2. Panel Discussion

（パネル討論）

The Status and Problems of Radiation Education in Various Countries
（海外諸国における
放射線教育の現状と課題）

2.1 RADIOLOGY EDUCATION IN HUNGARIAN SCHOOLS

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ABSTRACT

Basic concepts of nuclear physics are not more abstract and more difficult than those of electricity. For the orientation of the citizens of the 21st century, the Hungarian school curriculum has made them compulsory for all teenagers. According to the teachers' experience, the students find nuclear issues more relevant and more interesting than the topics inherited from the schoolbooks of earlier centuries.

1. AIM

School education -- relying on the pedagogical praxis of earlier teacher generations -- presents the mathematics of the Antiquity, the physics of the early Industrial Revolution (17/18th century) to the youth living in the 20/21st century. And the science teachers are surprised that the teenagers pay less and less attention to solve close-ended numerical problems about rigid bodies, direct currents, and geometrical optics, while living in an environment of semiconductor chips, mobile phones, and nuclear weapons. This conservative teaching habit excludes modern science and high tech from the human culture. Honest grassroots movements among the youth advocate a world free of 'alien' nuclear power and computer network, and advocate returning to the 'understandable' world of their ancestors.

The cleanest form of energy is offered by electricity, therefore it is the most comfortable and most popular option for people. In the last two decades Hungary utilized nuclear power to cover almost half of its electric consumption. This has made our country more independent from outside economical and political pressure. This is one of the main reasons, why statistical physics, atomic physics, nuclear physics, and astrophysics have become parts of the Hungarian high school curriculum. (The Japanese translations of the corresponding schoolbooks, written by Esther Toth, have been printed recently by the Maruzen Publishing Co. in Tokyo.) The actual official state curriculum has made the orientation in nuclear science compulsory already in the middle school, i.e. for all teenagers. Our experiences have been very positive: present teenagers -- even to-be poets, politicians, businessmen -- show much more interest towards radioactivity and nuclear power plants than towards forces acting on rigid bodies and direct current networks. Nuclear physics can be treated with much simpler mathematics than e.g. the resistance in case of alternating current.

2. NUCLEAR DROPLETS

Nuclei are much simpler structures than atoms, molecules, or solids. According to experiences (electric scattering on nuclei in the Rutherford experiment) nuclei are of *constant density*. Nuclei are made of (positive) *protons* and (neutral) *neutrons*. These constituents have almost equal masses. The protons repel each other electrically, but nuclei are still stable formations due to the intensive *nuclear attraction*, which acts among these nuclear particles. The nuclear attraction is about hundred times *stronger* than the electric repulsion, but it has a *short range*: much shorter than the size of the nucleus. These empirical properties of the nuclear force have the consequence that inside the nucleus each particle has the same number of neighbors, thus its binding energy is independent of the size of the nucleus, of the total number A of particles (constant heat of boiling). A particle on the surface, however, has fewer neighbors, thus its binding is weaker (surface tension). These characteristics of nuclear forces explain the constant density, the surface tension, and the spherical shape. Nuclei remind us on water droplets. The *fusion* of small droplets to a larger one would release energy, because fusion decreases the overall surface. But...

3. NUCLEAR VALLEY

Protons and neutrons -- like electrons in the atomic shell – are subject to the *Pauli principle*: on the energy ladder only two protons and two neutrons can stay on the same grade. This is why about half of particles are protons and half of them are neutrons in a stable nucleus. Thus the nuclear droplets are positively charged and repel each other by long-range electric force. The *intensity* of the short-ranged nuclear attraction and the *long range* of the electric repulsion make the nuclei to long-lasting structures. This explains the stability of chemical elements, which is the basic axiom of school chemistry.

The chemical properties of elements depend on their electron shells. The size of the electron shell depends upon the positive electric charge of the nucleus, i.e. on the number *Z* of protons in the nucleus. The Periodic Table of chemical elements terminates, however, at *Z*<100. The explanation is very simple: electric repulsion between two protons is about 100 times weaker than nuclear attraction. But the electric repulsion has a long range: the joint repulsion of all the other protons may become comparable to the nuclear attraction of the immediate neighbors in case of $Z \sim 100$, which destabilizes the very heavy (high *Z*) nuclei.

A nucleus is made of *Z* protons and *N* neutrons, altogether $A=Z+N$ particles. The average binding energy per particle is weakened if

a) *A* is small (large fraction of particles is on the surface),
b) *Z* is large (intensive electric repulsion acts among protons),
c) *Z*>*N* (protons are forced to high energy levels by the Pauli principle,)
d) *N*>*Z* (neutrons are forced to high energy levels by the Pauli principle).

Nuclear particles feel themselves most comfortable (possessing the deepest average binding energy per particle) at medium-sized nuclei ($A \sim 50$), with about 50 % protons and 50 % neutrons in them. This can be visualized by a map, indicating the ***average binding energy per particle*** versus Z and *N*. A narrow valley runs through the *Z*--*N*} plane, more or less following the $Z=N$ line. Two sides of the valley (*Z*>>*N* and *Z*<<*N*) are steep due to the Pauli principle. Starting from small $A=N+Z$ values, we walk downhill in the Nuclear Valley, due to the short range of nuclear attraction and decreasing relevance of surface energy; this is the *Yukawa slope*. For large Z values, however, we begin climbing uphill along Nuclear Valley, due to the electric repulsion between the many protons present in the nucleus, this is the *Coulomb slope*. At the deepest point we find the iron nucleus (*A*=56).

It is a remarkable fact of Nature, that the chemical elements populate the whole Nuclear Valley, but the most common metals are to be found at its deepest part: at the *Iron Sea*. We don't pick up a rusted iron nail, but we take a golden ring with.

	large Z Coulomb slope	
{*Z*<<*N*} Pauli slope	*Z~N, A~50* **IRON SEA**	*Z*>>*N* Pauli slope
	small A Yukawa slope	

4. RADIOACTIVITY

If one puts an arbitrary *Z* number of protons and *N* number of neutrons together, the system goes quickly to its energy ground state by emitting electromagnetic radiation within a tiny fraction of a second, in the same way as atoms do. But at nuclear transitions the emitted photons have much higher energy (*ã-radiation*).

If *N*>>*Z*, then the nucleus can transform itself to another nucleus of deeper energy by a *neutron proton* transmutation, releasing also a negative electron (and an antineutrino). But the transmutation of a nuclear particle is a *weak transition*, it takes much more time: minutes, days, even years. (*â-decay*).

If *Z*>>*N*, the *proton neutron* transmutation may lower the energy content of the nucleus. The proton can get rid of its positive charge by capturing an electron from the atomic shell. (By electron capture or by emitting a positive positron. In both cases a neutrino, too, is emitted. In order to decrease the lexical knowledge to be memorized by the students, we do not speak about positrons and neutrinos in the school. We speak only about electron emission to increase Z, electron capture do decrease Z. These â-transitions enable the nuclei to slide down the Pauli slope to reach the Nuclear Valley.) If we replace a neutron (standing high up on the energy ladder) by a proton, the new particle may find empty proton grades downstairs, therefore it jumps down, â-decays are usually followed by ã-decays.

If the electric charge of the nucleus is too large, by splitting into two parts it could decrease its energy: the two fragments would repel each other vehemently. But the first step of splitting would be the deformation of the spherical droplet, i.e. an increase of its surface, which means increasing surface energy. The energy will drop only after the formation of two spherical droplets out of a larger sphere: sliding down on the Coulomb slope may begin. Thus splitting of a large nucleus could liberate electric energy, but an energy barrier prevents it. A He nucleus may leak through this barrier by quantum tunneling, but that may take thousands, millions, even billions of years. (á*-decay*). For larger fragments the tunneling time would be even longer.

We experience that the nuclei, occurring in Nature, are to be found down, in the Nuclear Valley. This is the result of sliding down on the slopes. Radioactivity -- as *nuclear cooling* -- is a natural phenomenon in the same way as the cooling of hot water in a cup is -- but the released energies are larger, even million times larger.

5. OUR NUCLEAR HISTORY

In the Universe the most common chemical element is hydrogen, making about 75 % of the cosmic stuff. This hydrogen the leftover from the Early Hot Universe. In the first second of the cosmic history the temperature was so high, random thermal motion was so intensive, that composite nuclei could not survive. Cosmic history started with H. As if a shower had poured a lot of water at the Zero End of the Nuclear Valley. But positive protons repel each other therefore they cannot merge...

In the gradually cooling Universe gravitational attraction formed gas clouds. The work of gravity heated these contracting hydrogen clouds up to several million degrees. At such a high temperature there is a certain chance for the single-charged H nuclei (Z=1) to collide, to touch each other and to make He (Z=2) by nuclear fusion. The released nuclear energy feeds the starlight.

In the stellar interior the temperature is originally not high enough to make also the fusion of He nuclei (with charge +2e) possible. But when the H fuel of the star becomes exhausted, the gravitational pull heats the center to 100 million degree, and the fusion of He begins, three He make C, one more He makes O, these life essential elements. Such hot He burning stars are known as *red giants*.

When the He content of the star becomes exhausted, the star is very hot and it shines intensively. The energy loss is covered by further gravitational collapse. The central part of the star collapses to nuclear density, a *neutron star* is formed. The outer layers keep falling in and upon impact they are heated up to billion degree. At such a high temperature the collisions are so energetic, that nuclear droplets start boiling away. All nuclear reaction channels open up; the whole Periodic Table becomes populated. Nuclear matter is dispersed along the whole Nuclear Valley.

But this total nuclear freedom does not last long. Within minutes the heat of the layers falling in produces a thermal explosion: the giant star strips its outer layers off. Gas shells, rich in heavy metals, are ejected to the outer space. Faraway astronomers can register the brilliance of the quickly expanding hot gas sphere as *supernova explosion*. In the heat of this explosion even the heaviest elements (Z>90) were formed. Such an explosion occurred in this region of the Galaxy 4.6 billion years ago. (Its time can be read from radioactive clocks: by measuring the ratio of radioactive elements and their decay products in the most ancient meteorites.)

From the collision of the ejected dirty supernova-material and the pure interstellar hydrogen gas the Solar System has been formed. Thus the Sun is made of the lightest elements, with some metallic concentration. As the work of gravitational attraction warmed the Sun above 10 million centigrade, the nuclear fusion H
Sunshine is fed by the liberated binding energy of helium nuclei. (*Helios* is the Greek name of the Sun.)

The innermost planets were formed from dust grains, covered by the ice of H_2O and CO_2. The sunshine made these planet lukewarm, thus the volatile H_2, He, CH_4, Ne escaped. The radioactive elements, inherited from the supernova, melted the Earth in the first half billion years of her existence. Heavy metals (Fe, Co, Ni) sunk to the core of the planet. Lighter metallic oxides and silicates made the crust. As the radioactivity decreased, the crust solidified. Volcanism released CO_2 and H_2O, to make atmosphere and ocean. The sunshine, produced by *nuclear fusion* in the Sun, keeps the oceans liquid, warms the atmosphere, drives the winds and rivers, and feeds life by photosynthesis. Geothermal heat, produced by *radioactive nuclei* inside the Earth, manifests itself in hot springs and volcanism. These two phenomena, *the two flows in the Nuclear Valley towards the Iron Sea*, keep the Universe changing and they shape the face of our home planet.

Deeply inside the Earth the melted rock material expands, becomes lighter, and rises to the surface. Here the magma cools, solidifies, shrinks, becomes heavier and sinks down. This geothermal circulation drives the plate tectonic motion: continents collide, mountain chains are formed, between the continents oceanic rifts open up. India hits Asia at a speed of 4 cm/year, producing the Himalayas. Such plate tectonic drift has made the chain of islands, which is Japan today.

The composition of the Sun is changing due to nuclear fusion. Its temperature rises slowly; its luminosity increases by 5 % per billion years. The water was liquid on Venus 3-4 billion years ago, and then it evaporated to the atmosphere. The icy moons of the Jupiter will melt in 2-3 billion years from now. But liquid ocean is present on the Earth since 4 billion years, offering time long enough for biological evolution. What sort of air conditioning preserves the steady temperature of our blue-green planet?

The sunshine warms the soil. The lukewarm soil emits infrared radiation. Terrestrial temperature depends on the balance of heat input and output. The actual temperature depends sensitively on the CO_2 concentration of the atmosphere, because CO_2 molecules absorb this infrared radiation. Without the atmospheric CO_2 the Earth would be as frozen as the Moon is.

CO_2 is released by volcanism and is dissolved in rainwater, to make carbonic acid: CO_2+H_2O H $_2CO_3$. Carbonic acid attacks volcanic silicates and dissolves them into seawater in the form of limestone: $CaSiO_3 + H_2CO_3$ $CaCO_3 + H_2O + SiO_2$. The sedimentary limestone and sand sinks deeper and deeper. Down the limestone dissociates due to geothermal heat: $CaCO_3$ $CaO+CO_2$. The CO_2 rises into the atmosphere in carbonated springs. The calcium oxide and sand make $CaSiO_3$ again, and the molten silicate -- due to thermal expansion -- flows to the surface at volcanic eruption. This steady circulation of CO_2 is driven by the weathering of rocks (sunshine) downwards and volcanism (radioactivity) upwards.

If the climate warms up, e.g. due to increased solar luminosity or to increased CO_2 concentration in the atmosphere, the stronger thermal motion accelerates the chemical reactions. Faster weathering means extraction of more CO_2 from the atmosphere, thinning greenhouse, and lower temperature. (The speed of the geochemical reactions in the deep is not influenced by temperature changes outside) If the climate cools, weathering slows down, less CO_2 is extracted, and the increasing atmospheric CO_2 warms up the atmosphere. This *negative feedback* keeps the temperature of the biosphere at constant level. Our special planetary air conditioning is driven by sunshine (nuclear fusion) and geothermal heat (nuclear radioactivity). This air conditioning does not work on Venus (the planet is too hot, it does not have rainwater to make carbonic acid). It does not work on Mars either (the planet is too small, it cannot preserve radioactive heat to drive plate tectonics and volcanism). On the Earth, we are fortunate. The only problem is that the reaction time of the terrestrial air conditioning -- offered by Nature -- is rather long, several thousand years. It cannot offer defense against such a sudden attack like converting all fossil fuels into CO_2 during the few hundred years of the Industrial Revolution.

Thermonuclear fusion in the Sun and natural radioactivity in the Earth are both delayed cooling of supernova materials. They are natural phenomena, as the cooling of hot water in the pot and flow of rivers into the ocean. Well, the phenomena of Nature can be controlled and utilized, as the water mill does with the energy of the rainwater running down the valley. The efficiency can be enhanced; the level difference can be increased by constructing dam. Why don't we utilize the natural flow of nuclear matter along the Nuclear Valley towards the Iron Sea? The discovery of *nuclear fission* made the artificial transmutation of very heavy uranium into medium-heavy nuclei possible in nuclear reactors. A nuclear power plant is a straightforward utilization of a natural phenomenon in the same way as the water mill or windmill is. The advantage of nuclear power plant with respect to chemical power plants is that it does not affect the carbon-dioxide greenhouse.

It is a psychological fact, however, that nuclear power was discovered in the 20th century, in our lifetime. Humans have not got used to it through generation, like they learned to use firewood or riverflow or coal. It is now the duty of radiology education, to express in simple terms, what nuclear energy is. In conclusion, let us quote James Lovelock, the British atmospheric chemist, who has elaborated the Gaia model of the terrestrial biosphere, which has become the guiding principle of environmentalists:

-- The natural energy of Universe is nuclear energy, this feeds the starlight on the sky. From the point of view of the Director of the Universe chemical energy, wind energy, and water mill are insignificant phenomena, as a coal fired star would be. And if it is so, if the Universe of God is driven by nuclear power even today, then why do people demonstrate against making electricity out of nuclear power?

APPENDIX

For those teachers, who like formulas: The volume of the spherical nucleus is proportional to the number A of its constituents, thus its radius is $R=R_0A^{1/3}$ ($R_0=1.2\cdot10^{-15}$m). The binding energy contains the main (negative) term proportional to A. The binding is decreased by the (positive) surface energy proportional to 4ð R^2 and by the Coulomb energy $0.6(Ze)^2/4ðå_0R$. Due to the Pauli principle, a positive n^2 term appears in E/A (binding energy per particle) if the relative neutron excess $n=(N-Z)/A$ is different from zero. These altogether give the following formula:

$$E(A,Z)/A=-å_B+å_S A^{-1/3}+å_C Z^2/A^{4/3}+å_P(A-2Z)^2/A^2.$$

This is the equation for the Nuclear Valley, the positive terms describe the Yukawa slope (decreasing with increasing A), the Coulomb slope (rising with increasing Z) and the Pauli slopes (rising with increasing n^2). Comparison with the measured binding energies gives: $å_B$=2.52pJ, $å_S$=2.85pJ, $å_C$=0.11pJ, $å_P$=3.80pJ. For a fixed A particle number, E is a quadratic function of Z, its minimum $Z_{min}\}=0.5A/(1+0.0075A^{2/3})$ gives the most favorable proton content of the nucleus.

