ground surface of area of 1 m^2:

$$0.04\times 0.35 = 0.014 \text{ mR/h} = 0.14 \ \mu\text{Sv/h} = 1.23 \text{ mSv/y}$$

$$0.14\times 0.35 = 0.05 \text{ mR/h} = 0.5 \ \mu\text{Sv/h} = 4.4 \text{ mSv/y}$$

These values are 2 - 10 times of natural terrestrial annual dose of 0.4 mSv/y (worldwide average value)[10]. Although these estimation are a little underestimated, these additional external exposure doses due to the contamination would be reasonable in the order of magnitude. The authorities recommended resettlement to the population living in areas with the contamination densities more than 1480 kBq/m^2.[11]

In the report of 9 years after the occurrence of accident from Bryansk, an affair of radioactive contamination is almost the same as before[12]: the minimum value of contamination density of the territories was 57 kBq/m^2 (0.0015 mCi/m^2) and the maximum was 3486 kBq/m^2 (0.094

mCi/m^2). An internal exposure due to the eating habits of inhabitants was 0.2 - 1.4 mSv/y.

3.3 Radiation effects which gave to the human Body

a. Acute radiation syndrome

The 12 hours after the occurrence of accident, patients of 499 were transferred to Kiev and Moscow. A total of 237 occupationally exposed individuals were suggested to be suffering from clinical syndromes due to radiation exposure. The 149 patients were mild case, 55 middle case, 21 serious case and 21 extreme serious case. Their exposure doses were in the range of 1 - 10 Gy. The medical treatment such as shower washing with soap, blood collecting, urine test, measurement of radioiodine in the thyroid, hole body radioactivity measurement, treatment for burn and bone marrow failure. The number of persons who received exposure to radiation and who died by acute radiation hazards is shown in Table 3.

Table 3. The number of persons who received exposure to radiation and who died by acute radiation hazards

Clinical observed effects		Number of persons
Occupationally exposed individuals of clinical syndromes due to exposure		237
Patients of acute radiation syndrome		134
The dead out of these 134 patients within the first three months		28
Patients received doses greater than 10 Gy and received intestinal function change:	11	
The dead out of the 28 patient who died, with skin lesions that affected over 50 % of total body surface area:	26	
The dead, out of these 134, who died over the past ten years after the acute effect		14

b. Late and somatic effects

There is the thyroid effects as a clear evidence of public health effects of radiation exposure due to the Chernobyl accident. The increase of the thyroid cancer was observed in children. During 9 years since the accident occurred, the thyroid cancer was diagnosed in the cases of 800 children under 15 years old. More than 400 of these cases were in Belarus.

The incidence of thyroid cancer increased to 4.5X10^{-5} (cases of 400 /

pop. Belarus of 10^7) with significant high rate in comparison with the spontaneous incidence (10^{-6}) of thyroid cancer. For the affair of appearance of late and somatic hazards between the cases of Hiroshima and Chernobyl, the differences were found as shown in Table 4 (WHO report).

Table 4. Difference of type of appearance of late and somatic hazards between the cases of Hiroshima and Chernobyl

	Hiroshima	Chernobyl
Exposure	Momentary external exposure with large quantities of dose	External and internal exposure with small dose rate for long time
Incidence of of radiation induced thyroid cancer	Increase in the first 10 years after exposure	Increase in the 4 - 5 years after exposure
Incidence of radiation induced leukaemia	Increase in the first 2 years after exposure; Showing the peak of incidence in the first 7 years after exposure	

Among the inhabitants living in the contaminated territories, to date, an increase of incidence of leukaemia due to the radiation exposure did not observed. Among the 7.1 million inhabitants of contaminated territories and strict control zone, the fatalities due to radiation induced leukaemia were assumed to be the order of 470.[7] In the 1977 ICRP recommendation, the risk coefficient for leukaemia is 0.2×10^{-2}/Sv. If individual life dose is 30 mSv, the fatalities due to radiation induced leukaemia is calculated to be 470 (: $0.2x10^{-2}x0.03$ x7100000). This value would be impossible to distinguish from the spontaneous mortalities of 250000 due to leukaemia (: $3.5\times 10^{-3}\times 710000$ = 25000).

The fatalities due to radiation induced leukaemia among the 200,000 liquidators (see Table 1) was assumed to be 200[7] (Cf. $1.65x10^{-2}x0.1$ x200000 = 330). This value would also be difficult to distinguish from the spontaneous mortalities of 700 (: $3.5x10^{-3}x200000$ = 700).

c. Health effects coming from spiritual stress

Health effects of social severance due to the enforced evacuation and resettlement, and anxiety of hereditary effects on the descendants were increased.

4. Conclusion

At first the mutual relation of radiation related quantities such as radioactivity, adsorbed dose, effective dose equivalent, risk coefficient, etc. were explained together with radiation protection standards for a better understanding of the Chernobyl accident. In the description of consequences of Chernobyl accident, the radioactive contamination was explained in paying attention to the unit of contamination density. The fatality due the radiation induced cancer was estimated with use of radiation risk coefficient. These attempts would be a help of taking out of some rational ways in understanding the data shown in the reports.

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3.21 THE AUSTRALIAN NUCLEAR ASSOCIATION'S AWARD SCHEME FOR THE ADVANCEMENT OF NUCLEAR SCIENCE AND TECHNOLOGY AWARENESS IN SECONDARY SCHOOLS IN AUSTRALIA

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The Australian Nuclear Association (ANA), following the death of the founding treasurer of the Association in a motor vehicle accident, decided to commemorate his long-standing efforts on behalf of the Association through a Memorial Fund, set up in his name, from donations of the membership, for a scheme to advance awareness of nuclear science and technology in secondary schools in Australia. Thus, the ANA David Culley Memorial Award Scheme was established in 1993 to assist with projects chosen with selected secondary schools; David having been an educator himself and at that time, also a staff member of the Australian Nuclear Science and Technology Organisation (ANSTO). For the award scheme to work, a member of the ANA executive provides a link between the Association and a senior specialist staff member of ANSTO, where and with whose co-operation in the area of the project's topic some assistance may be given, together with the school science staff for the operation of the project. The Association provides a cheque to the school to cover basic expenses that may be encountered by the awardee school in the implementation of the project.