2.2 NUCLEAR PHYSICS TEACHING
FOR JAPANESE TEACHERS FROM A HUNGARIAN PHYSICS TEACHER
with Love and Respect

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ABSTRACT

I intend to give belief to science teachers living in an efficient society where entrance examinations and evening schools, making money and art of advertisement seems to be the emperor of the children's mind. If a nation does not want to import creative people from abroad, it will change the education any way. The changes should come from genuine teachers who work on the field, who meet the young people day by day. Nuclear literacy is only an example to show how we can catch the attention of the open minded young people. The teachers who love their students will find further possibilities.

1. LECTURES AND READING

At about 1980 the Hungarian physics teachers noticed that their students are not so interested in physics lessons as before. If the students were in a good term with their physics teachers they questioned them about semi-conductors or super-conductors, about molecular biology or nuclear power in break-time. And their questions were on *how these work, how they can be used* and not about the names of old and wise physicists having lived at the beginning of this century. That time the Hungarian Academy of Sciences initiated a movement to create a new science curriculum for schools. Then new school books were born. And new teaching methods begun to form.

One of the new chapters is nuclear physics. (The Japanese version of the Nuclear Physics text book was published by the Maruzen Co., Ltd., Tokyo in 1998 December in the excellent translation of Jumpei Ryu and Tae Ryu.) In this book nuclear physics is based on the binding energy of nuclei, or better: *on the changes of energy of nuclei.* In this structure nuclear physics consists of three main parts in the text book:

1. Experimental discovery of nuclei and neutron (Rutherford's, Chadwick's and other experiments, shown by computer simulation)
2. Droplet model for heavy nuclei (mapping the energy valley in the plot of energy per nucleon versus the number of neutrons and the number of protons)
3. Applications of the droplet model (radioactivity as "cooling" of nuclei, fusion, fission; natural and artificial radiation, health effects, reactors, power plants, bombs)

In Hungary this book is used in the last year of the high school which means about the 25% of the whole population. According to the last national curriculum (1996) a very simple version of nuclear physics and radiation protection have to be introduced to the whole population in the middle school before the age 16.

Problems (*in italics*, a possible solution in roman characters):

A good percentage of the older high school teachers, and all the middle school teachers missed the nuclear chapter of physics in their education. In the last 10-15 years many of the physics teachers went to voluntary postgraduate teacher training in nuclear physics courses because of the pressure of their students.

At the entrance examinations there are no questions about nuclear physics. In Hungary there are a few physics competitions where the first 10 students are accepted in universities without entrance exams. In the last year the Leo Szilard Competition on radiology was accepted also as one of these competitions.

Nuclear physics in the last year of the high school was too late, the students arrive with many ugly misconcepts about radioactivity learnt from newspapers and television. This is why the newest national curriculum brings nuclear physics earlier: to the age less than 16 years old and for the whole population.

2. SIMULATION AND EXPERIMENT

Nuclei don't age: their decay occurs as randomly as traffic accidents. Let ask the students of the whole class to stand up, then to throw a 10 Y coin every time when you clap! Those whose coin fall with the value facing upwards have to sit down. Let count the students standing after each clap! With this simple game you simulate the randomness of radioactive decays, in order to introduce the idea of half life time.

The computer offers many other possibilities for simulations, and not only for half life time but for the Rutherford's and the Chadwick's experiment, for the nuclear chain reactions, reactor or power plant simulations as computer games. These simulations can help to understand the non-visible phenomena, the experiments with expensive equipment.

But to understand something in a deep way means not only to be able to follow the logical steps of a proof leading to a conclusion. If you introduce everything via computers then your students will forget about the real world, nuclear physics may become a "virtual reality" (where everybody has at least three lives). In science one can understand something if one has one's own experiences. The teacher needs to offer experiments (not only computer simulation or video) for their students in the classroom. Here there are a few of the classroom experiments what is used in Hungary:

^{137}Cs is an artificial element on Earth, born in nuclear fission. It has a half life of 30 years, and by β decay it becomes ^{137}Ba. The ^{137}Ba is born usually in excited state, so it has to make a γ decay, with a half life time of 2.5 minutes. The Cs and

Ba can be separated by chemical solution. Many years ago East Germany produced a so called "school isotope generator": a porous ceramic pill absorbed ^{137}Cs on its inner surface was taken into a syringe. Thus the chemical solvent was able to wash out the Ba from the pill easily. The radioactivity of the solution containing ^{137}Ba can be measured by the simplest Geiger counter. Because of the short half life time, this experiment fits to lesson time.

From educational point of view it is important to show the students that radioactivity is a natural phenomenon. Putting six layers of ordinary medical gauze at the end of the tube of a vacuum cleaner one can collect the very small dust particles and small water droplets from the air in about 30 minutes. If there are any radioactive ions in the air they will stick to the dust. In this way, again with the simplest type of a Geiger counter, one can show the radioactivity of air in the school..

Even more simpler way to collect the radioactive ions from the air is by using a balloon. Blow a big balloon, rub it with hair to make it negatively charged, and hang the balloon not too far from the floor. (For better result use the ground level of the house.) Measure the clicks per minute by a Geiger counter before you blow up the balloon, this will be the background radiation. About a half an hour is enough to wait for the collection of radioactive ions from the air. Then let the air out of the balloon, and measure the clicks per minute again on the original sized surface of the balloon. (The surface was large when it collected the ions. Now, on the smaller surface there is higher density of radioactive material.)

In the last two cases one can also make a *measurement* and not only an observation of the presence of natural radioactivity. The radioactive ions in the air are coming from the decay of radon, the radioactive inert gas. Radon is everywhere on the Earth. After the decay of radon (^{222}Rn) radioactive polonium (^{218}Po), then radioactive lead (^{214}Pb), then radioactive bismuth (^{214}Bi), etc. are coming. The lead and the bismuth makes β and γ decays. This is why the simplest Geiger counter is able to detect them. The half life of the radioactivity of the dusty medical gauze or that of the balloon is about 40 minutes. (This comes from the 20 minutes half life of the ^{214}Pb and the 27 minutes half life of the ^{214}Bi.)

Problems:

Some teachers who were amazed by the computer possibilities tried to introduce "everything" by computer codes. - The only solution is to WAIT! Wait till the teacher realizes again that science is interesting because it can not leave away the real world. Most Hungarian teachers have already been cured from the disease of virtual reality.

East Germany does not exist any more to create such an inexpensive school isotope generator (60 US Dollar that time). Thus only those schools are happy to use it which bought this ^{137}Cs *source before* 1985 (*the half life of* ^{137}Cs *is* 30 years). *But other schools are poor to buy the expensive American or Japanese version of the same isotope generator.* - The radon is present everywhere, collecting the daughter elements by vacuum cleaner or charged balloon can solve this problem.

In the early 80-ies the Soviet Army was still present in Hungary. It was easy to buy from the soldiers (on the very black market) military Geiger tubes Bright young boys built up the electronics for these tubes creating very good Geiger counters. But the Soviet troops went out from Hungary ... These days some Ukrainian people bring relatively cheap Geiger counters from the Chernobyl region, selling them on the (not so) black market. In Japan the Geiger counter is not a problem, you can lend it from the State, each student could use them in the school or even at home.

3. EXPERIENCE AS EARLY AS POSSIBLE

When you teach your son to count, you use his fingers: "one, two, three, ..." You use his fingers although you do not explain at first to him that fingers are consisted of living cells, in those cells there are water molecules and DNA, and proteins... You use these fingers because they are at hand. When you teach your son to count, you do not stop at 2 and 3 and 5 explaining that they are primary numbers, even the concept of odd and even number is coming later when he is able to count routinely. The students know a lot of things about numbers before they learn number theory. We should not forget this practice when we want to make our pupils and students to be familiar with radioactivity.

With the help of a Geiger counter every pupil at the ages 10 to 14 can map the radioactivity in his or her environment. Where the Geiger counter is clicking faster, there is more radioactivity. They can observe the radiation of furniture, the swimming pool, the wall of the school, the soil in the garden, flowers, mushrooms or even their own body. If they find a granite wall they become excited and happy. (See also the experiments in the Fourth Elementary School in Nerima-ku, Tokyo).

In Hungary all the researchers thought there was no radon in homes at an unhealthy high level due to the geology of Hungary. Then in 1992 it turned out surprisingly that there was a small village in North Hungary where because of special geological reasons the indoor radon levels were high. The Hungarian School Network of Radon Survey started in that year. In that nice village, Mátraderecske, people did not understand why the white collar researchers were entering their homes and murmured not understandable words; the local people questioned them whether they were in danger or not, but it was in vain: there was no answer. Newspapers cried about the hell of radioactive homes in their village, about catastrophic situation but at the same time people did not sense anything special in their homes. Then I arrived to the village together with my students.

We went to the village school and we played together with the local students to make them experienced with Geiger counters. We talked about radioactivity, and about its health effect. The elementary school pupils became literate in radiation protection. They went home and they explained their parents what happened in the school. They asked their parents, grandparents, and other relatives, whether they could bring home small detectors (CR39) to know how high was the radon level in their bed rooms. In this way we were able to measure the radon in all the homes of the village. When the results came, together again with the local pupils we gave the results to the house owners. The pupils had to explain what was the meaning of 500 Bq/m^3, they had to speak about the meaning of yearly average, about the possible health effects. In the homes where the radon level was higher then 800 Bq/m^3, with the students we found out very cheap and effective mitigation methods after having consulted with the house owners.

In Mátraderecske our school laboratory (named RAD Lauder Lab) had learnt:

1. To make measurement at home (not only in physics lab) is a huge attraction for pupils.
2. It has became natural for pupils: radioactivity is everywhere, even in their bed rooms.
3. It is very important to let the house owners know the results in their home, with explanation at a mental level what they can follow.
4. The students were excited to learn as much as possible about the topics because they wanted to be well informed in front of their parents and relatives.
5. The pupils had to learn also how to communicate with people at different literacy levels and different attitudes towards the radioactivity.
6. We also learnt in Mátraderecske how to reduce the radon level where it is too high.

After the first two years of these lessons in Mátraderecske we have invited any other villages to take part in the radon survey. Up to now the RAD Lauder Lab - in co-operation with the local physics teachers and pupils - measured the radon level in more than 15 000 homes in Hungarian villages. This means also that about 15 000 Hungarian pupils learnt about natural radioactivity in the above mentioned direct way together with their parents. (Hungary is a small country, 10 million inhabitants, so 15 000 pupils are many.)

Problems:

Money for the detectors. If you want to make similar radon measurement in Japan one (only one!) detector costs (together with the evaluation done in USA) 60 US \$. In Hungary it is much cheaper. I buy the CR39 track detectors from United Kingdom for 0.5 US\$ each. We use a very simple box (0.07 US\$) for container. We have learnt how to etch the detectors. My old students built up a tracks counter machine. They also wrote an excellent image analyzing program for IBM PC. One result costs less than 1 US\$, including mailing, but not including the work made by the teachers and many pupils of the RAD Lauder Lab without any extra payment. To take part in the survey would costs about 2-300 US\$ for each school, but up to now I were able to create money by finding sponsors, so to take part in the survey is free for any Hungarian school.

One could think that this is *only childish work*, but in each year we take part at the International Intercompariṡion of Radon Measurement organized by the National Radiation Protection Board, England, and our data turn out to be good. The students and pupils are generally much much reliable than the adults ...

4. RESEARCH

"One can not make fire if one does not bear the temperature of fire." If a teacher has never felt the smell of scientific research at least on a small scale, he/she would not be able to educate for scientific thinking.

When a village school gets the results of the radon levels of homes, the teacher and the pupils try to explain themselves the differences. Why there is higher radon level in one room than in the neighboring room? Why was the result larger in Autumn than in Spring? Last year Winter the radon level was lower than this year, WHY? And so on, there are many more questions for discovery because the indoor radon level depends on many parameters: geology, house structure, meteorology, the way of living, etc. Discussing these questions - even only in the short breaks - a good teacher can teach deeper scientific thinking than during the official lessons by slopes and pulleys, AC and DC. For pupils and students the unknown is the real challenge. Taking part in the radon survey they feel that there are no written answers to choose one of them, but *they are* themselves who have to make hypothesis what should be checked by their own experiments.

In the last seven years the RAD Lauder Lab measured the radon level in many homes, enough to ask the question whether there is any health effect of high radon level. We collected the cancer cases with the help of the local doctors, and identified the bed rooms of the patients 15-20 years before the cancer turned up. In the case of women (younger than 60 years, no smokers) we can state with a probability not less than 98% that between 100 Bq/m^3 and 170 Bq/m^3 the cancer incidence is less than at lower or at higher radon activity concentrations. (For your orientation: the Japanese radon average in homes is only 39 Bq/m^3!) It means that a few times higher radioactivity from indoor radon than the average would result lower cancer risk! This was published in the medical journal Pathology Oncology Research, London (the editors did not say it would be a childish work).

From time to time in human history teachers should think it over whether what they teach is important for the next generation or it is not. One thing is sure: if the students hate to take part in physics lessons then those lessons are not worth at all. As teachers we have to *respect* the way of thinking of our students, because they will create the *future*. When the students refuse our pedagogical tricks which we wish them to lead the conclusions what was discovered many years ago by scientists, and when the students say that the evening schools are better than our morning schools because those tell them The Good Answer for the entrance examinations, I am afraid, they are right. They want to survive the entrance exams! If you are not able to fight against those creativity killer exams, you should find something else which is more interesting for your students. As a physics teacher I think the reality is the most interesting for my students. The Hungarian experience in the School Network of Radon Survey shows us a way how to activate again the curiosity and the responsibility in our students.

Problems:

There are many problems left! But these are interesting challenges. And **the love for your students may help you every time to solve these problems.**

2.3 PRESENT STATUS OF RADIATION EDUCATION IN BANGLADESH

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ABSTRACT

Radioisotopes and Radiation are being widely used in the fields of agriculture, medicine, industry for the benefit of people throughout the world. At the same time the use of radiation sources can do harm to man and environment. In order to ensure the safety against radiation hazards and safe use of radiation, proper education, training, knowledge and awareness are essential. Like other countries Bangladesh is trying to achieve economic development through application of isotopes and radiation technology in agriculture, food, industry, power, health or medicine. Basic education about radiation is incorporated in the school curriculum. Courses on radiation are also given in college and university education. Research organizations, universities carry out research and development works on different disciplines using radiation and radioisotopes. Seminars, workshops, conferences, trainings on isotopes and radiation are also being organized. In 1993 Government of Bangladesh passed the Nuclear Safety and Radiation Control Act-1993 for safe use of radiation. The present paper will cover the radiation education, research & development works on radiation, applications of radiation in agriculture, medicine and industry, personal safety and radiation protection against radiation hazard and rules & regulations of the nuclear safety and radiation control act practised in Bangladesh.

1. INTRODUCTION

Basic Radiation Education is started in high school level. Then more detailed radiation education is given in college and university levels. The course curriculum contains the topics like types, natures and sources of radiation, its properties and characteristics, its uses and benefits, its dangers and safety. Universities and research organizations carry out research and development works for peaceful uses of atomic energy in the fields of agriculture, medicine and industry for socio-economic development of the country. Personal safety and radiation protection is effectively ensured through the practice of Nuclear Safety and Radiation Control Act now in force in the country. Regularly organized seminars, symposium, workshops, conferences and training courses help to give proper education for the radiation workers to protect man and environment against the danger of ionizing radiation. The present paper will highlight the radiation education in Bangladesh.

2. RADIATION EDUCATION IN EDUCATION INSTITUTES

2.1 Educational curriculum concerning radiation in High Schools

The school students spend ten years to have Secondary School Certificate (SSC). In the last two years of their high school education in science group they are taught very basic radiation education e.g., X-rays, production of X-rays, uses and properties of X-rays, radioactivity, nature of radioactive rays, characteristics of radioactivity, properties of alpha, beta and gamma-rays, half life of radioactive elements, units of radioactivity, danger of radioactivity, nuclear energy, merits and demerits of nuclear energy. Students do not have any practical demonstration to handle the radioactive sources and X-rays at this level.

2.2. Educational curriculum concerning radiation in Colleges

After successful completion of SSC examination the students get admitted in two years education in the college level to have Higher Secondary Certificates (HSC). The course curriculum of the radiation education in science group covers cathode rays and its properties, X-rays, production of X-rays, its properties and different uses in the laboratory, medicine, industry, commerce, agriculture, detective departments, kinds of X-rays, unit of X-rays, radioactivity, characteristics of radioactivity, radioactive rays - alpha, beta and gamma rays, properties of radioactive rays, kinds of radioactivity - natural radioactivity and artificial radioactivity, units of radioactivity, radioactive decay laws, half life, mean life or average life, uses of radioactivity - medicine, agriculture, industry, some important terms - Isotopes, isobars, isotones, radioisotopes, uses of radioisotopes, cosmic rays, properties and kinds of cosmic rays, atomic models, structures of atoms and nucleus. No practical demonstration is conducted at this level also.

2.3 Education curriculum concerning radiation in University

The general universities provide four years of study - three years in undergraduate level (Honours) and one year in post-graduate level (M.Sc.) in the science faculty. The technical universities/institutes also offer four years of study to have B.Sc. (Engg.) degree but medical colleges have five years of study to have MBBS degree. The course curriculum of technical universities and institutes does not contain much about the radiation education. Some basic knowledge about radiation is given. Radiology is taught in the medical colleges for awarding degree of MBBS in radiology. But in general universities a broad range of radiation education is taught both in undergraduate and post-graduate levels in the Faculty of Physical Sciences. Major topics in the course curriculum are as follows:

Atomic physics: quantum nature of radiation, photoelectric effects, compton effects, electron diffraction, Rutherford scattering, electron spin, production of X-rays, X-ray scattering.

Nuclear physics: basic properties of nuclei, radioactivity, alpha emission, gamma radiation, beta decay, interaction of radiation with matter, nuclear models, nuclear reactions, nuclear reactors, nuclear fissions, nuclear fusions, accelerators.

Radiological physics: units and measurements, biological effects of ionizing radiations, external and internal effects, low-level radiation effects, radiation protection guide and shielding, radiation detection.

Medical physics: Imaging technique - gamma camera, CAT scanner, radiopharmaceuticals radiotherapy, radiation protection, radiation dosimetry.

Nuclear and Radiochemistry: basic concepts of nuclear and radiochemistry and radiation chemistry, the atomic nucleus and its properties, radioactivity and radioactive decay laws, nuclear reactions and fission, interaction of radiation with matter and detection of nuclear radiation, nuclear reactors, cyclotron, Van de Graaff accelerators, production and uses of radioisotopes, nuclear, nuclear related and radiochemical methods of analysis and their application, nuclear power and safety.

Students at university level carry out practical experiments and research works on some selected topics of radiation. After awarding M.Sc. degrees, students may get admitted to M.Phil and Ph.D. degrees in local universities. Courses in Health Physics, Medical Physics and Radiation Protection cover the following topics:

Nuclear physics, nuclear reactors, nuclear models, physics of radiology, health physics, radiation biophysics, physics of radiotherapy, medical physics, reactor physics, radiation protection.

Universities in close collaboration with the research organizations carry out also research works on medical physics, nuclear physics, reactor physics and other related subjects for higher studies leading to M.Phil and Ph.D.

Radiation education background from High School to University levels has so far been described. Now the research and development works and applications of radiation technology and radioisotopes carried out in different research organizations are described below:

3. RESEARCH & DEVELOPMENT WORKS AND APPLICATIONS

3.1 Bangladesh Atomic Energy Commission

Since its formation, Bangladesh Atomic Energy Commission (BAEC) is playing a pioneering role in the country's nuclear research programme. BAEC has undertaken research and development programme in the peaceful use of atomic energy in its various establishments to develop indigenous expertise and thus achieve the cherished goal of self-reliance through national efforts and international cooperation. Its primary objectives are:

- Promotion of peaceful uses of atomic energy in agriculture, medicine and industry;
- Development of related technology like electronics, computer, materials science, etc.
- Planning, Implementation and Operation of nuclear power plants.
- Services in the sterilization of medical products, food preservation, non-destructive testing, elemental analysis, hydrology, etc.

3.1.1 Its major nuclear facilities are:

- 3 MW TRIGA MARK-II Research Reactor
- 3 MeV Van de Graaff Accelerator
- 14 MeV Neutron Generator
- 50,000 Curies Co^{60} Gamma Source

3.1.2 Major areas of activities in nuclear field

3.1.2.1 Physical Sciences

- Analytical methods such as Proton Induced X-ray Emission (PIXE), Proton Induced Gamma Emission (PIGE), X-ray Fluorescence (XRF), Neutron Activation Analysis (NAA), Atomic Absorption Spectrometry, Gas Chromatography, Polarographic techniques have been developed. Some of these methods are being used in analytical services and research. Trace element analysis of various samples including water, air, human hair, nail, body tissues & fluids, pulses, tobacco, food staffs is also carried out.
- Radiation vulcanization of natural rubber - latex
- Nucleonic Control System for paper, steel industries
- Non-Destructive Testing (X-ray radiography, gamma radiography, neutron radiograph), necessary services are rendered to the industries.
- Isotopes in industry and hydrology

  Application of tracer technique has been made in studying different problems in hydrology like aquifer condition related to exploration of ground water, sand and silt movement etc.

  Tracer techniques are also being used for calibration of flow rate measurement, distillation column scanning at Petrochemical Industries, RTD measurement in different industries like fertilizer, cement, paper, chemical etc, measurement of levels and interfaces in different vessels.

3.1.2.2 Biological Sciences

- Agrochemical research.

  Analytical laboratory infrastructure based on nuclear and related conventional instrumental techniques has been developed and provides necessary analytical services for analysis of pesticide residue in food and environmental samples.
- Food preservation and medical product sterilization.

  BAEC has made laudable achievement in using nuclear radiation for food preservation, pest control and medical product sterilization. Experiments are also being carried out for genetic improvement of microbes and higher plants that are of economic importance. BAEC and BEXIMCO jointly installed a "Gamma Tech" commercial plant in 1993 with 1,30,000 Curies Co^{60} Gamma Source.
- Tissue Banking:

  Radiation sterilization of tissue grafts for use in rehabilitative surgery.
- Nuclear Medicine

  BAEC is rendering valuable services to the country's population through its nuclear medicine centres. There are at present 14 Nuclear Medicine Centres situated all over the country. Radioisotopes are used for diagnosis and curative purposes. The investigations include diagnostics and treatment of thyroid gland diseases, scanning of brain, liver, kidney, bone etc., identification of diseases of liver and skin due to malnutrition and localization of tumour in various parts of the body. With the establishment of 3MW TRIGA MARK-II research reactor, some radioisotopes like technetium-99m, iodine-131, fluorine - 18 are produced and are used in the nuclear medicine centres. Some essential radioisotopes are imported from abroad.

3.2 Bangladesh Institute of Nuclear Agriculture

Better mutant varieties of rice, jute, pulses and some other crops have been evolved using nuclear radiation at the Bangladesh Institute of Nuclear Agriculture (BINA). Optimum use of different fertilizers in different types of soil and radiation sterilization of insects have been studied. BINA is the only organization which is doing research works on agriculture using nuclear techniques.

4. NUCLEAR SAFETY AND RADIATION CONTROL

Nuclear Safety and Radiation Control (NSRC) Act 1993 was passed by the Government of Bangladesh. Bangladesh Atomic Energy Commission has been entrusted and empowered for implementation and enforcement of the Act. The NSRC Division of BAEC has been empowered with the following duties and responsibilities:

- Development and strengthening of necessary Nuclear Safety and Radiation Control Infrastructure in the country through the successful implementation and enforcement of Nuclear Safety and Radiation Control Act, 1993.
- Planning, motivation, coordination, direction and control of all R&D and routine activities pertaining to Health Physics and Radiation Protection in the country in order to save life, health, property and environment from the undue risks and deleterious effects of ionizing radiation.
- Preparation/adoption of necessary rules/regulations, standards, codes, guides etc. of various practices involving nuclear and radiation technology in the country.
- Advisory and coordination activities and identifying the problems relating to nuclear safety and radiation control particularly in BAEC and also in other establishments/organizations in the country.
- Supervision of overall activities of various Health Physics Laboratories of BAEC including Radioactivity Testing Laboratory at Chittagong.
- Issuance of NOC/Permits for import of radioactive sources/materials in the country.
- Liaison with the Ministry of Science and Technology as well as different national and international bodies on the matters of nuclear safety and radiation control.
- Research and development activities aiming at strengthening nuclear safety and radiation control activities including safe radioactive waste management.
- Organizing/conducting training courses and seminars on different aspects of nuclear safety and radiation control.

Nuclear Safety and Radiation Control Regulations and Rules have already been prepared and passed by the Government and are being practised in the country. In addition to NSRC Division there are three backup laboratories in BAEC. These are (a) Health Physics and Radiation Monitoring Laboratory, (b) Radiation Control and Waste

Management Laboratory, (c) Radiation Testing Laboratory. A salient features of the activities are summarized below:

i) For peaceful application of ionizing radiation in industry, medicine and research, the NSRC Division is being issued NOC/permit for import of radiation sources and materials to different industries & organizations.

ii) Radiation protection services are being offered.

iii) Under the general supervision and guidance of NSRC Division radioactivity level of imported and locally produced (for exports) milk, milk powder and other food materials are being tested at different laboratories of BAEC to determine the maximum acceptable level of radioactivity as per Government directions.

iv) Regulation supervision of the safety and radiation protection activities of the TRIGA MARK-II Research Reactor.

v) In collaboration with NSRC Division, the Secondary Standard Dosimetry Laboratory (SSDL) and Health Physics & Radiation Monitoring Laboratory of BAEC standardize and calibrate radiation measuring equipment/instrument and X-ray machines of different Government and private hospitals and clinics in the country and also make inventories of radioactive materials and X-ray machines.

vi) In addition to the above activities this Division also reviews and examines the radiation protection programme, area and environmental monitoring activities, emergency preparedness plan and suggests certain recommendations to the concerned authority.

vii) The NSRC Division organizes training courses on Nuclear Safety and Radiation Protection to make awareness among the radiation workers and public for safe use of the radiation sources.

ix) Measurement of radioactivity in environmental samples.

x) Personnel Radiation Monitoring services in the country.

xi) Radiation Survey and Dosimetry in Hospital.

xii) Inspection services for radiation protection.

xiii) Management and disposal of radioactive waste.

xiv) Calibration of deep therapy and teletherapy units.

xv) IAEA/RCA Personnel Dosimetry Intercomparison.

xvi) Education

BAEC conducts and offers lectures and demonstrations in Radiological Physics and Radiation Protection in Part-I Post-graduate Medical courses for DMRD, DMRT of Medical Colleges and FCPS (Radiology) and FCPS (Radiotherapy) of Bangladesh College of Physicians and Surgeons (FCPS). Post-graduate students of universities carry out their research works leading to M.Phil and Ph.D on Health Physics, Medical Physics and Radiation Protection.

5. INTERNATIONAL COLLABORATION

Bangladesh has active collaboration with

i) UNDP/IAEA/RCA Regional Project on the use of Isotopes and Radiation to Strengthen Technology and Support Environmentally Sustainable Development.

ii) IAEA Technical Cooperation Project .

Under these two international collaborations, Bangladesh receives equipment, experts and trainings.

6. CONCLUSION

Through proper radiation education and training and regularly organized seminars, conferences people are becoming more awared about the benefits of radiation and its uses in agriculture, medicine and industry for socio-economic development of the country. People specially the radiation workers are very much careful and conscious about the safe handling and use of radiation sources to protect man and environment. Nuclear Safety and Radiation Control authority is enforcing the rules & regulations in the country effectively and efficiently.

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2.4 RADIATION EDUCATION IN INDIA: CURRENT STATUS

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ABSTRACT

Like others, Indians too have fear of nuclear radiation, probably because of weaker systems of proper radiation-education to the sizable illiterates. Even in urban areas, laboratories are ill equipped and radioactivity-wise practically non-functional. Only through textbooks, some concepts are introduced and the media and Internet are yet almost non-influential. Some national institutes (DAE Labs.) and a few universities including ours are involved in research and teaching. National associations (INS, IANCAS) voluntarily organize workshops, symposia, practicals for the teachers/students and informative speeches for all. Syllabus emphasizing experiments for the age group 14-17 years is proposed and implementation-methodology is discussed.

INTRODUCTION

The pioneering efforts by Jamshedji Tata for promoting science and technology education in India resulted in establishing the Institute of Science, Bangalore. Dr. Homi J. Bhabha, a student of this Institute, lead the foundation stone of Tata Institute of Fundamental Research (TIFR) and then the Atomic Energy Establishment (1948). It was Bhabha's vision and inspiration that put India on the nuclear energy map and lead her towards peaceful uses of nuclear energy; since India possess limited amount of fossil fuels and irregular hydropower sources, promoting nuclear energy programs as an alternative had been a must. The well-planned foundation and systematic growth of nuclear technology became a trendsetter for many high technologies in India.

In order to achieve quicker technological progress after the independence (1947) certain important areas were emphasized, nuclear technology obviously remaining on priority. The nuclear power corporation is now in a position to plan setting up 17 more plants by the year 2020 to raise the total installed capacity to 20,000 MW. This has placed considerable demands on advanced material technologies and the spin-off from nuclear achievements could form the basis of the emergence of certain major industries. To support this, the DAE Training Division will have to expand its program still further producing skilled specialists. Concurrently, in order to sustain the impact of technological growth in India, radiation education system has to take firm roots in the entire nation. Besides nuclear energy, India has made significant growth in the radioisotope production. Diagnostic and therapeutic facilities utilizing isotopes have become essential all over the country to treat cancer; however, these are available only in a few specialized institutions. There are 120 cobalt-60 units in the country and it is estimated that for every one million people at least one unit is required; that means the present need is of about 1000 Cobalt-60 units. To generate and sustain such rapid growth, the requirements of the nuclear materials and correspondingly the need for solutions to the related environmental problems will increase and accordingly the burden on the education systems; producing specialists in all streams, educating the entire society.

EDUCATION- BACKGROUND

Education is the training of mind, brain and character, developing requisite abilities, attitude, knowledge, interests, skill, understanding and values in a person to enable him make worthwhile contribution to human welfare. Enthusiastic minds of the younger generation need to be well familiar with the world around and the vast strides of its scientific and technological developments. Very soon the Indian population will cross the one billion mark and at present, half the illiterates of the world live in India. A considerable fraction of the society is striving for mere survival and resides mainly in the rural areas. Because of poor attention given to education during the past 50 years of independence, benefits achieved through the technological development have not percolated to the weaker/poor sections. Besides, since the medium of instruction for science and technology courses is English and because the number of English medium schools is much smaller in comparison with the regional language-schools even in the urban areas, these courses are out of reach of the rural Indians.

In spite of the above, India has a large number of higher education institutions. There are over 225 central, state and deemed to be universities and more than 8000 affiliated and autonomous colleges. The number of teachers is 300,000 and the student strength is eight million, which is going up at a rate of 4.5% per annum. As per the government statistics, in the year 1990-91 the number of pupils in the age group 6-11 was 10 million, in the group 11-14, it was 33.3 million, in the group 14-17 it was 20.9 million and at the university stage (age: 18+ years) studying in arts, science and commerce faculties alone was 4.4 million. The complexity exists because of the population spread in urban, semi-urban, rural and remote areas, use of regional languages for teaching and a diverse socio-economic-geographical background. Even though the financial input in higher education has increased almost 10 times in the last five decades, there is a resource crunch and most of the money nowadays is going for keeping the system running rather than initiation of new programs. It is no wonder then that India has widely varying academic standards and the technology education still remains to be a negligible fraction of the traditional education.

THE 'FEAR' PROBLEM

Nuclear energy is significant since it is going to be the major source of energy to remain after the first half of the 21st century. Radiation education, therefore, must be brought into regular curriculum of high school level and its futuristic growth and benefits should be stressed with positive attitude. On the other hand the impact of 200,000 human kills at one stroke in the year 1945 is so strong that even today its effects are persistently felt and revealed in the writings by educationists, politicians and many others. Years ago the present Indian Prime Minister, Mr. A.B. Vajpayee, expressed his utter disheartening through the poem (translated by us) as :

'.....Did they feel at least for a moment
That whatever has happened
Is not at all good for the mankind?
If they feel so, then the time will not punish them;
But if they do not, history will never forgive them.'

The fear developed in the hearts of Indians is so deep-rooted that it explodes out wherever possible. A chapter from a voluminous book written by Indians on medicine is with the title, 'Nuclear Hazards'; and the benefits of radiation are also included under the same heading! Professional text book writers for the high school students emphasize:

'Pollution due to radiation is a dangerous pollution of modern times. The ultraviolet rays, x- rays beta rays and more penetrating gamma rays are more and more hazardous to the body. They show adverse effects on cell growth and interfere with the genetic constitution and metabolic activities. The harmful radioactive waste is a great problem.'

PRESENT RADIATION SYLABI

Although there has been an increasing trend of nuclear energy production and of application of nuclear radiation in our day-to-day life, the spread of its scientific / technological knowledge among the Indian masses is extremely poor. The authors fear that there is always a limit to the gap between technological development of the society and the knowledge received by the society about the development. When the gap widens further, no longer being able to sustain the pressure, the society may develop enmity with that technology, howsoever beneficial it may be! And as per the university set up the existing nuclear - radiation courses on the whole are only theoretical, students do not find opportunity to even observe demonstrated experiments. Only a handful of Indian universities in the disciplines like chemistry, biology, medicine or engineering teach and do research in the radiation field. In physics, this number is sizable; however, practically none of these disciplines offer a rigorous laboratory course. Lab-work is, as if, a part of an outcome of pure science! On the other hand, the courses conducted in BARC are vocational. An urgent need appears to diversify the 'single track' education of the pure academic type and to bring down such courses to the teenagers so that vocationalization of nuclear and radiation education spreads. Such training would be related to productivity, preparation of individuals for jobs and employment potentiality, broadening of horizon, dignity of labor and more importantly, a maximum utilization of the material and human resources in the country.