The initial undertaking of the scheme involved a competition, limited to those Sydney based secondary schools within the immediate municipal local government district of the Lucas Heights research reactor of ANSTO (HIFAR), being invited by the ANA, to apply for assistance in an experimental project in which an application of nuclear science, specifically neutron activation analysis (NAA), would be able to demonstrated. Co-incidentally, this municipal region in the South East of Sydney, contains the sites of the first recorded landings on the East coast of Australia by Europeans; Cook of Britain in April, 1770, which led to the colonisation by the British, followed by La Perouse of France two weeks later. The region also boasts the well known surf beach of Cronulla, with nearby Gunnamatta Bay behind the headland.

Although there were several applications from the schools of the region the clear winner, as decided by the selection committee, was De La Salle College, Cronulla. Their proposal incorporated a plan to measure the level of various pollutants in local waterways and from the waste water outfall from that region of Sydney. At this time there was significant interest within the same local community in possible levels of radioactive waste water that may have emanated from ANSTO as the waste water outfall also includes the ANSTO sewer discharge. (Thus the trigger for the school's interest may well have been an interest backed by both their geographic location and the parental political influence within the school).

The Association, through a member of the ANA executive further discussed the proposal with the school's physics teacher. The initial plan of waste water effluent analysis, both for radioactivity content and for heavy metals by NAA yielded no significant pollutant levels in either case. After further discussion with the science staff it was decided to make the project more "interesting" by amending the aim to centre on NAA of various heavy metals, specifically within the region of Gunnamatta Bay near to the school. So the first project of the ANA David Culley Memorial Fund was developed with assistance, and indeed close liaison, from the Director of the ANSTO

NAA Becquerel Laboratories Division, Dr. David Garnett. Students from the school together with their teacher and Dr. Garnett redefined the parameters of the project to examine regions of the beach area for heavy metal content. Many of the students of the school use this and adjacent sectors of the beach for recreation throughout most of the year. A second set of samples for comparison was gathered from near the local sports oval.

Several of the students visited ANSTO during the processing of the samples in preparation for activation and again during the counting process. The raw data was presented to the physics students for their own analyses with the results ultimately allowing the students to develop their own animated presentation of their work at the subsequent ANSTO "Open Day". The project took significantly longer than was initially thought, partially due to the overriding requirements of the general curriculum workload, and to the extensive extra curricula activities of secondary school students in sporting and other recreation activities. The results, which included the plotting of Arsenic against Chromium concentrations (four distinct regions of interest) for the first set of samples and the level of gold against distance from the local oval (two distinct regions of interest) posed more questions in the minds of the students than were able to be hypothesised at the time.

ANSTO, as part of their general public relations program provide an Open Day each two years for clients, for local schools and tertiary institutions, and for the general public. This provides an opportunity for visitors to see the operation of the Australian principal nuclear activities venue and site of Australia's only nuclear research reactor. It was indeed an honour for the first ANA David Culley Memorial Project to have been included.

This project set the pattern for the ANA David Culley Award: as most projects to date have been underestimated in the overall times required. However, this factor is now incorporated within the process of liaison with the school to allow as many of the students as practical to be included often through the combination of students from two year levels, viz., Years 10 and 11 or 11 and 12.

The Australian secondary education system covers the years 7 to 12 with the schools being responsible for preparation for the Higher School Certificate series of examinations of Year 12 under State Education Departmental supervision. Although each State of Australia is autonomous in its education program, the examinations in the individual States are broadly consistent between themselves. Also, the Australian secondary education system allows for two types of secondary schools to operate in parallel: those operated by the State (i.e. Government Schools), and those under private (i.e non-State) control, the latter often of a religious or sectarian base, yet with compulsory registration and standards under the particular State system.

For the second ANA David Culley Memorial Award a different approach was tried. Rather than an "open" invitation for a variety of schools to make a submission to the Association, the broad context of an agricultural flavour for the award was set in order to spread the interest (and opportunities for participation) to a larger region than hitherto. Assistance was sought from Landcare Australia for a recommendation of possible Agricultural High Schools that may be interested in participating: Agricultural High Schools being part of the State education system being generally located outside the main metropolitan areas of Sydney and environs, whereas the previous awardee belonged to the Catholic Education System.

Several of the State Agricultural High Schools were contacted with one, the Farrer Memorial Agricultural High School, at Calala (near Tamworth), the centre of a major grain and grazing region some 320 kilometres North of Sydney, proposing their investigation into the silting of the local water supply, in a project designed to compare the historical and recent erosion rates in the catchment of the Moore Creek Reservoir that occurred through concentrated tree felling activities shortly after the reservoir's construction. The reservoir is now completely full of sediment and cannot contribute to the local water management system. (Again note the possible local political interests behind the proposed project). In this case, Dr. Peter Airey, the then Chairman of the ANA, worked closely with the Farrar Memorial Agricultural High School overseeing the low level counting of Be7 and Cs137 in the students sediment soil profile samples: thus differentiating between new and older silt. With modern erosion rates confirmed as much lower than the earlier rates, comparative estimates of actual erosion could contribute greatly to any decision on the future of the reservoir.

Some difficulties were experienced in the carrying out of that year's ANA David Culley Memorial Award because of the distance between Sydney and Tamworth and the infrequent contacts between the parties and delays in the student's visit to Sydney with accommodation being outside the parameters of the ANA's consideration: local drought conditions limiting the availability of the school's excursion funds. However, following the visit to ANSTO by the students the low level counting results were able to be presented which allowed determination of the rate and times of silt build up to be calculated.

Having made approaches to one school within the Catholic education system and one within the State education system (albeit outside Sydney), the third award was made under an again modified system of selection by approaching a large Protestant private girls' school, Pymble Ladies' College of some 1500 students, which had expressed an interest in pursuing a multidisciplinary concept based on anthropological specimen C 14 dating of remnants of various Aboriginal activities that had then recently become available, being exposed during the construction of a nearby freeway. The application of carbon dating principles was driven by the physics students as their contribution to the overall team.