Wherever delivered lectures in the universities and colleges we always asked questions like, how does the radioactivity appear in the environment?, what is natural radioactivity?, how to generate nuclear energy?, what is its importance?, what is the role of radioactivity in human activities ?, etc. To our surprise almost none of the students and even very few teachers from the refresher courses had just partial information! On the contrary, most of them expressed their fear about the past and present nuclear bombs, Chernobyl accident, radiation hazards, and so on. This clearly indicated that availability of knowledge at all levels, school, college or even at the university is insufficient. Looking at the syllabus that is framed for the age group 14-17 years, one finds some topics on radiation education; however, these are largely unrelated to the questions arising in the minds of students of that age group. For example, the children in the age group 14-15 years, the syllabus in Maharashtra State contains alpha, beta, gamma radiation and their properties, radioactive transformations, cathode and x-rays-properties and uses, radiation-pollution, etc. While for the group 15-17 years, the prescribed topics are nuclear structure: size and properties, energy levels- magnetism and shape; radioactivity, decay kinetics, determination of age of a sample, artificial radioactivity, isotope applications, binding energy, nuclear reactions: fission and fusion, carbon-nitrogen and solar energy cycles, etc.

The science syllabi for the age group 14-17 years thus include only one or two chapters on radiation in the whole science course, particularly related to physics and chemistry. Syllabi for higher levels are mainly based on English medium books written by foreign authors. Not many eminent scientists or university professors have written textbooks for the radiation course for these children. Situation is still worse regarding practicals; no experiment is performed in the laboratories. At all levels including the post- graduate one, nuclear-radiation chemistry/ physics courses and the courses like radiation biology or applied nuclear physics remain as theory courses. Hardly one/two practicals are conducted in a few institutions at the M.Sc. or rarely at the B.Sc. level. This is the real drawback in the present education system in India. Further, very large section of even urban population is deprived of any sort of vocational training. Radiation-training courses should evolve and spread into the university system. At present there are no such vocational training systems except one, which is run very effectively at the BARC.

In the existing teaching and research programs of the universities, instead of expansion, retrogation is going on; taking and example of chemistry, the established research groups present in some 7-8 institutions are rapidly shrinking their contribution and influence on the society is correspondingly getting diminished. There is an urgent need to revert this situation giving substantial support to the development of radiation-teaching/research in the universities.

PROPOSED SYLLABUS

One must be clear in mind that energy from the nucleus has to be harnessed to sustain the modern way of living. Energy crises are at the horizon; in the later part of the 21st century these are going to be severe and as the situation stands today there does not appear to be any alternative to obtain energy from the nucleus. With further advancement in technology, more and more attention will have to be paid for minimizing the outcome of artificial radiation in the human environment. Already efforts have gone in extensively in this endeavor. It becomes imperative, therefore, to introduce radiation education that highlights such efforts, and the achievements made all over the world in an unbiased way. Education must also include radiation environment nature has created for us. Everybody must be aware that the world he lives in, since and prior to the days of Adam and Eve, is full of natural radioactivity. Not only that, all of us are bombarded by cosmic radiation from outer space but also that our bodies contain radioactive polonium and radium in our bones; our muscles contain radioactive carbon, radioactive potassium; radioactive noble gases and radioactive tritium exist in our lungs, and so on. Thus the natural and artificial substances we eat and drink each day irradiate us from within. The authors would like to stress that this aspect should be introduced and exemplified to the school going children. There is a paramount need to create consciousness of the environment, permeating all ages and all sections of the society, beginning with the childhood. Education should not be monopoly of university, school or any advanced laboratory, nor it is a time-bound learning experience. It is a way of life, a long way of life. Specifically in the Indian context, education has to compete with the 21st century problems of explosion of population, poverty and illiteracy, hurdles of language barrier, of caste, class, regional imbalance, and so on. It needs to prepare the entire society to bear and sustain the impacts of modern technology which includes the nuclear one.

Based on emphasis to natural radioactivity in the environment and considering the enormous growing energy needs, fast depletion of the conventional energy sources, innumerable applications of radioisotopes and great efforts being put in and already achieved success in the safety aspects, the following syllabus is proposed for teenagers (14-17 years), to be spread over 3 years of schooling.

A. Applied Oriented Topics

1. What is radioactivity: radioactivity in the environment, cosmic rays, and radioactivity in our bodies; uranium, thorium nuclei and their daughters in nature
2. Discovery and epoch making historical inventions
3. How the radioactivity is detected and estimated: elementary concepts of GM and scintillation counters
4. Fission of nuclei: how energy releases ($E=mc^2$), depleting conventional sources and the need of harnessing nuclear energy, conversion into electrical energy
5. Radiation generated for human prosperity against radiation in the environment
6. Radiation effects on cells: maximum permissible doses,
   radiation safety, radiation protection-physical and biological scavengers
7. Radioisotope production in reactors
8. Applications of radioisotopes in:
   a. Agriculture
   b. Pest control: food preservation
   c. Medical: diagnosis and treatment
   d. Industry and related problems
   e. Production of new polymers, etc.

B. Theory Topics

1. Radioactivity: decay kinetics, radioactive elements, parent-daughter decay-growth relationships, alpha decay, and nuclear de-excitation, counting errors
2. Interaction of radiation with matter, units of measuring radiation dose , dosimetry, radiolysis water: free radicals ,time scale
3. Typical reactions involved in the preparation of radioisotopes
4. Analytical methods, age determinations, etc.

(Numerical problems should be solved.)

C. Laboratory Experiments

1. Determination of background radiation using GM detector/survey meter
2. Stopping beta's by Al foil, E_{max} of beta particles
3. Half-thickness stopping gammas by Pb and Cu foils
4. Application of thin film detector
5. Liquid GM counter: daughter separation and $t_{1/2}$ determination (uranium series)
6. ^{40}K activity: ^{40}KCl, $^{40}KClO_3$ and NaCl from Lab.
7. Dosimeter: $Fe^{+2} \dashrightarrow Fe^{+3}$
8. G-value determination: $(CHCl_3) \rightarrow$ HCl measurement
9. Polymerization by radiation (viscometer)
10. Measurement of activity in pitchblend
11. Photoprint-Becquerel's Expt.
12. Demonstration: high activity near volcanic springs-survey meter

Dry Experiments

13. ^{14}C disintegration per day in the body muscles
14. ^{40}K dis./day in muscles
15. ^{222}Rn inhalation, disintegration per day
16. ^{226}Ra and Po dis/day in bones
17. Counting error: concept of statistics
18. Average radioactivity dis/day in a human cell
19. Video demonstration of all the above experiments
20. Film shows projecting significance of the pioneering contributions

(Experimentation Center / Mobile Lab. / Museum, etc. may be developed as a common facility for all the schools in a city. Such centers need to be funded by the DAE and also may be donated instruments in working order.)

The above syllabus is proposed only in the form of guidelines. Further details will have to be worked out by senior radiation scientists from different disciplines at various levels. Also, they need to write standard textbooks, teachers' guides, etc. in English and the regional languages. It is to be realized that merely introducing good, balanced syllabus will not serve the purpose. Bookish knowledge on radiation would lack in providing skill and also scientific attitude. The system needs to be revolutionized and for that one has to begin with the teacher education programs. The philosophy is that once a teacher knows the goal and approach, intuitively develops the required skill to propogate and the whole society then assimilates the knowledge automatically. A sound program for teachers, therefore, is essential for the qualitative improvement and expansion of radiation education. Globalization of radiation education also must be considered in the long run. The end of the present century should mark the end of a uniform education policy by introducing a variety of programs to suit the aptitude, ability and availability of students at all levels. These challenges can be met only through the dedicated teachers. Without sacrifice by this community, nothing can be created, evolved or achieved. The preference by youngsters for moneymaking and luxury oriented education needs to be transformed and hence it has become an absolute need of the day that teachers inculcate devotion academic approach emphasizing on sacrifice, co-existence and citizenship of the world community.

EFFORTS BY VARIOUS ORGANIZATIONS

The small but concrete role being played by of various Indian associations concerning the field of radiation is worth mentioning in the context of education. These have been organizing symposia, workshops including practical courses, informative talks and discussions all over the country; also publish radiation-oriented literature and regularly bring out bulletins. Various programs are being executed by the Indian Association of Nuclear Chemists and Allied Scientists and the Indian Nuclear Society. Over 2,000 life members coming from different disciplines ranging from basic sciences to reactor engineering to biology to medicine, are the member of the INS. As we recollect, 10 years ago the first IANCAS workshop was held in our University for seven days and attended by over 50 university teachers. Total 8 instructors who came at their personal travel expenditure taking privilege leave, worked day and night to set 8-10 laboratory experiments. The overwhelming success and the wholehearted voluntary participation by the teachers gave tremendous impetus to this activity since then. During the past 2-3 years, the activity entered the high school streams as well, adopting regional language as the medium of instruction. Over thirty, 'One-day lecture-cum-demonstration' programs for school children were conducted and attended by over 3000 students and 150 schoolteachers. Authors of this article also have visited on their own and lectured several times before a large number of teacher and student audiences at various levels in different institutions across the country. During the past ten years INS conducted over 50 seminars/lectures while over the period of three years IANCAS carried out rigorous two-week workshops for university teachers at 15 different locations in the country. Nevertheless, this is certainly not enough; wholehearted support and efforts by many are required to reach the desired goal. It all needs solid foundation of personal sacrifice as well, time-wise, energy-wise, even money-wise, if necessary. Such efforts should be supported by the media. The Information Technology Center in Pune University has planned to start link up a number of institutions in and around. This project is developing in collaboration with some foreign universities and the Internet will soon link all the universities, colleges, schools and research organizations in India.

CONCLUSION

If the human race desires to enjoy the enormous source of nuclear energy all through the future centuries, then it needs to put in integrated efforts towards abandoning the existing deadly nuclear weapons. These are the major cause of keeping alive the deep-rooted fear into the minds of the innocent world-community. To eliminate fear, there is a great need of applying will, courage and efforts for the implementation of appropriate radiation-education programs all over the world. Indians are indeed in the stage of effective execution in this context one may recollect what Rabindranath Tagore (NL) had emphasized half a century ago, ' A man shall be incomplete till he has not learnt to put his hand and mind to good and efficient purpose.'

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2.5 PUBLIC INFORMATION AND EDUCATION ON RADIATION SAFETY AND PROTECTION IN INDONESIA

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ABSTRACT

This paper presents a brief overview of public information and education concerning nuclear science and technology in general and radiation safety and protection in particular in Indonesia from the perspective of promoting the development and utilization of nuclear science and technology in the country. The role of nuclear science and technology in Indonesia is first introduced, followed by an overview of the nuclear activities in the country. Basic considerations, major objectives of the public information and education program on radiation safety and protection as well as basic and operational strategies to achieve those objectives are then presented. Major programs including highlights of the past and present activities as well as the prospect on future course of actions are discussed.

1. INTRODUCTION

First of all I wish to express my sincere appreciation and thanks to the Organizing Committee, in particular to Professor Matsuura, for having kindly invited me to participate at this distinguished International Symposium on Radiation Education, held here in Tokyo 11-14 December 1998. I am sure that this important meeting will give me an ample opportunity to widen my horizon on various aspects of Radiation Education, including public information and education, which in my view should primarily be aimed at achieving public awareness, public appreciation, public acceptance and finally public support and participation in the development and utilization of nuclear science and technology.

In my country, and perhaps also in many other countries, the word **"radiation"** is generally still associated with **"nuclear radiation"**, meaning the **"Rays of Death"**. This negative perception was primarily caused by the fear of the potential catastrophe that could result from nuclear technology, as has been demonstrated by the devastating effects of nuclear radiation resulting from the explosion of nuclear bombs in Hiroshima and Nagasaki in 1945, which had brought the World War II to an abrupt end. To these groups of uninformed, under-informed or misinformed people, radiation is something to be feared; one should stay away from it, as it can bring nothing but sufferings and death! In my country, this perception was further reinforced by accidents at Nuclear Power Plants, such as the Chernobyl nuclear accident in 1986.

In contrast to other modern technologies, therefore, nuclear technology is marked with such a traumatic start, which had generated such a strong emotional public resistance towards the introduction, expansion or even continuation of the utilization of nuclear energy in many countries including in the most technologically advanced countries with highly educated majority of the population. Emotion has in fact significantly outweighed rational thinking in judging the benefits and risks of nuclear technology.

In view of the above, radiation education, or more specifically education on the nature, scientific and practical aspects of various types of radiation, constitutes in my view one of the fundamental pillars for the healthy development and application of nuclear science and technology worldwide. The ultimate aim of radiation education should in my view be to pull nuclear technology down from its present seat on the **"throne of death"** in the mind of many people and put it on the similar footing and treatment as other branches modern science and technology.

In this paper I shall present a brief overview on public information and education concerning radiation safety and protection in Indonesia from the perspective of promoting the development and utilization of nuclear science and technology in the country. For that purpose, I shall first briefly introduce the role of nuclear science and technology in Indonesia, followed by an overview of the nuclear activities in the country. Having presented some basic considerations, major objectives of the public information and education program on radiation safety and protection are spelled out, followed by basic and operational strategies to achieve those objectives. Major programs including highlights of the past and present activities as well as the prospect on future course of actions are discussed and summarized in the conclusion.

2. NUCLEAR SCIENCE AND TECHNOLOGY IN INDONESIA

"Breathtakingly beautiful, looking just like a bunch of emeralds on a blue velvet scattered around the equator from east to west, ..."! I could imagine those words coming from an artist-austronaut describing the beauty of the Indonesian archipelago while looking at the earth from his space ship!

Indeed, Indonesia is not only a beautiful country, strategically located in the tropics and inhabited by over 200 million people with a great diversity of languages and cultures, but it also possesses a large variety of natural resources. In short, Indonesia has a tremendous potential to become a major world power, and the strongest nation in South-East Asia. Socio-political stability, empowerment of the people and mastery of science and technology are in my view the three basic pillars for the promotion of economic and social progress.

Considering the financial, economic and socio-cultural problems presently threatening the country, mastery and application of science and technology including nuclear science and technology by Indonesians becomes in my view even more crucial for economic recovery and progress. The conducive atmosphere for the promotion of efforts to master and apply science and technology in the country is only possible if the public and the government are aware, appreciate, accept and support the endeavour. Towards this end, information and education play a key role. In the case of nuclear science and technology, information and education on radiation safety and protection constitute an important component.

❑ Role of Nuclear Science and Technology in National Development

As a developing country, especially in view of its vast economic potential - strategic geography, natural and human resources, Indonesia has a vital interest in the development and utilization of appropriate modern sciences and technologies as a driving force in the development of the country. In this context, nuclear technology has a wide spectrum of competitive, and in many cases, unique benefits to offer to the nation. Apart from power generation, nuclear techniques play an important role in Agriculture, Livestock production, Health, Industry and Environment.

Nuclear activities in Indonesia were started in 1957 as national response to the nuclear bomb testing activities in the South Pacific. Institutional, legal, scientific-technical infrastructures and the necessary human resources were developed. Scientific-technical works were initially concentrated in the detection and analysis of effects of radioactive fallout to the environment and health of the population.

❑ National Atomic Energy Agency (BATAN)

Founded in 1964, BATAN - the National Atomic Energy Agency of the Republic of Indonesia - was given the authority and responsibility as the highest national institution to develop and utilize nuclear science and technology solely for peaceful purposes for the safety, health and welfare of the Indonesian people. Since then, nuclear science and technology were systematically developed, initially primarily focussed in the fields of Agriculture, Livestock, Health, Hydrology, Sedimentology and Environment.

Step by step and in collaboration with the International Atomic Energy Agency (IAEA) as well as through bilateral cooperation with many advanced countries including Japan, human resources and scientific-technical infrastructure were systematically developed in Bandung, Jakarta (Pasar Jum'at Complex) and in Yogyakarta to support the increasing application of nuclear techniques in the aforementioned areas. Two Triga-type research reactors were acquired for Bandung (250 kW in 1964, upgraded to 1 MW in 1971) and Yogyakarta (150 kW in 1974).

A big quantum leap was made in 1978 with the establishment of a new Nuclear Research Complex in Serpong, located about 40 km south-east of Jakarta. This research complex was equipped with a 30 MW MTR-type research reactor, fuel element fabrication installations for research as well as experimental power reactors, radioisotope production center, radio-metallurgy laboratory, radioactive waste treatment installation, neutron beam scattering facilities and several supporting facilities. This complex was envisaged as a stepping stone for the introduction of Nuclear Power Plants and nuclear based/related industries in Indonesia. Despite the current financial and economic difficulties, preparatory activities towards an intelligent and public supported decision making for the introduction of nuclear power in Indonesia are still continued.

3. PUBLIC INFORMATION AND EDUCATION

As mentioned above, public information and education, in particular on radiation safety and protection, plays a key role for the acceptance and support in the development and application of nuclear science and technology in Indonesia. The fact that the application of nuclear technology was highlighted with such a traumatic start, makes it particularly challenging to inform and educate the public, that nuclear energy does not simply mean destruction, suffering and death! Even more challenging is the task to make the public aware of and appreciate, and finally accept and support the peaceful and beneficial application of nuclear science and technology for the society. In the case of the Indonesian public, the aforementioned task is made even more difficult by the various nuclear accidents, such those that have occurred at Chernobyl, Three Miles Island and Monju nuclear power plants.

❑ Basic Considerations

There are three major factors that have been considered and taken into account in developing appropriate strategy and programs on "radiation information and education" in Indonesia. These three factors are:

1. ***Negative image of nuclear technology***
   Apart from the ghost of nuclear explosion in Hiroshima and Nagasaki, public uneasiness and fear of nuclear technology have been significantly reinforced by the unfortunate accidents at nuclear power plants, such as Chernobyl, Three Mile Islands and Monju. Some of the technical-administrative their handling of these accidents, and in particular their incorrect, incomplete or distorted reporting in the mass media, have contributed significantly to the negative image in public perception in Indonesia.

2. ***Cultural diversity and generally still low level of education***
   The fact that Indonesia is inhabited by over 200 ethnic groups (tribes) with different languages, cultures and levels of education presents a special challenge in designing the appropriate strategy and programs of public information and education. The specific socio-cultural features of the different population groups have to be considered and taken into account in order to achieve the desired impact.

3. ***Large size of the Indonesian archipelago***
   With the available financial, manpower and infrastructure support, the large size of the Indonesian archipelago poses also quite a challenge, in particular in conducting information and education programs via two-way communication method.

With those challenges in mind, the limitations on the side of the available resources and confronted also with small but very vocal and financially strong anti-nuclear groups, public information and education program in nuclear science and technology, especially in radiation safety and protection, in Indonesia is not only a science and an art but also a test of stamina at the same time.

❑ Objectives and Strategy

The major objectives of the public information and education program on radiation safety and protection in Indonesia may be stated as follows:

- To achieve and strengthen awareness and appreciation by the general public, the scientific/intellectual community and the government officials that nuclear science and technology are indeed a useful and manageable branch of science and technology.

- To win and strengthen acceptance and support by the public, intellectuals and decision makers for the development and application of nuclear science and technology in the national development.

- To obtain public participation in the national effort towards achieving a nuclear-arm free world.

The general strategy to achieve those goals may be classified into basic and operation strategies as follows.

1. ***Basic Strategy***
   - Respect and take into account the cultural diversity of the population

- Ensure a balanced view of the benefits and risks of nuclear science and technology, in particular on radiation safety and protection
- Take advantage of the national and international links and cooperation

2. *Operational strategy*
   - Classify the target population into three target groups, namely the general public, the intellectuals and the decision makers
   - Train specialized **"JUPEN"** (Public Information Specialists), who should master not only the overall perspective of the scientific-technical subject in question but also the necessary techniques in public/mass communication
   - Take advantage of the modern public/mass communication technology, such as the electronic mass media.

❑ Programs and Activities

The programs and activities are designed to suit the target groups. The programs may classified into the following categories:

1. ***One-way communication program***
   This program includes provision of various types of reading materials (literature), audio-visual materials, permanent and travelling exhibitions, plays and wayangs (Javanese shadow plays).
2. ***Two-way communication program***
   This program includes dialogs, discussions, and other types of direct two-way communication among the participants.
3. ***Mixed program***
   This program includes seminars, symposia, workshops, special courses for teachers and special interest-groups, where opportunities for exchanges of opinions, questions and answers session may follow the presentation of the public information specialists.

In the past few years the activities have been concentrated on informing and educating the public on the benefits and risks of Nuclear Power Plants. Major areas of concern were the economics, safety and technology of nuclear power plants. The use of the Javanese shadow play (wayang) and the use of community leaders (religious and tribe leaders, and other informal leaders in the society) have been found to be effective in conveying the desired message to the target audience in the general public.

Since the start of the economic crisis and the emphasis of the government policy to reduce the increasing level poverty, the focus of activities has been shifted to highlight the benefits of radioisotopes and radiation and other nuclear techniques in the field of agriculture, livestock production, industry and human health. A new BATAN initiative, known as the **"AMD"** (Atom Masuk Desa - Atom in the Village)" program has been intensively communicated to the public and has received a very positive response from the beneficiaries, especially from the small farmers in the rural areas.

In the future, in particular after the easing of the current economic crisis, BATAN intends to make a balanced focus between the efforts to popularize the benefits of nuclear fission reactors to generate power on one side and those to highlight the benefits of nuclear radiation and radioisotopes in solving problems connected with the basic human needs, such as food and health.

4. CONCLUDING REMARKS

Despite the very limited budget and the challenges described above, judged from the benefits-costs analysis, the results so far obtained have been generally quite encouraging. The expected output and outcome of the implemented programs as well as their impact have been very good. The policy and strategies developed and implemented by BATAN have been well supported by the government, by the parliament and by the public.

For the future, the program on public information and education is still hampered by the very limited funding. This situation needs to be improved in order to reach more target groups in the population. The number of trained public information specialists needs to be significantly increased. In addition the facilities and the technical infrastructure support needs to be further improved. In addition, links and cooperation at the national and international levels need to be strengthened, and the use of community leaders should be expanded.

<AD-December 1998>

2.6 RADIO CONVERSATION BETWEEN SCIENTISTS AND THE PUBLIC AS A MEAN FOR UNDERSTANDING PUBLIC PERCEPTION OF RADIATION RISK.

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ABSTRACT

Radio broadcasts with phone-ins in which the public can interact directly with scientists in the studios can represent a very useful tool for analysing public understanding of science. An in depth analysis of the listeners' questions and of the scientists' reactions - despite the obviously low statistical relevance - can provide important clues on the spontaneous and emotional components of the attitudes of the citizens toward science, and of the attitude of scientists toward citizens' concerns.

As an example of the opportunities such an approach may offer, a series of live radio broadcasts on radiation and its applications (the first three transmitted in Italy in November and December 1998) is presented. Each broadcast involved an introductory presentation by two or three invited scientists, followed by phone-ins. The questions of the listeners are analysed and commented. A strong need for a deeper understanding of the methodological principle of radiation research seemed to emerge. The broadcasts also stressed how the need of an interaction between scientists and the public is at least as urgent as the transfer of information to the public.

In the future, the same approach will be extended to other fields of science and to other radio channels, with the aim of designing a methodology for the exploitation of specific features of radio broadcasts for promoting the dissemination of scientific culture.

1. INTRODUCTION

Among mass media, a local radio has several characteristics that tend to enhance the sense of friendliness and belonging - essential to any true communication. There are several reasons for this: mainly, the radio is often perceived as an additional "voice in the family", it does not require our complete attention but can be a part of the environment, and keeps company instead of being a mere source of information, etc. A local radio can therefore be a kind of non-intrusive neighbour, easy to turn to, either for a chat, or for discussing some vital problem.

Some radio stations or networks allow a direct contact between the listener and the conductor. Through phone calls, listeners can ask for a favourite song, answer a serious or a jockey quiz, state an opinion, ask a question, communicate with each others, etc.. Radio Popolare di Milano (see section 2.1), since its birth in 1976, has been concerned with this form of access and with keeping an ongoing dialogue with and among the audience. Indeed, it devotes a large fraction of the daily schedule to the participation of the listeners, which is direct, spontaneous and not filtered by the conductor who has no way of knowing in advance who will be on air.

The freedom of access is very valuable when dealing with science related topics. Reporting science in a radio broadcast is not an easy task: "Science is usually presented as a continuous, coherent, concrete activity [...]. Science does not like superficiality, trivialization, or talk of 'breakthroughs'. In its nature, broadcasting is episodic, fragmented, ephemeral [...]. This mismatch between the demands of science and the ability of broadcasting to meet them creates many profound problems in communicating the significance and excitement of scientific discovery to a lay audience."[1]. But, in a radio programme on science, "good broadcasters will rely heavily on analogies to stimulate the imagination. It is not a very precise way of communicating, but it can be very evocative"[2]. A radio broadcast has therefore many limitations and many advantages: for our purpose here, it can represent a possibility for the listeners to express their feelings about science, emphasising the emotional aspects rather than the rational aspects of their personal relationship with science.

Indeed, one of the main problems concerning science communication is a two-sided gap between the scientist and the public. On one side stands the public, for whom the scientist speaks in an arcane and barely understandable language from an unreachable research laboratory, in a separate world. This leads to a perception of the scientific work as the main source of problems associated with modern life-style, or, even worse, to a loss of interest in scientific issues (as if they were not driving changes so forcefully). On the other side stands the scientist: quoting the French physicist Jean-Marc Lévy-Leblond, "If science communication is so inefficient, couldn't it be because it answers questions that were never expressed by the 'public', instead of grasping the real ones – even if their meaning may be confused and mostly implied?"[3]. As a matter of facts, the occasions when a scientist can have a direct contact with the public, and be exposed to questions, comments or criticisms, are very few both for the science student and for the professional researcher. Moreover, the highly demanding effort to devote time and thought to the communication of one's scientific work to the general public, is often not sufficiently rewarded by the scientific community itself. This is particularly true in Italy, characterised by a traditionally humanities-oriented culture and a lack of university programs devoted to science communication (with the exception of the newly created Master in Science Communication in Trieste[4]), but can be extended, with various corrections, to other European countries, among which the activism of British scientists in taking part in public debates is the only notable exception.

A scientific communication event where the interaction between the scientists and the public is possible (such as a conference or, as in our case, a radio broadcast with phone-ins), should therefore aim at making both sides willing to get better acquainted with the other's interests and concerns, and take this opportunity to educate both the public, and the scientists involved, not about science in general - a rather unachievable aim - but to paying due attention to what the other is actually saying.

In this paper, a series of radio broadcasts devoted to radiation and their application in different fields is presented. A brief description of *Radio Popolare* and of the weekly magazine *Il ciclotrone* is presented. Three live "special issues", broadcast every two weeks (5 and 19 November 3 December 1998) within *Il ciclotrone* are analysed. The content of the presentations and explanations by the scientists during the broadcasts are only outlined, and the attention is focused on the questions the listeners asked the scientists.

The broadcasts here presented are intended as preliminary experiments. They will represent the basis for the development of a methodology intended to exploit specific features of the radio for understanding public perception of science and improving the quality of science communication. Due to the inevitably limited number of questions and to their highly scattered nature, a quantitative, statistical analysis cannot be conducted, even when, as prospected, the same approach will be systematically extended to other fields of science and to other radio channels belonging to the Network of Radio Popolare. Indeed, these types of programmes have to be regarded more as live performances than well-planned and organised ones, thus emphasising the spontaneous reactions of the public. In the following, a qualitative analysis is therefore attempted, with the main objective of understanding how these types of interactions could help the scientific community to grasp and interpret the type of information needed by the audience.

2. RADIO POPOLARE AND THE WEEKLY SCIENCE MAGAZINE *IL CICLOTRONE*

2.1 Radio Popolare, Milan (Italy)

Radio Popolare was founded in January 1976 as a "community radio", broadcasting in Lombardy, the richest and most populated region of Italy. It broadcasts mostly news, culture and debates (with phone-ins). At first a co-operative with few underpaid workers and many unpaid volunteers, it is now a company with a staff of 45 people (one third of whom are professional journalists), and with about 150 external collaborators covering specific topics and expertise. Approximately 60% of its stock is owned by over 12,000 shareholders, the rest by the co-operative. Revenues are evenly split between advertising and subscriptions. 13,800 listeners support the radio by freely paying an average annual fee of 180 dollars. In the last five years, Radio Popolare has built a network all over Italy, supplying news and programmes by satellite to 20 smaller local radios. The radio has an average audience in Lombardy of 250.000 listeners a day, with peaks during the news. Most of them (45%) are in the age range 25-44, with middle or higher education curricula.

2.2 Il ciclotrone

Il ciclotrone is a weekly magazine, one hour long, devoted to science and technology. It was started in 1986 by one of the authors (S. Coyaud) and since then has been a regular appointment for the listeners. It is edited by a journalist (S. Coyaud) and a researcher (M. Merzagora) and relies on a pool of experts, doing physics, astrophysics, biology, maths (no chemistry, regretfully), linked by a common taste for science communication and story-telling. The programme attempts to tackle hard science lightly but without oversimplifying (according to Albert Einstein's *motto* that "We should make things as simple as possible, but not simpler").

Apart from few series - on climate sciences earlier this year, or recently on radiation - the format is flexible. Scientific conferences and events open to the public are announced, books reviewed, and one or two core issues discussed with specialists.

During the years, *Il ciclotrone* has evolved. Some aspects, however, remain unchanged. In order to exploit the specific features of a radio broadcast as much as possible, *Il ciclotrone* is often conceived as a conversation between the audience and the scientists in the studio. As opposed to printed media, the radio does not need a reporter: the authors of scientific researches can report on their own work, and the journalist tries to awaken or summarise public curiosity. Moreover, by allowing non-filtered phone calls, the listener can talk directly to a Nobel laureate, or ask an expert about the safety of frozen foods or the means to get rid of space debris and so on. *Il ciclotrone* is constantly seeking the participation of the audience: technology – whether space travel, Information Technology or biotech - kindles heats debates, and so do topics whose social impact is clear, e.g. genetics, neurochemistry of illegal drugs, greenhouse gases and atmospheric chemistry, etc. When treating so called hard sciences, e.g. basic research in physics or molecular biology, the call for participation is somewhat less successful, but over the years listeners' participation has been considerably improving.

Besides merely numerical data on the audience, one of the main assessment of the success of the program is, in the authors' opinion, the satisfaction of the invited scientists with the opportunity to communicate with an intelligent if untrained audience, showing true interest and curiosity for their work.

3. AWASH IN A SEA OF RADIATION

To celebrate the centenary of the discovery of radium, several issues of *Il ciclotrone* are devoted to radiation and to how radiation is involved in various aspects of our daily life. Three issues have been already broadcast at the moment this symposium is being held. Common aspects of the programs were the definition of the technical terms (e.g., dose, radioprotection, e.m. field), and a brief historical background pointing out the evolution of scientific knowledge on the subject. After some 20 minutes of presentation by two or three hosts, the phone-ins started and more specific topics were then selected on the basis of the listeners' requests. Here is a brief description of the content of the broadcasts.

1) Introduction: radiation effects and radioprotection.

Invited scientists: G. Tosi, professor at the Specialization School in Medical Physics, University of Milan, head of the Radioprotection Unit at the European Institute of Oncology (IEO, Milan); G. de Luca, physician specialised in occupational medicine at the National Agency for the Protection of the Environment (ANPA).

Contents: introduction to the term "radiation" and related quantities; introduction of the notion of natural background; discovery of X-rays and natural radioactivity; first acknowledgements of health hazards; definition of stochastic and deterministic effects; basic principles of radioprotection; Italian and European legislation on radioprotection.

2) Radiology and radiotherapy

Invited scientists: R. Orecchia, professor at the Faculty of Medicine, University of Milan; G. Pedroli, director of the Sanitary Physics Division at the Niguarda Hospital, Milan.

Contents: medical applications of radiation; a brief history of radiology and radiotherapy; costs-benefits analysis in diagnostic and radiotherapy; evolution of different techniques, from their origins to recent advancements.

3) Non ionising radiation

Invited scientists: P. Vecchia, director of the Radioprotection Unit at the National Health Institute (Istituto Superiore di Sanità, ISS), president of the Italian Association for Radiation Protection (AIRP); L. Venturi, scientific director of the environmentalist organisation *Legambiente*; M. Fronte, journalist and science writer[5], Zadig Agency, Milan.

Contents: definition of non ionising radiation; present knowledge on health effects of electromagnetic fields; environmental problem of electromagnetic pollution and attitude of various environmentalist groups; the particular attention that the Italian press devoted to the matter in recent times.

Other broadcasts will follow, concerning other specific application of radiation, such as food irradiation, applications in agronomy, the indoor radon emissions, etc. These are scheduled for the first semester of 1999.

4. QUESTIONS LEADING TO MORE QUESTIONS

"Scientific information must be conceived as a means of spreading questions, - not answers"[6]. Although this statement is probably agreed upon and well understood by most researchers and scientific journalists, the common citizen, as it emerged from the questions analysed, wants to obtain from a scientist unambiguous answers.

Three main types of questions can be identified throughout the three broadcasts: a) questions related to personal problems; b) questions aimed at a better understanding of the general issue; c) questions or comments aimed at giving an interpretation of the public attitude towards radiation exposure.

As expected, the first type was particularly frequent during the broadcast on radiology and radiotherapy: understandably, medical issues are of personal concern to everyone, and the listeners tend to take the opportunity of a radio program to get additional medical advises on a specific disease. These type of questions were of greater interest during the *radioprotection* and *non ionising radiation* programmes: after the general presentation by the scientists, people were asking about the risk of living in a house without foundations located in a volcanic area, of placing "possibly radioactive" heat insulator in the house, of living next to a large antenna ("I am feeling a bit nervous lately: shall my wife blame it on the antenna we have over our roof?"), etc. The listeners were demanding precise answers, numbers, and clear-cut definitions: this is what science, according to its widespread perception, is supposed to provide.