Unfortunately, with many other groups having access to the limited range of specimens (and finding that many of the Aboriginal artefacts had, in fact, been interfered with, and permission of the local Aboriginal community inordinately delayed), the school concluded that although the principles of their initial investigations would be maintained, the central project would be shifted to effectively complete a major investigation in co-operation with the Australian Museum in the dating of a large (and basically undisturbed) Aboriginal midden in a different location, yet still near Sydney.

Samples of sections of the Aboriginal midden were made available through the Museum and with the permission of the local Aboriginal tribe members for carbon dating, using the ANSTO atomic mass spectrometry facilities in co-operation with the head of the physics section, Dr. Claudio Tuniz, whereby minimal sample size specimens were able to be analysed. The results provided the students with the term over which the midden had been used by the local tribe, this working in well with the student's Aboriginal studies program.

The 1997, and fourth ANA David Culley Memorial Award coupled the Association's executive recommendation to incorporate a sector on neutron diffraction, with an industrial emphasis. This time a Catholic regional secondary school, Loyola College, in the industrial sector of

Western Sydney was selected. The school, only some four years old, consists solely of Years 11 and 12, drawing its students from five parochial Catholic schools within the district. The school has some 250 pupils from over 50 national cultures - a most exhilarating educational environment! The school science club, following acceptance by the school administration, and comprising students from both Years many of whom were 'new' to the school, virtually drove the program with the advice and assistance from the two chemistry and physics teaching staff members: these two staff members having industrial experience in radiochemistry and nuclear activities respectively, in government and industrial laboratories prior to teaching.

The project, which relied on the comprehension of the responses to Bragg's Law, and wave and penetration properties of neutrons in various media, required the teaching staff and the Year 12 group to bring the newer pupils to this level of understanding. Also, prior to any demonstrational program at HIFAR, a senior health physicist from ANSTO's Health and Safety Division accompanied by a neutron diffraction specialist from the neutron physics group under Dr. Chris Howard provided resumes of the requirements and facilities at ANSTO, discussing with the science club members how to demonstrate stress relationships within various engineering structural materials under "in-beam" working conditions. The group of students visited HIFAR having some of their own ideas demonstrated in the operations. Stress analysis was shown to be of particular relevance to many of the students, especially those living within the heavy industry zone of Sydney and being aware of nearby industrial practices.

This year's award was made to Trinity Grammar School, Melbourne, a Protestant private boys' school some 1000 kilometres south of Sydney, and under a different State jurisdiction to the previous awards. Included in its curricula, each boy spends time at the school camp near Bendigo, the centre of a former major gold mining region of central Victoria.

Again, NAA was the choice in nuclear techniques recommended by the ANA executive committee for demonstration. To date the students have carried out their own preliminary investigations on the applications of NAA (with particular reference to ore analysis) having some guidance from Dr. David Garnett of Becquerel Laboratories, and are scheduled to collect a limited number of initial trial rock samples from a region expected to yield significant traces of gold during their stay at the school camp this week. These will be prepared for shipment to Sydney for analysis. Next year the second part of the project will be carried out based on the initial sample results. With the second half of the present student team assuming responsibility for the newcomers, no doubt some modification of the sampling zone will follow. Thus the new team would be expected complete the project, including visiting ANSTO early in the new year.

The ANA, over the past four years has hosted the "Nuclear Science and Engineering in Australia" series of conferences, each held over two full days and in conjunction with the Australian Institute of Nuclear Science and Engineering (AINSE) and the Nuclear Engineering Panel of the Institution of Engineers, Australia (IE Aust). Having both the opportunity and the consent of the conference organising committees, the 1995 and 1997 conferences included poster displays of the ANA David Culley Memorial Award projects, the first two at ANA '95, with the second pair at ANA '97, where students of the respective schools (accompanied by a school staff member) were able to discuss their projects with the conference delegates.

It is hoped a similar opportunity will be available to the current awardee at the ANA '99 Nuclear Science and Engineering in Australia conference.

In order to maintain the balance of choice with the ANA David Culley Memorial Award the next award will need to be a High School within a State education system.

The ANA is very grateful for the co-operation and involvement of both the ANSTO Administration and individual staff members, as well as the staff members of the participating schools, and especially the enthusiastic and rewarding response of the students.

3.22 WOMEN SCIENTISTS JOINING ROKKASHO WOMEN TO SCIENCES

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ABSTRACT

Women scientists generally play a great role in the public acceptance (PA) for the national policy of atomic energy developing in Japan. The reason may be that, when a woman scientist stands in the presence of women audience, she will be ready to be accepted by them as a person with the same gender, emotion and thought to themselves. A case of interchange between the Rokkasho women and the women scientists either resident at the nuclear site of Rokkasho or staying for a short time at Rokkasho by invitation has been described from the viewpoint of PA for the national policy of atomic energy developing, and more fundamentally, for promotion of science education.

1. INTRODUCTION

Rokkasho-mura is located in the center of the Peninsula Shimokita and on the Pacific Ocean side of Aomori Prefecture, north end of the Honshu Island of Japan. The peninsula is well known for its shape of axe, and called as the Peninsula Axe, a grip of which corresponds to the position of Rokkasho. There exists a base of the oil storage for emergency and a base of atomic energy in the village and thus the village plays a great role in the policy for energy and now becomes well known. The U-235 enrichment plant, the storage center of low-level drums from domestic RI facilities , the storage center of vitrified residue of domestic burnt nuclear fuels re-processed in France or in UK and returned by ship, and the cooling pool of burnt nucler fuel brought from domestic nuclear power stations are in operation. The plant for re-processing of the domestic burnt nuclear fuel is under construction. Rokkasho is characterized as a nuclear site of the vitrified residue storage and the re-processing plant both of which are found only there in Japan.