These questions induced most of the invited scientists to devote specific attention to methodological matters, introducing the concepts of stochastic and deterministic effects, of non-threshold effects, etc. heavily relying on analogies with easily understandable hazards. As an example, convincing analogies were the speed limits on freeways to explain how to deal with non-threshold effects in legislation (keeping a low speed does not prevent us from having an accident, but respecting speed limits is in any case a good way to lower the probability of an accident), or the risk of smoking or drinking as an example of stochastic effects (almost everybody knows somebody who has been smoking for years without consequences, and somebody who had lung cancer or cardiovascular diseases due to smoking and drinking). As a matter of facts, the authors had the impression that although the listeners were asking for precise data, answers strictly based on data were not considered satisfactory. "The decrease of the dose limit has not reassured the public and may even have increased anxiety because it revealed uncertainty with regard to risk and triggered controversies among scientists. [...] These reactions to ionising radiation further confirm that fear is actually not related to data but to mental models."[7] Thus explanation of the *methods* adopted in the disciplines described, appeared much more urgent than the actual results of the quoted studies.

It appears that the *statistical* association between exposure and incidence of a disease has to face a natural barrier in the common understanding of radiation risk. The fact that in some cases "... the connection between low-level insult and bodily harm is probably as difficult to prove as the connection between witches and failed crops"[8] is not generally accepted by the public. Moreover, there seems to be a natural "appeal", often mediated by the press, related to not clear-cut conclusions, leading to a rationally unexpected greater impact of so called "phantom risks" (see ref. 9 for a discussion on this subject) with respect to well assessed "real" risks. This tendency is enhanced when the source of risk is ubiquitous, but invisible and undetectable through standard household appliances, as in the case of electromagnetic fields, which are presents in our environment everywhere and everyday of our whole life. The conflict between scientific assertions and public perception of the content of the assertions themselves, is in these cases enhanced by the very different meaning of the world "risk" in the scientific and general public domains, as clearly stressed in the ICRP publication 60[10].

Concerning the relationship between scientific conclusions and reports by the press, several other questions induced the invited scientists to stress methodological issues. During the broadcast on electromagnetic pollution ("electrosmog" is a term which is making headway in the newspaper headlines), three listeners quoted a recent observation of an increased tumour incidence in an area in central Italy (Marche), possibly due to the presence of a large military radar. After epidemiological studies, no increase in tumour incidence was found, but public opinion seemed unconvinced. An explanation of statistical significance, and of the so-called "selective attention" effect was therefore needed. The invited scientists then tried to point out how the aims and constraints of a news report are intrinsically different from those of a scientific research. These interactions between scientists and the audience made clear, in the authors' opinion, that a deeper understanding of the media procedures and choices relative to scientific topics, together with a serious consideration of citizen's concerns expressed by self-organised pressure groups[11] (even when obviously driven by irrational fears), is of uttermost importance in defining the criteria for a successful information on radiation effects.

Other questions were clearly intended to get a better grasp of the problem. Examples are: "What is the difference between a radiograph and a long-distance flight in terms of exposure to radiation?"; "Is the intensity of electromagnetic fields influenced by daily and/or global climate change?"; "Does the increased power of mobile telephones increase the associated risk?"; "Does the absorbed dose accumulate over the years?"; "Why, in the current legislation, professional workers are allowed a higher exposure than the general public?".

In this case, the reactions of the invited scientists were strictly professional: the questions are clear, the underlying concern is explicit and not hidden, and in most cases there is a clear answer to those kinds of questions.

Among this type of questions, two listeners who appeared to have had some professional experience in the past, stressed how the doses presently used for a radiograph are considerably lower than a few decades ago. The scientists answered very correctly, quoting many pioneer radiologists who experienced severe diseases, and stressing how technical improvements and a correct evaluation of the risks involved grew very slowly and are still subject to refinements. Explaining science as a constantly evolving “work in progress”, quoting failures and mistakes as well as successes can be of extreme value for transmitting the correct messages to the public. Indeed, the claim of authority for a scientific statement can inspire distrust in the public, especially if the specific topic is not yet a well established knowledge. On the contrary, making explicit that science is able to explain many things, but not everything, can help shrinking the gap between the scientist and the public, generating confidence and trust.

A third set of questions tried, as requested by the conductor during the broadcasts, to give an interpretation to the often-irrational attitude of the public towards the risk related to radiation exposure. In particular, two listeners proposed the following, interesting arguments: *a)* due to the extremely high incidence of neoplastic diseases, people tend to associate radiation with the pain that cancer treatment inflicts to the patient, with his distress and that of his relatives. Even if in the case of radiotherapy radiation is “good”, an unconscious association is unavoidable. *b)* Concerning electromagnetic fields, the lack of clear cut answers, and the daily exposure to which we are all exposed during our lifetime, generate a state of stress in the citizen. This limits the possibility of adopting a rational attitude toward the problem.

5. CONCLUSIONS AND FURTHER DEVELOPMENTS

The firsts three broadcasts of a series of radio programmes devoted to radiation and its many applications in our daily life were presented. The broadcasts were a first attempt to develop an approach for analysing public understanding of sciences starting from the questions posed to the scientists during a radio broadcast, and the answers of the scientists.

Main advantages of the approach are:

- it allows a direct contact between the public and the scientists, generating confidence and trust;
- it can represent a non-intrusive way to promote public understanding of science;
- it can help educating the scientists to communicate their researches;
- it allows to analyse the spontaneous and emotional feelings of the public toward scientific research, thus representing a possible complement of statistical analyses.

Even considering the limited data set available up to now, the approach described seems to be very promising and a few conclusions can be drawn.

- The dissemination of data and research results is not necessarily reassuring for the population. Often people strongly demand data, but are then disappointed by them, realising that they are much more difficult to "use" than expected. Therefore, the information on radiation related topics should probably focus more on the methodologies adopted in research rather than on their results. Only by clarifying the stochastic nature of low exposure risk, the statistical content of epidemiological studies, etc., a fruitful education of the public seems possible.
- A scientific research and a news report cover the same event in a completely different way. Since the public is exposed to news coverage at first, the mechanisms regulating the work of the media needs to be well understood by the scientific community. In other words, a "wrong" article on a newspaper could be also regarded as a negative experiment, which make us angry but can be very helpful in redirecting our researches.

- The true interrogatives of the public, even when confused and implicit – needs to be carefully considered, also taking into account irrational and emotional aspects, which tend to escape from the quantitative analysis which the scientific community is more likely to accept.

In the future, other specifically designed broadcasts will be edited, transmitted and analysed. Three more programmes on radiation are already scheduled in the next few months, and the same scheme will be applied to other scientific topics, such as biotechnolgies and genetically modified organisms, public founding of scientific research, earth sciences, etc. The same approach will be extended to other local radios of the "Popolare Network", each having peculiar characteristics and a different audience. Also, a retrospective analysis of similar experiences in other European countries would be desirable.

As a larger data base of questions and answer will become available, it will be possible to draw a general scheme on how to exploit interactive radio broadcasts as a mean for understanding public perception of science, and the pros and cons of such approach will be singled out.

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2.7 日本の高等学校における放射線・原子力教育の現状

PRESENT STATUS OF RADIATION AND NUCLEAR EDUCATION AT HIGH SCHOOL IN JAPAN

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日本原子力学会内に設けられている「原子力教育・研究」特別専門委員会では、平成 8 年にその活動の一環として高等学校で用いられている理科および社会の教科書の調査を行った。その結果、エネルギー、放射線および原子力関連の記述のより一層の充実を求める必要があるとの結論に達した。ここではその調査結果の概要を報告し、関連する学習指導要領の改訂に関する要望を述べる。

1. はじめに

環境、エネルギー問題に関してわが国の置かれた状況を考えると、原子力発電の一層の安全性を確保しつつ，使用済み燃料の処理・処分技術を高度化して核燃料サイクル技術の完成を図ることが急務である。このためには、原子力に対する国民の正しい理解を得ると共に、この分野に優秀な技術者を確保していくことが不可欠である。

ところが、現在世の中には若者のいわゆる「理科離れ」、「工学離れ」と呼ばれる現象が見られ、加えて原子力の産業としての定着が進むにつれて「原子力」という言葉が若者に対して、これまでほどに新鮮かつ魅力的な響きを与えなくなってきている。また原子力の安全性に関して、原子力関連技術者・研究者が払っている多大の努力が国民に伝達されておらず、このことが国民の不安を誘発することにもなっており、人材確保に困難を来す遠因ともなっている。このような状況にあって、原子力教育にかかわる大学等の関係者は将来に強い危機感を抱き、初等・中等教育における理科・社会教育ないし原子力教育の改善が必要であると認識し、上記教育に用いられる教科書の調査を行った。

2．高等学校教科書（公民，地理，理科）における原子力関連の記述の現状と問題点

1）社会系教科

（1）社会系教科書（現代社会，政治・経済，地理Ａ）において原子力発電は，①資源・エネルギー及び②環境，の視点から記述されている。前者については，地球的課題としての資源エネルギー問題，国際社会の動向，現代の経済や国民生活等との関連において論ぜられている。一方，後者については，技術の発展が地球環境の破壊をもたらす一例として，チェルノブイリ発電所の事故を取り上げて論じているものが多く，さらには核実験による環境汚染の問題に言及しているものもある。

（2）一般に原子力発電の問題を社会系教科書で扱うとすれば，各発電方法の長所，短所を客観的に併記した上で，その選択について考えさせる立場を取るのが適切と考えられるが，現行教科書ではこの点から見て妥当性を欠くものが見られる。その多くは，記述に公正を欠き，原子力発電の短所の説明には力を入れているが，長所については極めて簡単な説明にとどめるか，あるいは記述を省略している。これらのケースでは執筆者の原子力発電に対する否定的な主観が根底にあり，それが使用された語句の端々に表れているように感ぜられることが多い。例えば，①極端な事例を示し，あたかもすべてのケースがそうであるかのような印象を与える記述，②曖昧でイメージを損なうような語句や表現を用いている記述，③根拠が不明確であったり誤って伝えられた海外の原子力事情の一面を強調する記述等が多く見られる　。

（3）より複雑な状況を生じているのは，問題の多くが表現上の微妙な言葉の綾に起因している点である。すなわち，不適切と判断される表現のうち，明らかな誤りと断定できる例はむしろ少数で，多くは原子力発電に関する表現に微妙な偏りがあり，記述全体のトーンが感性的又はバランスを欠くと判断される状況である。したがってたとえ一部の語句を訂正しても，全体のトーンはほとんど変わらない。教科書の記述としては本来，より客観的で，中立的な立場からの記述が必要であると判断され，この状況を是正するためには記述の大幅な改訂が必要であると考える。

2）理科（「総合理科」の指導資料を含む）

（1）理科教科書では，物理及び総合理科（指導資料）の中で放射線や原子核，さらには原子炉や原子力発電についてある程度詳しい記述がある。これらは一部を除けば社会系教科書に比べ客観的で，ある程度正しい理解が得られるよう配慮されているとの印象を受ける。記述もバランスが取れており，例えば放射線の危険性について述べると同時にその利用についても記述されているという具合である。

（2）一部の教科書で原子力発電の安全性や放射性廃棄物の処分に関連して，社会系教科書と類似した記述が見られる。これは物理の学習指導要領の中で，「放射能及び原子力の利用とその安全性の問題にも簡単に触れること。」と書かれていることに従ったものと推定されるが，その内容に「理科」の立場から具体的な記述がなく，「問題あり」というような簡単な表現で終わってしまっている。

（3）物理の教科書や総合理科の指導資料の中に見られる放射線や原子力発電などに関連した記述を詳細に見ると，用いられている数値や単位，用語や図面等に誤りや適切でないものが幾つか見受けられる。

（4）化学ＩＡでは５教科書中３点に，生物ＩＡでは５教科書中１点に，地学ＩＡでは１教科書中１点に，環境の保全と資源利用に関連した記述があり，その中で一部原子力発電やウラン資源に関連した事項が取り上げられている。しかし地学ＩＡを除き，その内容は，社会系教科書と類似して極めて希薄であるか，あるいは記述がないに等しい。例えば，化石燃料の使用について温室効果や酸性雨の問題が取り上げられておらず，またそれと対比する形での原子力発電の位置付けがなく，エネルギーの新技術としても原子力に関する記述が全くない（化学ＩＡ）という例もある。

（5）化学ＩＢでは１１教科書のいずれにおいても原子力及び放射線関連の記述は見られない。生物ＩＢの８教科書ではいずれも原子力に関連した記述は見られないが，放射線について突然変異に関連して触れているのみである。地学ＩＢでは４教科書中１点にウラン資源に関連する記述が見られるが，その内容は極めて貧弱である。

（6）理科教科書に関連する最大の問題点は，放射線，放射能や原子力について物理と総合理科（指導資料）の中である程度取り扱われているものの，化学や生物，地学では全く記述されていないか，ほとんど記述がないに等しいことにある。これは生徒が物理を選択しない場合，放射線や原子力について正しい理解を得る機会がないことを意味している。さらに，平成６年度における高等学校理科の全教科書中に占める物理（ＩＡ＋ＩＢ）の採択率は１１％にすぎないこと　，総合理科においては教科書すらないこと，また全体の６０％近くを占める化学ＩＢ（３３．８％）と生物ＩＢ（２４．３％）　に放射線や原子力に関連する記述がないに等しいことを考えると，次世代を背負って立つ若者に与えるその影響は深刻である。これは，ひとり原子力関連分野に対する影響ばかりでなく，ミクロの視点が必要とされる先端科学技術すべてについて同様の影響をもつと思われる。

３．学習指導要領改訂の要望

既に述べたように，我が国において原子力発電は基幹エネルギー源として他に変えがたい地位を占めるに至っており，当面この原子力エネルギーを堅持しながら，核燃料サイクルを健全に完結させていくことが，今後の命題である。そのうえさらに長期的な視点に立って，地球環境の保全，エネルギー資源の確保と有効利用を考えながら，我が国がどのようなエネルギー源の選択を行っていくかは，我が国の将来の発展にとって極めて重要である。

一方，原子力に関連する諸問題には国民の関心も高く，種々の議論があり，原子力は単に科学技術の問題であるばかりでなく，大きな社会問題となっている。

このような状況にあって，我が国の今後の原子力の利用に当たっては，原子力に対する国民の正しい理解を得ながら，それに基づいた適切な判断を求めていくことが不可欠である。このために高等学校における理科と社会の科目の中で取り上げられる原子力に関連した教育が極めて重要な役割を担っている。この期待される役割を果たすためには，現在の学習指導要領の言葉を借りれば，「自然の事物・現象についての理解を図り，人間と自然とのかかわりについて認識させる。」中で，原子核や放射線，放射能に関する理解を深め，「人間尊重と科学的な探究の精神にもとづいて広い視野に立って現代の社会と人間について理解を深めさせる」過程において原子力利用技術に関する正しい知識を得させ，「現代社会の基本的な問題に対する判断力の基礎を培う。」と共に「国際社会に生きる日本人としての自覚と資質を養う。」ことが必要である。

しかしながら，現在の社会系教科書及び一部の理科教科書中での原子力に関する記述は偏って，バランスを欠き，前述の目標を達成するには不十分であると考える。社会系教科書における原子力に関する記述の問題点は既に述べたとおりであり，これらがより客観的で中立的な記述に改善され，その本来の目標が達成されるよう学習指導要領及びその解説の中で指導がなされることを希望するものである。

社会系教科で原子力のように高度に技術的な問題を取り扱う場合には，原子力に関する正しい科学的理解を生徒がもっていることが不可欠であり，誤った知識に基づいては，正しい判断を下すことは困難である。この点に関連して，原子力について正しい科学知識をもつ日本の高校生の割合が国際的に比較して著しく低いという最近の調査結果　に深い危惧の念を抱くものである。

原子力に関連した科学的理解を深めさせるのは理科教科においてであると考えられるが，既に述べたように，現在の理科教科書及び指導資料における放射線，放射能や原子力に関する記述は一部の教科（物理と総合理科）に限られており，これらの科目を選択しない大多数の生徒は放射線や原子力に関する科学的理解を得る機会が極めて乏しい状況となっている。このことが上述の高校生のエネルギー教育の調査結果にも如実に表れたものと推定される。現代の科学・技術の根幹をなす原子・分子に関する理解を生徒に求める上で，放射線や放射能の知識は不可欠のものであり，その記述が物理及び総合理科以外にほとんど見られないことは憂慮するべき状況と考える。理科教科書についてこの点の改善を図り，生徒の科目の選択にかかわらず，放射線，放射能や原子力に関する科学的な理解がある程度得られるよう，前記二科目以外の教科書においても関連事項の記述とその内容の充実を強く望むものである。

参考：　高等学校教科書中の原子力に関する不適切な記述例

以下には調査を行った高等学校教科書（平成５年検定済み，公民，地理，理科）についてすべてを網羅するものではなく，一部の例のみを示す。

１）極端な事例を示し，あたかも全体がそうであるかのような印象を与える記述

①「いったん事故が起こると，放射能の及ぼす影響は大きく，放射性物質によって地球上はおおわれてしまう。」
「高等学校　政治・経済」，第一学習社，ｐ．１０１．

②「核燃料輸送中の事故や核ジャックの可能性があること，原子力関連施設に対する軍事攻撃を受けた場合，通常兵器によるものでも核戦争なみの放射能被害を生じること」
「現代社会」，山川出版社，ｐ．４９．

③「また原子力発電に利用された冷却水や洗浄水なども沿岸の海に放出されている。このような累積する核廃棄物の処理は，運転中の放射能もれや核燃料の再処理工場の安全などとともに人類を核汚染から守るうえで重要な課題である。」
「地理Ｂ」，教育出版社，ｐ．１１５．

④「核分裂による放射能は，直接人間の生命を奪うほか，その放射能によって白血病やガンなどの治癒の困難な病を引き起こし，胎児にも影響を及ぼす。さらに，動植物が被爆した場合でも食物連鎖によって人間の体内に蓄積され，人間に被害が生じる。」
「地理Ｂ」，教育出版社，ｐ．１１４．

⑤「放射能漏れだけでなく，使用ずみの核燃料を含む放射性廃棄物の処理や廃炉の解体などに関連して，安全性を確立するじゅうぶんな見通しがいまのところ立っていない」
「現代社会」，三省堂，ｐ．７７．

⑥「原子力発電所から排出される使用済み燃料やその他の放射性廃棄物は，焼却できないため特殊容器に入れて保存することになっているが，それらは増加する一方であり，最終的な処理技術も確立していないことなどから……」
「新政治・経済」，清水書院，ｐ．１３７．

⑦「放射線の毒性を解決する技術的方法は確立されておらず……」
「新高校現代社会」，一橋出版，p．１９．

２）曖昧でイメージを損なうような語句（下線部）や表現を用いている記述

①「爆発したチェルノブイリ原発の内部」
「新高校現代社会」，一橋出版，p．１９．

②「しかし，核分裂により生ずる「死の灰」の処理など，安全性をめぐる問題が他の代替エネルギーとは異る点であり……」
「新高校現代社会」，一橋出版，p．１１．

③「関西電力美浜原発２号機で，核燃料を冷やす１次冷却水が大量に漏れだし……」
「新高校現代社会」，一橋出版，p．１１．

④「「死の灰」のひろがりは風向に左右された。チェルノブイリに東京を重ねると……」
「現代地理Ｂ」，清水書院，p．１８３．

⑤チェルノブイリ事故に関連して
「……原子炉が爆発する事故が起こった。被災者の数は数十万とも数百万ともいわれる。原子炉は２人の遺体とともにコンクリートで固められ……」
「高校物理ＩＡ」，新興出版社，啓林館，第３部冒頭写真の説明.

⑥「原子力には原子炉の爆発や放射線漏れをいかにして防ぐかという大きな課題がある。」
「高校物理ＩＡ」，実教出版，p．８７．

３）根拠が不明確であったり誤って伝えられた海外の原子力事情の一面を強調する記述

①「１９７９年のアメリカのスリーマイル島の原子力発電所の事故でも，周辺地域に多大な放射能被害をもたらした。」
「高等学校　現代社会」，数研出版，p．２５．

②「使用済み核燃料の廃棄物が年々増加し，ヨーロッパでは，地下の岩塩鉱山跡や大西洋の深海底への投棄が実施されている。」
「地理Ｂ」，教出出版，p．１１５．

③「アメリカでは，スリーマイル島原子力発電所の新設を認めない方針をとってきたが，代替エネルギーの見通しができてから廃止という形で見直しがおこなわれ，１９９１年原子力発電所の増設を発表した。」

「現代社会」，実教出版，ｐ．４４．

チェルノブイリ事故に関連して

④「このチェルノブイリ事故は野菜，牛乳，小麦などの食物を汚染したばかりでなく，事故後５年以上たっても白血病や甲状腺ガンなど深刻な後遺症に苦しむ人びとを増加させている*)。」

「現代社会」，三省堂，ｐ．７６．

⑤「甲状腺やリンパ腺の異常，白血病や各種のガンが多発している*)。」

「地理Ｂ」，東京書籍，ｐ．１３４．

⑥「チェルノブイリ原子力発電所の事故によって，大量の放射線物質が大気中に放出され，周辺地域では甲状腺癌で苦しむ子供がふえている*)。」

「新詳地理Ｂ最新版」，帝国書院，ｐ．１０２．

⑦「……その後の放射線被曝などによる死者は７０００人とする報告もある。」

「現代社会」，三省堂，ｐ．７６．

註

１）下線および波線は本書作製にあたり付したものである。

２）＊国際原子力機関（ＩＡＥＡ）の要請を受けた国際諮問委員会（ＩＡＣ）の調査結果によれば，チェルノブイリ事故の放射線被ばくを原因とする白血病やガンの発生はこの時点（１９９１年）までに確認されていない。なお，その後の調査によれば，１９９４年の時点で事故の放射線被ばくによる影響として白血病が増加していることは確認されていない。ベラルーシ及びウクライナとロシアの一部地域で甲状腺疾患が増加しているが，これとチェルノブイリ事故からの被ばく線量との関係については，今後の調査と研究を待つ必要があるとされている。

2.8 PRESENT STATUS OF RADIATION EDUCATION IN KOREA

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ABSTRACT

Korea is one of the world's most dynamic countries in the use of nuclear energy for power generation. Fourteen NPPs are currently in commercial operation and six additional plants are under construction. According to the country's Long Term Power Development Plan, ten more NPPs will be constructed by 2015. The Korean government has experienced difficulties in acquiring nuclear facility sites and is, therefore, well aware of the importance of public acceptance. Many programs have been initiated to educate the public on the values and benefits of nuclear energy. This paper discusses one of the long-term programs that focus on education for future generations, which include education programs for teachers and students, nuclear facility visit programs, seminars and workshops, scholarship programs, and school curriculum reorganization activities.

1. INTRODUCTION

Korea is one of the world's most dynamic countries in the use of nuclear energy for power generation. Since 1978 when the first commercial NPP (nuclear power plant) Kori #1 unit began operation, the nuclear power generation has been vitalized and currently fourteen NPPs are in commercial operation and six additional plants are under construction. According to the country's Long Term Power Development Plan, ten more NPPs will be constructed by 2015.[1)]

Along with the nuclear power generation, the application of radiation and radioisotopes (RIs) has contributed to the development of industries, scientific research, disease diagnosis and therapy. The areas of application have diversified in parallel with the nation's economic development and the enhancement of the quality of life. As of December 31, 1997, the number of institutions using radiation and RIs had reached 1,315.[2,3)] Table 1 shows the current radiation and RI application statistics.

Table 1. Radiation & RI Applications Statistics in Korea.

Category of Organization		Type of Use		Total	# of Users
		RI	Rad. Gen.		
Industrial Firms	General	536	347	883	800
	N. D. T.	35	34	69	35
	Sales	22	4	26	23
	Subtotal	593	385	978	858
Hospitals		111	40	151	111
Education & Research Org.		204	195	399	339
Others		5	2	7	7
Total		913	622	1,535	1,315

The Korean government has experienced difficulties in acquiring nuclear facility sites, especially radioactive waste management facility sites. From this experience, the importance of public acceptance (PA) was understood and many programs have been initiated to educate the public on the values and benefits of nuclear energy.

One of the long-term PA activities is education programs for future generations. This paper reviews the current status of atomic energy education in Korea and introduces the current activities on the topic.[4)]

2. OVERVIEW OF CURRENT SCHOOL CURRICULUMS

Textbooks play important roles in the education of the youngsters. Especially in Korea, the authority of textbooks is said to be comparable to that of the Bible. The sequences and contents of school education follow those of textbooks and every detail of textbook has important meaning.[5)] Furthermore most schools adopt almost same curriculums and textbooks.

Elementary school (6 year course) curriculums do not cover much of atomic energy. The "Society" subject introduces atomic energy as one of power sources and "Society Investigation" subject deals with the annual electricity generation statistics and the comparison of power sources : hydroelectric, fossil fuel, atomic, etc. It is strange to note that the symbol of power plant does not appear on maps.

Middle school (3 year course) curriculums cover basic knowledge of atomic energy and nuclear power generation in "Science", "Technology", "Industry", and "Environment" subjects. The "Environment" subject deals with the comparison of the fossil fuel and nuclear power plant and the radioactive waste management problems. The "Society" and "Politics" subjects deal with nuclear power generation statistics and the importance of nuclear Non-Proliferation Treaty. It is notable that there are room for role play on the topic that "If radioactive waste management facility is built in our village "

High school (3 year course) curriculums cover comprehensive knowledge on atomic energy uses. The basics of atomic physics such as atomic structures, radiation, RI applications, chain reactions, PWR & PHWR, nuclear fusion, radioactive waste management, are covered in "Science", "Physics", "Chemistry", "Mechanics", "Industry", etc. The statistics of energy resources are dealt in "Geography". The "Ethics" describes the KEDO activities positively in relation to the reunification of Korean Peninsula. The "Electric Power" subject covers the comprehensive knowledge on NPP. The radioactive waste management problems are dealt in "Politics" and some discussion topics related to atomic energy issues were provided in "Literature" and "Narration" subjects. The current educational curriculums and those related to atomic energy were tabulated in Table 2 and 3.[6)]

Table 2. Statistics of Subjects/Texts Related to Atomic Energy(AER).

	# of subjects		# of texts	
	Total	AER	Total	AER
Elementary School	29	5	38	5
Middle School	21	12	168	44
High School	77	42	310	181
Total	127	59	516	230

Table 3. Subjects Related to Atomic Energy.

	Subjects related to atomic energy
Elementary School	Society 1 2 3, Living Guide, Maps
Middle School	Environment, Korean Language, Society, Ethics, History, Industry 1 2 3, Science 1 2 3, Maps
High School	Industrial Chemistry, Physics, Chemistry, Industrial Mechanics, Geology, Introduction to Industry, Politics, Ethics, Power Generation, General Electricity, Food, Biology, Fishery, Environment Technology, Society, Physics Experiment, History of Science, Literature, Writing, Geography, Society & Culture, Narration, Industry, Technology, Geology 1 2, Biology 1 2, Physics 1 2, Chemistry 1 2, Maps, etc.

3. CURRENT ACTIVITIES ON NEXT GENERATION EDUCATION

Next generation education program is composed of lecture courses, nuclear facility visit programs, seminars and workshops, scholarship program, and school curriculum reorganization program.

The purpose of lecture program is to disseminate scientific information on the peaceful use of nuclear energy. This program is composed of lecture courses for teachers and students, and nuclear expert's lectures at schools. In 1997, we held 173 lecture courses and 17,029 teachers and students participated.

In order to build the familiar and sound image on NPPs, nuclear facility visit program is opened and nuclear science camps for students, workshops for professor are organized. The detailed statistics of above programs is summarized in Table 4.

In addition to the above activities, educational aids such as educators' guides and audio-visual materials are prepared and distributed to help them learn and teach nuclear energy extensively and correctly. To inspire an appetite for writing and to foster culture in the youngsters, we invite middle and high school students to enter writing and drawing contests. Contest entrants will have chanced to win overseas trips.

Table 4. Next Generation Education Statistics.

Program	1996		1997	
	# of courses	# of persons	# of courses	# of persons
Lecture Courses	28	5,306	173	17,029
- Teachers	20	3,594	16	2,083
- Students	8	1,712	21	7,383
- Nuclear expert lectures	-	-	136	7,563
Nuclear Facility Visit	9	600	8	1,042
- University students	4	160	4	160
- High school students	5	440	4	782
Seminars & Workshops	12	635	13	818
- Nuclear science camps	2	160	1	300
- Workshop for teacher	6	435	8	468
- Workshop for professor	4	40	4	50

While providing integrated and systematic educational programs for the youngsters, we try to have school curriculums reorganized to deliver an accurate picture of nuclear energy. As shown in Table 5, there are about 2.4 million students and teachers in Korea. Because of the limitations of manpower and fund, the direct educational approaches such as lecture courses, nuclear facility visit program, etc. reach only 1% of students. Thus most emphases are on school curriculum reorganization program.

Table 5. Number of Schools, Students, and Teachers.[7]

	Elementary	Middle School	High School
# of Schools	5,721	2,720	1,892
# of Students	3,800,540	2,379,963	2,331,725
# of Teachers	138,670	97,931	104,404
Total	3,944,931	2,480,614	2,438,021

As shown at Table 2 and 3, subjects and textbooks related to atomic energy are surveyed and requests for corrections regarding the negative or wrong descriptions, are made to the Ministry of Education. In 1996 for the 18 requested subjects, 6 corrections were made.

Besides the curriculum survey, Next Generation Education Committee was formed to converge the opinions on the atomic energy education, which is composed of educational and nuclear experts. Nuclear facility visits for textbook authors are organized to give them the right knowledge on atomic energy use so that they may describe atomic energy matters objectively. Also supportive activities such as preparation of educational aids and arrangement of topical meeting on atomic energy, are supplied.

4. CONCLUSIONS

In order to bring up our future generations to understand the peaceful use of atomic energy, the proper educations on the topic are very important. This paper reviewed the present status of school education in Korea.

This paper introduced direct educational approaches such as lecture courses, nuclear facility visit program, etc. and indirect educational approaches of school curriculum reorganization program. Considering the efficiency of education, which can be defined by the influence of education, it is concluded that most emphasis should be made to school curriculum reorganization program.

ACKNOWLEDGEMENT

The author wishes to acknowledge the support of the MOCIE and the OKAEA for providing valuable materials.

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2.9 STATUS OF RADIATION EDUCATION AND TRAINING IN THE PHILIPPINES

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ABSTRACT

There are three major sources and levels of obtaining radiation or nuclear education and training in the Philippines: the secondary schools or high schools; colleges and universities; and training courses in nuclear science and radiation protection offered by government agencies such as the Philippine Nuclear Research Institute (PNRI) of the Department of Science and Technology and the Radiation Health Service (RHS) of the Department of Health. This paper summarizes the status, some of the activities and some of the problems of radiation education in the Philippines.

1. INTRODUCTION

At the present time, there is a general negative public perception about anything associated with the word "radiation" or "nuclear". The most comprehensive and effective way to counteract this negative perception would be to educate the young generation in schools and introduce nuclear science topics in all levels of the educational system. Radiation and nuclear science topics are not taught in the elementary school. There is a need to upgrade and effectively implement nuclear science education in the secondary level or high school. There are 6,673 schools offering secondary education all over the Philippines, and there are around 100,000 high school science teachers.

The Philippine Nuclear Research Institute (PNRI), an institute under the Department of Science and Technology (DOST), is the sole government agency in charge of matters pertaining to nuclear science and technology, and the regulation of nuclear energy. The PNRI is tasked with fast-tracking nuclear education and information, together with the Department of Education, Culture and Sports (DECS), the Commission on Higher Education (CHED), and some other government agencies which constitute the Subcommittee on Nuclear Power Public Education and Information, by virtue of Executive Order 243 enacted by then President Ramos on May 12, 1995. This Executive Order created the Nuclear Power Steering Committee and the Subcommittee on Nuclear Power Public Education and Information is one of the subcommittees under it.

The only other govenment agency that provides radiation education/radiation protection training is the Radiation Health Service (RHS), an agency under the Department of Health responsible for licensing users of X-ray machines. RHS provides radiation protection training to X-ray technicians and users.

2. PRESENT STATUS OF RADIATION EDUCATION/TRAINING ACTIVITIES

2.1 Secondary School or High School Radiation Education

The system of secondary school or high school education in the Philippines has a duration of four years; other countries have five or six years. Secondary education follows the completion of six or seven years of elementary education. The secondary school science education program consists of General Science (First Year), Biology (Second Year), Chemistry (Third Year) and Physics (Fourth Year). Each course is taught for two periods equivalent to 80 minutes per day, with a credit of two units. Radiation and nuclear science/ technology including nuclear power are taught mainly in the fourth year science and technology curriculum, under Physics. In the general and specific learning competencies for fourth year high school Physics, radiation and nuclear science topics including nuclear power are taught last, under the chapter on "Matter and Energy." As published by the Bureau of Secondary Education, of the Department of Education, Culture and Sports, Table 1 lists the General and Specific Learning Competencies under "Matter and Energy," which is the last chapter to be taught in the fourth year high school science and technology curriculum.[1]

Table 1. General and Specific Learning Competencies Under "Matter and Energy"[1]

VII. Matter and Energy

1. Demonstrate understanding on the dual nature of matter and energy
   - 1.1 Explain photoelectric effect.
   - 1.2 Use the photon theory to explain fluorescence and the principles of a photo cell, photovoltaic cell and laser.
   - 1.3 Restate the meaning of the dual nature of matter and energy in one's own words.
   - 1.4 Explain Einstein's matter-energy equivalence, mass defect, and nuclear binding energy.
   - 1.5 Differentiate nuclear fission, chain reaction and fusion.
2. Manifest scientific thinking on nuclear radiation.
   - 2.1 Recognize the contributions of Becquerel, Pierre and Marie Curie on radioactivity.
   - 2.2 Distinguish three types of radiations given off by radioactive substances and their effects on living things.
   - 2.3 Write equations on nuclear reactions.
   - 2.4 Cite some uses of radioisotopes in medicine, agriculture and industry.
   - 2.5 Explain the principle of radiation safety.
3. Understand basic physics principles of a nuclear power plant and a nuclear weapon and their effects on man and the environment.
   - 3.1 Compute the energy released in a nuclear reaction.
   - 3.2 Describe the important features of a fission reactor.
   - 3.3 Explain the fission and fusion processes in nuclear weapons.
   - 3.4 Discuss environmental effects of nuclear reactors and weapons.
   - 3.5 Evaluate the findings made by scientists, environmental experts and other technocrats on the use of nuclear power in the Philippines.
4. Explain energy and interactions as unifying concepts in physics.
   - 4.1 Describe and differentiate some elementary particles.
   - 4.2 Explain four basic interactions.
   - 4.3 Discuss briefly the physicists' search for unification in physics.