2. METHODOLOGY

In the village, many organizations are engaged in PA activities on their own viewpoints. We describe PA activities performed by those organizations and discuss what is the most desirable PA activity from the viewpoint of the public. Organizations we refer to here are as follows:

1. Japan Nuclear Fuel Limited (JNFL).

2. Institute for Environmental Sciences (IES).
3. Social Education Section (SES), Rokkasho Education Commitee (REC).
4. the Reading Circle, the Rokkasho Culture Society (RCS).
5. the Society of Japanese Women Scientists (SJWS).
6. the Soroptimist International of Aomori (SI Aomori).
7. the Peninsula Shimokita Activation Society.

2-1. Japan Nuclear Fuel Limited (JNFL)

JNFL is a practicer of the national policy for atomic energy developing. It has a special facility of circular type building for PA named Rokkasho Visitors Center (RVC), which exhibits panels for outline of Rokkasho nuclear site and the national policy of energy, a model of about 2/3 scale in length of the re-processing plant, and life-sized models of stainless steel vessels for high-level vitrified residue and low-level drums in each storage center as well as a science museum. Panels describing fundamental principles of related nuclear techniques, panels and specimens for geological problems and mineralogy on the siteroblem, and apparatus to demonstrate radiation are exhibited for visitors to obtain basic knowledges and to understand scientific and technical aspects of the policy. Manpower of RVC is supplied by JNFL and electric company, and included persons employed after retirement from Rokkasho village office at comparatively high rank , and young ladies employed from all over Aomori Prefecture. In this way, RVC provides considerable chances of employment for the regional people. PA of the RVC is characterized as that of the promoter of the policy.

2-2. Instiute for Environmental Sciences (IES)

IES was established in 1990 as a foundation under Science and Technology Agency (STA) on demand from Rokkasho Village and Aomori Prefecture[1]. The main theme of investigation at the Institue consists of dynamical aspect of elememts circulation in the environment at the present stage for operation of the RP plant in near future, high technology for closed environment for long stay of human beings in cosmic space or on the lunar surface in future, and biological effects of extremely low-level radiation on mice. Studies on local industy, agriculture and fishery are also recommended and will be promoted on demand from various kinds of regional organization. As for PA, lectures on scientific topics were requested by various kinds of groups in the regional society even at early stage of the establish, although no special staff was provided for the purpose. In most cases, scientists were invited as lecturers for classes of Villagers School by the organizer the Social Education Section, for example, a woman scientist[2,3] of IES was invited as a lecturer for Ladies Class of the School. In 1994, PA division was set up under the name of the Regional Collaboration Office, and two positions in charge of PA were provided by IES. For the first step to the regional people, hearing about science education was made[4] from the principals of the junior high schools in the village. Panphlets on scientific topics met in the daily life named *IES Mini Encyclopedia*[5] have been published once a month, and widely distributed in Rokkasho and surrouding villages and towns. Facilities of IES are always opened to visitors. Special events are held for villagers on some national holidays. IES Science Experiment Class is opened at either IES or village facilities on village festivals. Also requests are often made for sending lecturers on scientific theme[6-10]. The feature of PA by IES may be said to be regarded as mainly so-called a "top-down" PA on the course of the upper organization, although the attitude of IES is neutral to promotion of the national policy for atomic energy.

2-3. Social Education Section (SES), Rokkasho Education Commitee (REC)

Social Education Section, Rokkasho Education Commitee is responsible for all phases of education except school education. Social education has been done at community centers intersperced in the village. The Community Center which located adjacent to the village office and has been the biggest one, was used for events by villagers. In 1995 construction of the building with a theater and the Villagers Library was planned toward completion in near future. Then, SES organized the Rokkasho Culture Society (RCS) as users of the facilities. REC, to which SES belongs, organized the Library Consolidation Commitee for opening of the Library, and officially appointed[11] for IES Regional Collaboration Staff to be a member of the Commitee. Official appointments to scientists as well are often made by various organizations[12,13]. SES also officially demanded for IES Reginal Collabaration Staff to be a representative of the Reading Circle[14], one of the clubs organized under RCS. RCS consists of both the old clubs by villagers own with long history and newly organized ones in 1995. PA by SES is characterized as a "top-down" PA on the policy of village administration. It may be, however, said to be changable by impacts from other new organizations in the village.

2-4. The Reading Circle, the Rokkasho Culture Society (RCS)

One substantial representative was appointed by SES from village women. Then she recommended eight persons as charter members of the circle. During three years, members of the circle increased to twenty-one persons, and bulletins of the circle[15] accumulated seventy issues. Literacy for self-expression was especially recommended among the members. After activities for one year, annual compiling of the bulletins was made at their own expense, and named *Massages from Rokkasho Women*[16], in which one[17] of the members wrote that she expressed herself in the ultimate. The book has led them to discover their own ability of expression. The second volume of *Messages from Rokkasho Women*[18] was compiled in the next year, in which Scientific articles were written by villager members[19, 20] as well. The third volume of the *Messages from Rokkasho Women*[21], was compiled in this year, in which one of villager members confesses that, apart from merit or demerit of the nuclear facilities siting in Rokkasho, owing to these facilities, we greatly appreciate to obtain intimate acquantance with women scientists[22]. In addition to reading and writing, they appealed their thouth by way of actions. Events and conferences are they held or joined as follows:

1. Exchange Meeting with the North-east Branch, the Society of Japanese Women Scientists, Tomari, Rokkasho, Nov. 1995
2. Exchange Meeting with the Summer School of Nuclear Chemistry, Hachinohe, Aug. 1996. Transportation was supported by Japan Atomic Energy Relations Organization.
3. The 1st Festival Rokkasho Culture Society, Obuchi, Rokkasho, Mar. 1997
4. Exchange Meeting with the Soroptimist International of Aomori, Rokkasho Visitor Center, May 1997. Transportation was supported by Mutsu Ogawara Development Bureau, Aomori Prefecture.
5. The 1st Conferance for Rokkasho Women Massages from the Frontier of Energy Base, Rokkasho Culture Exchange Plaza, Oct. 1997. The Conference was supported by the Ministry of Education through SJWS, and collaborated by the Soroptimist International of Aomori.
6. The Prefectural Conference of '97 Partnership for Men and Women Cooperative Participation, Aomori, Nov. 1997. Transportation was supported by SES, Rokkasho Education Commitee.
7. Annual Conference for Sciences of Feminism and Gender 1998, Workshop for Group Activities, Ranzan, Aug. 1998. Transportation of one person is supported by the National Women Education Center.

Activities through these publications and events are regarded as a so-called "bottom-up" PA by villagers themselves, and is so creative that we may call it Self Acceptance rather than PA. Through these activities of their own accord, they become more interested in scientific aspects of the nuclear facilities siting[23]. Scientific topics[23-25] as well as radiation sciences[12, 26-28] were often introduced in the Villager School and also in outside organizations.

2-5. The Society of Japanese Women Scientists (SJWS)

SJWS was establised in 1958 for the purpose of science for peace appealed by peace-loving people including Raichoh Hiratsuka, a famous feminist, and Prof. Shin'ichiroh Tomonaga, a Nobel laureate in physics 1965. For the first time and even long after the establishment, SJWS has been only a group of women scientists for their friendship. SJWS, however, recently has been active in introducing science experiments[29] to children. Women scientists have played a great role in Rokkasho[30-50], Aomori and other cities[51-64] for people, especially, for women to feel intimate with science[65, 66] through friendship.

2-6. The Soroptimist International of Aomori (SI Aomori)

This club is Aomori City Branch of the Soroptimists International which is worldwide known organization of women with profession and social status. Members of SI Aomori in the capital of the Aomori Prefecture are interested in the Mutsu Ogawara Development and the national policy of atomic energy developing in the Peninsula Shimokita, and cooperative to Rokkasho Women. The Economical and Social Development Service Commitee, the Environmental Service Commitee, and the Public Infomation Commitee played a important role in the Conference in Rokkasho.

2-7. The Peninsula Shimokita Activation Society

This society is famous for its typical botom-up activities, for example, the Dream Axe Train from Shinjuku Station to directly Mutsu Station. The Motto of the Society is "Activation of the Peninsula Shimokita for the Shimokita People and by the Shimokita People"[67]. The members consist of meyers of 11 local governments in the Peninsula Shimokita, heads of both public and private enterprices relating to energy, information, transpotations on land and sea, members from relating bureaus of the prefecture, and scientists. One of the most emphasized activities is drowing-up of *Long-term Vision for the Peninsula Shimokita*[67], which is entirely self-made plan through sincere studies and discussions by the members. The present version of the Vision has been recently accomplished its role, because many items in the Vision have been already realized. Now, discussions for *Long-term Vision for the Peninsula Shimokita, Part II* are going on.

2-8. Other organizations

Mutsu Ogawara Development Bureau, Aomori Prefecture (MO Bureau) and Japan Atomic Energy Relations Organization should be also reffered in the context of PA. The Peninsula Shimokita has been characterized by the long history of development under governmental planning since Meiji era, mainly because of low productivity of agriculture due to a special climate condition. The development related to the present atomic energy industry is also one of these kinds of the plannings. Aomori Prefecture as local government is also responsible for the planning, and is promoting it. People can be subsidized by the MO Bureau for regional industry, transportation for inspection of the facilities, and requests for lecturers. MO Bureau is important from local activities, while the other is responsible for all aspects of PA activities in all over Japan, especially in East Japan. The two organizations were contributable to our activities. The purpose of the present report, however, is rather bottom-up activities of the regional people than top-down and governmental ones, and details will be described elsewhere.

3. DISCUSSION

Practical re-processing in big scale has not been experinced in Japan, and re-processing in Rokkasho itself should be regarded as a kind of grand experiment for national policy for atomic enegy developing. Thus, safety and reliabilily are important aspects in this field, and especially, the latter is related to human relations of people with scientists and engineers of the national or private organizations responsible for the national policy of atomic energy developing. The technical problem has a contemporary limit due to the nuclear materials at the present time: their origins, places of occurrence, preparation methods, and analytical chemistry. Engineers and scientists as well are responsible for investigation of these basic aspects of the problem. Mass media should write only what is necessary from view point of science and technology. They should not stir up people to any directions. Teachers should introduce nuclear science, especially, radiochemistry in the curriculum through elementary and junior high school without hesitation and delay. Radioactive elements are source of energy: decay heat, electrons of not only natural, that is, negative charge but also positive charge, rare gases and rare metals. There exists not "waste" but "source of energy" in vocabulary of the nuclear and radiochemistry. This year is the century anniversary of discovery of Polonium and Radium. Madam Curie and one[68, 69] of the contemporary women scientists were sinsere in studies handling radioactive samples in large quantities or during experiments for many hours with their own hands under the atmosphere of radioactive gases, and died from probable effect of radiation. It would be suggested that sincere and sustainable study with enpowerment of literacy[70] for apprehension and own expession for communications are the most desirable PA activity from the viewpoint of the public.

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3.23 RADIATION EDUCATION VERSUS „RADIOPHOBIA" – PUBLIC PERCEPTION OF RADIATION

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ABSTRACT

In this article the author presents the basis and reasons of the public radiophobia in Poland. He mentions about person's mentality historically based on the "cold war" and Soviet's military and technologically domination in this part of Europe.

Besides of the historical and sociological sources he pays attention on a few aspects, which – in his opinion – intensified the negative public responses: Chernobyl catastrophe, the coal-lobby influences, the political parties (not only "green") games during election time, existing of old conventional coal power stations, accessibility of own cheap coal, cost of transformation from communistic to free-market economy, low-level of public pro-ecology thinking and so on. On the other hand the author describes some non-realistic attitudes of society – for example – they accept nuclear medicine while do not agree to develop nuclear power engineering.

Finally he presents conclusions, which can change public perception of radiation.

1. INTRODUCTION

The majority of people active in social and economic policies and majority of experts dealing with radiation believe that the radiation and nuclear power program may be developed and implemented only with public consent and acceptance.

In Poland during parliamentary debate on "Foundation for the Polish energy policies up to 2010" the importance of public attitudes toward radiation has been recalled repeatedly in the context of the future development of nuclear power in Poland.

In the governmental document, accepted by Polish Parliament on 11 January 1996, it has been stated that "nuclear power plant construction is not foreseen up to the year 2010; nevertheless it has been assumed that the appraisals of the economic feasibility and the public acceptance level for such investments will be conducted".

Thus, the need for such assessments of public opinions and attitudes toward radiation and nuclear power has been recognized and accepted by the highest legislative power organ in Poland.

The first public opinion polls on the attitudes toward above problems have been conducted in August 1989. The subsequent four series of assessments of public opinion and social attitudes have been performed by the "Demoskop-market and social research" company and have been commissioned by National Atomic Energy Agency and by Polish Power Grid Company. They were conducted in December 1991, in November 1994, in August 1996 and in May 1998.

The questions covered the following topics:

- position on the nuclear power;
- level of information on the nuclear power;
- opinions on various ionizing radiation applications.

The statistical estimation error for the sample numbering 999 people is equal to 3.2% with the level of confidence 0.95 %.

The following socio-demographic characteristics have been taken into account: gender, age, education level, place of residence, type of work, professional position and place of employment.

2.PUBLIC ATTITUDES TOWARD NUCLEAR POWER IN 1989-1998

Fig.1 shows the distribution of replies to the question if, among other types of energy sources, the nuclear energy should be used to satisfy national power demands.

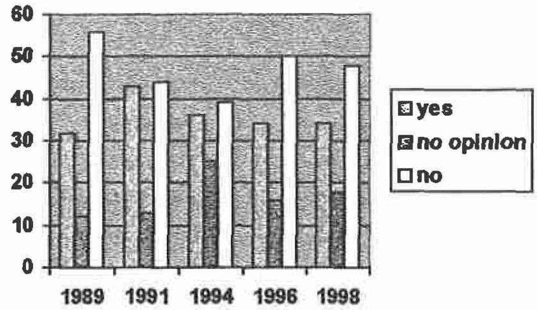

Fig.1.The respondents' attitudes toward nuclear power in 1989, 1991, 1994, 1996 and 1998.

From the numbers quoted it may be concluded that the most dynamic change in public attitudes toward nuclear power in Poland occurred in 1989-1991. In the following years the population has been divided into three groups: the nuclear power proponents (≈35%), opponents (≈40-45%) and undecided (≈15-25%).
The significant increase of the fraction accepting the nuclear option at the turn of eighties and nineties may be explained by the change in the socio-political situation. The feelings have been quieted, the emotions subdued.
The more difficult question is: why, during the recent years, the number of nuclear power proponents in Poland is smaller than the number of its opponents?
The possible explanation of this social phenomenon include the low level of the social awareness as regards the topic in question, but this is not the single reason and probably not the most important one. The opinions on the nuclear energy applications for electricity production are formed not only on the basis of knowledge but also are influenced by emotions.
It is very difficult to assess this emotional component of the attitudes toward nuclear power. It may be deemed significant.

The emotions are intensified by periodically recurring rumors of some nuclear accident, which cause very strong public reactions. On the occasion of 10-th and 12-th anniversary of Chernobyl accident, some very suggestive TV programs have been shown, including some unpublished documentary pictures of the disaster. The respondents in the 1998 polls, asked for a statement on benefits and threats related to the nuclear energy applications, answered : nuclear power means threat – 55%, it means benefits – 29%. The people in Poland are afraid of nuclear power because they are being systematically alarmed and intimidated.
The 1998 polls confirmed the correlation found previously (1989), namely that the higher education level, the higher acceptance of nuclear power.
In 1998, as in 1991 and 1994 the responses "difficult to say" which indicate lack of interest or lack of information, are given mainly by people with only elementary education, farmers, people with the smallest incomes, women and older people. The fraction of " difficult to say" answer for the questions addressing the general attitude toward nuclear power, is similar to the

fraction of such answers given to questions on other national social or political problems - for example - the parliamentary elections of the consequences of the NATO membership.
Fig.2. shows the man and women opinion on nuclear power uses.

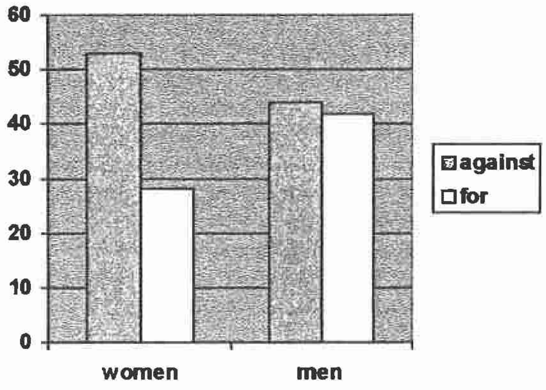

Fig.2.Men and women opinions on nuclear power uses.

The young people (up to 24) display above average acceptance, while those aged over 60 – less than average.
Very high acceptance of nuclear power has been seen among students and businessman-entrepreneurs – Fig.3. and Fig.4.

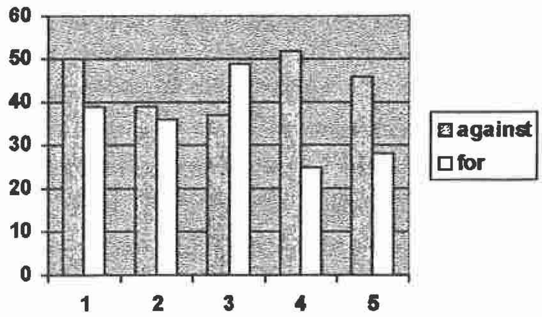

Fig.3.Respondents' opinion on the possible nuclear power uses, according to the type of work (1-employed, 2-unemployed, 3-pupils/students, 4-pensioners/disabled, 5-homemakers).

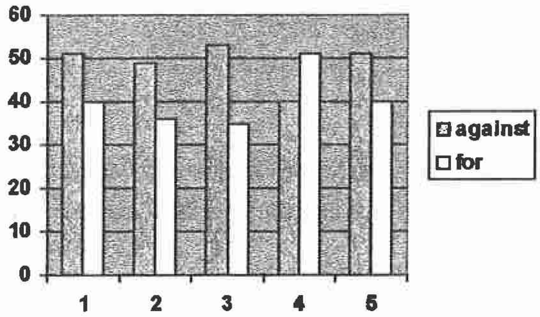

Fig.4. Respondents' opinions on the possible nuclear power uses, according to the work position (1-intellectuals/proffesionals, 2-white-collar workers, 3-manual workers, 4-entrepreneurs, 5-farmers).

3. THE LEVEL OF PUBLIC KNOWLADGE ON THE RADIATION AND NUCLEAR POWER BENEFITS AND HARMS

The relevant knowledge and the access to the information on atomic problems evidently influence the public attitudes toward radiation and nuclear power plants development in Poland. The question: do you feel that you are adequately informed on radiation and nuclear power problems by newspapers, radio and TV ?" the fractions of assenting answers in various years have been as on Fig.5.

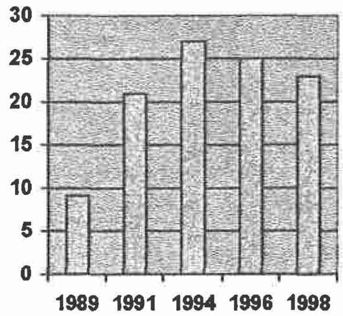

Fig.5. Respondents' opinions on the adequate information on radiation and nuclear problems.

Among those who feel that they are better informed of the radiation and nuclear power benefits and detriments are mainly the people with higher or occupational education and the most wealthy. The people employed in the institutions financed from national budget feel themselves adequately informed on those matters.

The problem of information is connected to the problem of trust and confidence in various source of information on atomic problems. The polls from 1996 and 1998 confirm the high level of trust bestowed in Poland upon the ecologists. Even more trusted are the research scientists (nuclear physicists-30%) and engineers (17%) – Fig.6. The politicians have to expect nearly no trust at all. According to the 1998 report, the confidence and trust level granted to ecologists decreased significantly as compared to that in 1996, by 6%.

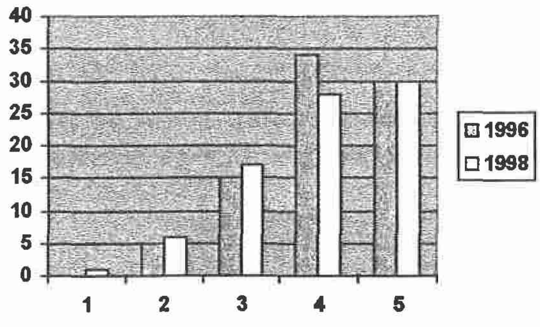

Fig.6.Reliable information source – in 1996 and 1998
(1-politicians,2-journalists,3-power engineers,4- ecologists,5-nuclear physicists).

4. OPTIONS ON VAROIUS IONIZING RADIATION

The respondents have been asked about their opinion on food for assuring better hygiene. 40% of respondents assent to this method (39% were against it), but this consent appears to be rather weak. Numerous responses "rather yes" (33%) and discrepancy between "decidedly

not" (14%) are indicative of this weakness. The characteristics shaping in the strongest way the respondents'' consent to food irradiation for hygienic purposes are : gender, age and place of residence. Males, respondents' young or middle aged and larger cities inhabitants accept food irradiation much more frequently than the others.
Moreover, the respondents have been asked about their acceptance of ionizing radiation applications in three other fields: in the arms and explosives detectors, for radiological thoracic examination and for industrial process control.
It turned out that all these applications enjoy a similar and high (60-70%) approval level. Quite evident relatively enthusiastic, as opposed to the response to food irradiation for hygienic purposes, is seen in much more abundant "decidedly yes" answers (from 23 to 27%). The objection against ionizing radiation uses in these fields is relatively small and fluctuates from 18% for thoracic examinations to 16% for radiation use in the search for arms and explosives.
The respondents have been asked to point to those ionizing radiation applications which, in their view, should be specially promoted and popularized. The following six possibilities have been offered : industrial applications, food irradiation for hygienic purposes, disposable medical equipment sterilization, medical diagnostics and therapy, applications in geology, hydrology and environmental protection, works of art. radiative maintenance and examination. The chart of the support for all types of application is shown in the Fig.7. The acceptance is given in terms of an average, which – depending on the acceptance scale – could assume the value between 1 (the lowest acceptance) and 5 (the largest acceptance).

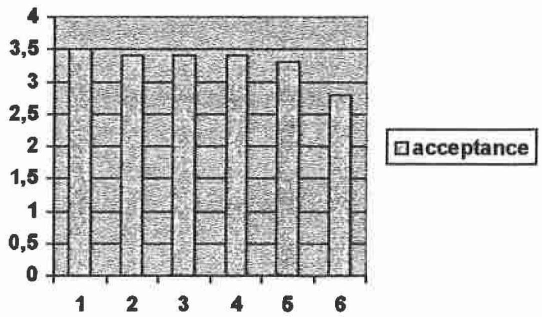

Fig.7. Support for various ionizing radiation applications (1-medical equipment sterilization, 2-works of art radiative maintenance and examination, 3-geology, hydrology and environmental protection, 4-medical diagnostics and therapy, 5- industrial applications, 6- food irradiation for hygienic purpose).

The disposable medical equipment sterilization enjoys the largest acceptance. The smallest is given to food irradiation for hygienic purposes. For all applications the total approval index has been found, as an average over all individual ratings. This average value has been found to be 3,3.
The acceptance of different ionizing radiation applications is connected with the acceptance of nuclear power in general. This conclusion, even if seemingly somewhat obvious, confirms the existence of a group of people, who consistently express approval for nuclear power and fear neither various applications of ionizing radiation nor using the atomic nucleus for acquiring electric energy. Presently, only 10% of the population belong to this group.

5. SUMMARY AND CONCLUSIONS

Pudlic opinion in Poland is not disposed toward electricity production in nuclear power plants and radiation. The conviction that one is satisfactorily informed on power supply matters is very weak. Even if the information not necessarily the most important factor in shaping human attitudes, the public information problem becomes one of the key issues for the institutions interested in radiation and nuclear power development in Poland.

To be more precise : if pupils and students attending various schools are ready to support the radiation and nuclear power program, thus and so the nuclear matters should be included in the educational curriculum (on all school levels).

Also potential investors in future NPPs should involve themselves in broad educational campaigns. Various media may take part in such activities, especially TV with its educational programs.

The older people, uneducated, poor, rural and small inhabitants, women, unemployed and retired are among those most afraid of the radiation. Their views should be taken into account when taking up the activities aimed at changing the Polish public attitudes toward radiation program.

71% of Poles want to restrict coal combustion. It's a good sign.

The polls results confirmed the significant support of Poles (over 60%) for various ionizing radiation applications. This means that the radiation uses may be developed in Poland on a broader scale and unhindered.

Stability is one of the characteristic traits of public attitudes. Nevertheless, the results presented here should inspire a national agenda for activities including educational and informational tasks as well as those influencing emotions, for demonstrating the benefits from radiation and nuclear power. Thoughtful and persistent activities of all involved communities and institutions may lead to significant improvements in the knowledge concerning radiation, thus – to a possible change in public attitudes toward radiation and nuclear power option in Poland.

How to prevent a rumor and protect from nuclear panic (Polish experience).

Nuclear rumors started to appear after the Chernobyl accident. In spite of the principally correct behavior of the authorities and nuclear community following the disaster, the public was terribly scared by the accident. Any cancer cases, skin disasters, allergies were associated with the reactor meltdown in Chernobyl.

In the atmosphere of fear, with a lack of sufficient information and a very low radiation awareness, it was not difficult to spread a rumor about a new nuclear threat.

In last years in Poland every few months new gossip about nuclear accidents spread out. In 1995 there was widely know rumor on nuclear accident in Jaslovskie Bohunice in Slovakia. Another gossip about nuclear catastrophe in Mochovce was also spread, although, as it is well known, not one nuclear reactor is operating yet in Mochovce.

In May 1996 a gossip about nuclear accident in Chernobyl spread throughout Poland. The rumor was so serious that people stayed in long queues to get stable iodine, in kinder gardens the children were kept inside. Telecommunication company registered thousands of extra long distance calls. On May 9-th the rumor reached its peak. The geography of spreading the rumor is not exactly known. The biggest number of reports about supposed radiological risks were noted in West and South of Poland. The large city of Opole has been paralyzed for several hours.

There are not any credible information why and where this gossip came from? It is generally accepted that the rumor started after intensive campaign in mass media on 10-th anniversary of Chernobyl disaster. The media added to this rumor, especially one of the private radio stations, which broadcast news about the accident. Some informers pointed to a local German radio station as the original source of the rumor. It may be worthnoting that in early May of 1995 there were quite strong protests in Germany against transportation of radioactive waste to the German repository in Goerleben.

In Poland journalists tried to verify the rumor in different, not always properly selected government agencies. Many different journalists asked even the President of Poland and other representatives of public life whether there was a real danger.
Many people who requested that it should take a stand on the supposed nuclear accident approached the National Atomic Energy Agency. The NAEA is a particular institution – it is at the same time government body and a specialized agency. Therefore it enjoys more confidence than other government agencies.
In order to give journalists the most convincing explanation the operator of the Chernobyl NPP was contacted and the Polish radiation monitoring stations were requested to take measurements. With the necessary information collected, a press conference was called during which the precise information was given, including the time of the conversation with the Chernobyl NPP operator, his name, the reactor capacity during the conversation and different data describing radiation levels in Poland, i.e. dose rate, air contamination. Determined, reliable and credible presentation of this information in mass media – supported by statements of the authorities from Ministry of Environment Protection, Ministry of Public Health and Ministry of Defense calmed down the panic immediately. From one day to another the topic vanished from public life. What's more interesting – there were attempts to describe and explain the whole problem and demands to punish irresponsible journalists who caused the panic.
It is not easy to answer the question how to prevent a rumor and protect from nuclear panic. It seems that one of the reason for occasionally spread rumors is the memory of the 1989 accident, refreshed at least once a year at the end of April. Another reason why people pick up their ears to various unverified news may be the condition of the sarcophagus of the destroyed reactor, as well as the safety of reactors in this part of Europe. The media many times reported various incidents in those NPPs.
An important factor that makes the public in Poland oversensitive is illegal transport of radioactive and fissionable materials from the so-called "post-communistic" countries.
The sense of danger and fear is aggravated by irresponsible publications. With little knowledge of radiation issues and lack of confidence in the state authorities, the public is easily deceived and frequently yields to panic.
The question is then how to prevent rumors, how to nip the rumor-raised panic in the bud.
The conclusions which should be drawn from the above mentioned incident (which was the biggest but not the only one public event in Poland in last few years) could be as follows :

- each gossip should be addressed as soon as it arises at the best by the competent authorities or person with high scientific standard or social prestige;
- each information on nuclear accident and incidents and their results – should be done quietly and thoughtfully;
- press law or other law acts should include procedure for consideration of responsibility of media people for widespreading false, not documented information, which can cause serious social problems (in different fields);
- the cooperation between nuclear institutions with journalists should be closer and should be based on partner and friendship relation principle;
- in bilateral agreements signed by Poland among with Ukraine, Lithuania, Russia, Slovak Republic necessity of the mutual early notification, even in regard to the smallest incidents, must be included;
- the systems of radiological monitoring should be developed in such a way that they will give the quickest and most exact information about actual radiation level;
- the education of society in radiation and radiological protection questions should be carried out constantly, consequently and more effectively;
- the public should be prepared for the eventuality of a nuclear threat;

- the reactor emergency simulation exercises should be carried out to practice steps required in such a situation;
- citizens should have an easy access to written information how they should behave when radiation emergency is announced.

The above conclusions could create a possibility for changing the public attitude towards radiation and nuclear power in Poland.

(This article based on the Report on public opinion polls – "Polish society attitudes toward nuclear power and ionizing radiation applications" which has been performed by "Demoskop" and has been commissioned by National Atomic Energy Agency).