The main problem of radiation education in the secondary or high school level is that many high school science teachers omit teaching radiation and nuclear topics since they are found in the last chapter, and taken up towards the end of the school year. In addition, a vast majority of the science teachers do not have the necessary qualifications, competence and training to teach these topics. In general, the situation in the Philippines is that only around 20% or even less, depending on the field of science, of high school science teachers are qualified to teach these subjects. This means, for example, that many of the high school Physics teachers are not actually Physics majors. To solve this problem there is an urgent need to educate and train science teachers in order to give them enough confidence to teach nuclear science to their students. There is also a need for the availability of good audio/visual teaching aids that would make radiation and nuclear science topics interesting and understandable. These would include teaching modules complete with visual aids such as transparencies or tape slides, and computer-aided instruction for use in those schools where computers are available to the students. Another approach to solve this problem would be to introduce nuclear science topics in the present secondary school curricula, not only under Physics (Fourth Year) but also in the lower years as well. Some possible entry points for nuclear science topics are shown in Table 2.

Table 2. Some Possible Entry Points for Topics on Radiation and Nuclear Science in the High School Curricula[2]

SCIENCE SUBJECT	POSSIBLE ENTRY POINT
General Science (First Year High School)	Topic on Energy - under forms and transformations of energy, and sources of energy, nuclear energy could be introduced
Biology (Second Year High School)	Topic on Genetics - under gene mutation, radiation could be introduced as producing better strains of plants, as used in mutation breeding
Chemistry (Third Year High School)	Topic on Inside the Atom - under structure of the atom and subatomic particles, radioactivity and transmutation of the elements could be discussed
Physics (Fourth Year High School)	Topic on Matter and Energy - this is the main entry point of topics on nuclear science, nuclear power plants and radiation safety

2.2 College or University Level Radiation Education

In the Philippines, not all curricula for a Bachelor of Science college or university degree incorporate nuclear science/technology as a one semester course (consisting of 3 units). Although recommended by the Technical Panel of the Commission on Higher Education (CHED), it is not a requirement but the option of a particular school to include nuclear science and technology topics as a one semester course in some Bachelor of Science curricula. For example, the B.S. Physics curriculum may include one semester of Nuclear and Particle Physics; the B.S. Chemical Engineering curriculum may include one semester of nuclear chemistry or nuclear chemical engineering. The B.S. Electrical Engineering curriculum includes one semester of nuclear engineering. The B.S. in Radiologic Technology includes one semester of radiation protection. There is only one university offering a masteral degree in Medical Physics, and radiation protection is included as a one-semester course in its curriculum. Although in the past an M.S. Nuclear Engineering degree was offered at the University of the Philippines in preparation for the first nuclear power plant, this M.S. program has been inactive since the government decided not to operate this nuclear power plant.

2.3 PNRI Activities

The Philippine Nuclear Research Institute regularly conducts training courses in nuclear science and technology, and radiation protection to users of radioisotopes in academic and research institutions, hospitals and medical institutions, and different industrial companies. It also conducts training courses in nuclear science and technology for high school science teachers, and college/university faculty. The five-week training courses are: Seminar in Nuclear Science for High School Science Teachers; Nuclear Science for University/College Faculty; and Radiation Cytogenetics Course. Some of the four-week courses are: Radioisotope Techniques Training Course (either for medical, for academe, or for agriculture); Industrial Uses of Radioisotopes Course; and Radiological Health and Safety Course. Two-week courses include the Training Course on Radioimmunoassay, and Radiographic Testing (Nondestructive Testing) Course. A one-week Introduction to Nuclear Science Course is also offered to high school teachers, or university faculty upon request by a particular school or university. A three-day Radiation Safety Course is also offered to industrial companies using radioisotopes in nuclear gauges (for example, level gauges and thickness gauges), to hospitals, and to research institutions.

Some of the common topics discussed in these training courses are: (a) Sources of Radiation; (b) Radioactivity and Radioactive Decay; (c) Interaction of Radiation with Matter; (d) Radiation Quantities and Units; (e) Radiation Detection; (f) Biological Effects of Radiation; (g) Basic Principles and Concepts in Radiation Protection; (h) Radwaste Management Principles and Practices. In addition, the courses for teachers would include topics on nuclear power and nuclear energy.

Up to the present time 6,959 have received some radiation education/training from the PNRI. The trainees include all users of radioisotopes in the Philippines: researchers, practitioners in the medical field and industry, as well as high school teachers and university faculty. Except for those who take the Radiographic Testing (Nondestructive Testing) Courses, the trainees are required to have a minimum of Bachelor of Science degrees in the sciences or engineering. Figure 1 shows the number who availed of training from the PNRI per year, while Figure 2 shows the distribution of these trainees per sector or field (industry, medical, academe, others).

The PNRI also conducts one-day nuclear awareness seminars, held in different high schools, for the students. This seminar usually includes a demonstration of the detection of radiation using a survey meter, as well as the effect of distance on the intensity of radiation. Table 3 shows the number of nuclear awareness seminars per year for the last five years, as well as the number of students per year.

Table 3. Number of Nuclear Awareness Seminars Conducted by PNRI and the Number of Students

Year	1994	1995	1996	1997	1998
No. of seminars	8	12	7	9	7
No. of students	1,135	2,784	2,320	2,167	750

In cooperation with the Radioisotope Society of the Philippines, PNRI developed ten teaching modules in nuclear science for use by science teachers, complete with instructional materials such as script, and transparencies as visual aid. Although these teaching modules had been trialed and received positive feedback, mass reproduction of these modules has not yet been done. These ten training modules are on the following topics: (1) The Atom; (2) Radiation - Where From, and What For? ; (3) The Unstable Nucleus; (4) What is Radioactivity; (5) The Radioactive Clock - How Old Is Old? ; (6) Is Interaction With Ionizing Radiation Exciting?; (7) Biological Effects of Radiation; (8) Uses of Radioisotopes in Industry, Medicine, and Agriculture; (9) Nuclear Power; (10) Environmental Impact of Nuclear Energy.

2.4 RHS Activities

For users of X-ray machines, the government agency in charge of regulations and licensing is the Radiation Health Service (RHS) of the Department of Health. RHS is also actively involved in providing radiation education/radiation protection training to doctors and residents in radiology, X-ray technicians, dental X-ray and industrial X-ray users. There are around 2,000 medical X-ray facilities in the Philippines; of these, 30% are located in the National Capital Region or the Metro Manila area.

Before 1995, the RHS trained, on the average, around 450 personnel per year in the following courses:[3] (a) Six-week "Training on Radiation Physics and Protection, Radiographic Techniques and Film Interpretation of Chest, Skeletal System and Emergency Radiographs"; (b) Three-day "Seminar on Radiation Physics and Protection and Radiographic Techniques for Dental X-ray Units Users and Operators." Starting in 1995, RHS offered the workshop on "Radiation Safety in Medical Radiography for X-ray/ Radiologic Technologists." This 26-hour training/workshop enables X-ray/radiologic technologists to become Radiation Safety Officers, and is a requirement for licensing of X-ray facilities. The radiation-related topics in the syllabus for this training/workshop are: (a) Production of X-ray and Its Properties; (b) Interaction of Radiation with Matter; (c) Radiation Quantities and Units; (d) Biological Effects; (e) Principles of Radiation Protection; (f) Personnel Monitoring; (g) X-ray Room Design.

3. Additional Future Activities

In 1998, as part of a Regional Cooperative Agreement (RCA) and International Atomic Energy Agency (IAEA) project, the Philippines participated in the trialing of distance education or distance learning modules in radiation protection. These distance learning modules were developed at the Australian Nuclear Science and Technology Organisation (ANSTO). Under Phase 2 of the project, these modules will be trialed in the Open University of the University of the Philippines. These modules will also be trialed in Thailand, New Zealand, Korea, and Mongolia. After the trials and once put in their final form, these modules will be published by the International Atomic Energy Agency and will be free for use by countries desiring to do so, and may be translated to the native language of a particular country. These modules could in the future be transformed to electronic format to be availed of using the internet.

As part of the activity of the Subcommittee on Nuclear Power Public Education and Information, 36 additional Teaching Modules on radiation and nuclear topics are being developed by the University of the Philippines - Institute for Science and Mathematics Education and Development. These are designed for use from the First Year to the Fourth Year of high school, and designed for continuity of learning on a spiral method. Each module includes a Teacher's Resource Manual and a Student Resource Manual.

Although at present there are some weekly science programs on television designed for science teachers, high school and elementary students, radiation and nuclear science related topics still need to be incorporated into these television programs.

The Philippines is coming up with an Education Technology Master Plan whose aim is to improve the accessibility and quality of education through the use of Information Technology and other innovative education technologies. The different government agencies involved in this master plan are the Department of Education, Culture and Sports (DECS), the Technical Education and Skills Development Authority (TESDA), the Commission on Higher Education (CHED), and the Department of Science and Technology (DOST). If incorporated into the Master Plan, Information Technology (IT) will be a powerful vehicle for radiation education in the future.

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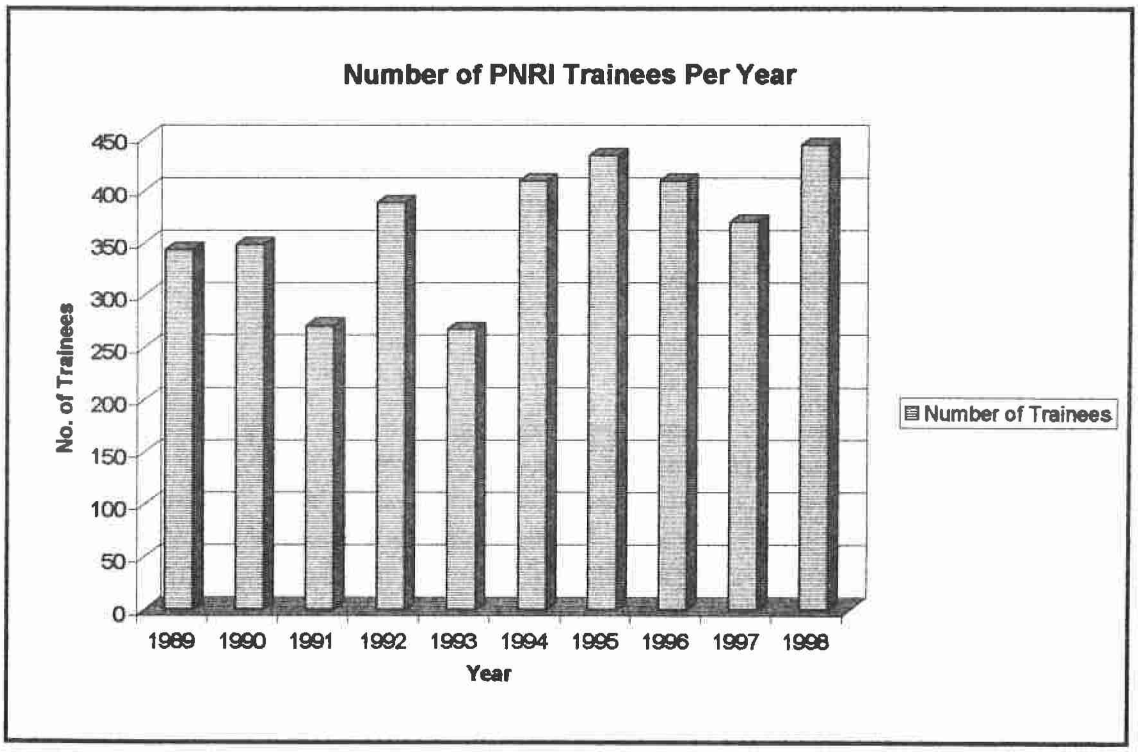

Figure 1.

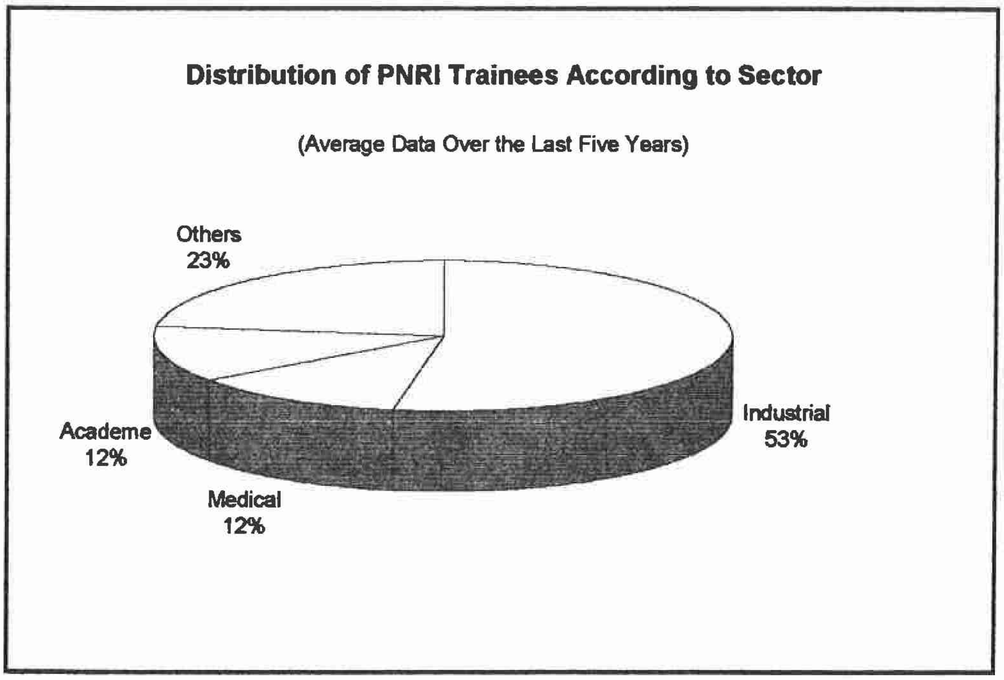

Figure 2.

2.10 RADIATION EDUCATION IN POLAND – THE PRESENT STATUS AND PERSPECTIVES

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ABSTRACT

The necessity for the continued education about radiation (both in nuclear science and the technical application of radioisotopes) in the educational system is obvious.

For many years this subject has been part of a students education in physics as well as nonphysical areas of study, such as chemistry, biology, medicine, ecology and agriculture.

Unfortunately in the wake of the disaster at Chernobyl, a number of negative factors have resulted that have undermined both education in this crucial area and financial investment in Polish radiation institutes. Some sociologists have termed this behaviour/viewpoint "radio - phobia phenomena". Might I be so bold as to recoin it as "nuclear related paranoia" since it has caused a general breakdown in rational , "cause and effect analysis" even within respectable scientific circles, including prominent radiobiologists, who now accept radiation only as a destructive factor in biological and human life.

Unfortunately in Poland there is a good basis for the development of "radio-phobia" amongst the population. Firstly, in the past, the development of the A-bomb coupled with the rise of two diametrically opposed political and military systems (dividing East and West), up until 1989 led to extensive worldwide research which considered only the damaging effects of exposure to radiation in the event of world conflict. This created the basis for the false and totally unscientific belief that exposure to radiation in both high and low doses were strangely equal and therefore harmful to humanity. The voice of reasonable scientific research, that proved that this was patently not the case, was drowned under the insistence, by many, that the use of nuclear physics for the creation of civilian power sources equated that of an S.S.20 or Pershing II nuclear warhead, a few of these misinformed persons going so far as to claim that missles were perhaps even more desirable than civilian nuclear projects because as they put it to the Danes, "at least, unlike Barseback, there not in your backyard".

Now might be the last chance we have to rid society of this hocus-pocus and change their way of thinking about radiation and nuclear physics in general.

The most important factor in this campaign will be the promotion and presentation of radiation in simple-understandable terms through the following outlets, (popular articles, TV programs, objective classroom presentations and so on), designed to be easily understandable to society as a whole. In this support is to be found in some governmental and independent organizations which do attempt to show radiation as bio-positive, human friendly and an economically indispensable factor for the future. However our fight with the so-called "coal lobby" will continue to be difficult. Help by international organizations such as the I.A.E.A will not suffice in this battle.

In this article the author tries to describe the Polish education system and statistical data showing the present status of radiation science, radiation education and the quantity of students and experts in the field.

As a nuclear physicist and specialist in radiation protection, lecturer and an Inspector of Radiation Protection, he provides insights from his own experience and offers his conclusions regarding efforts to encourage and promote radiation science and education.

1. INTRODUCTION

Interest in nuclear science and its applications began before 1970, in connection with the start of designs for the First Polish Nuclear Plant (FPNP). After Chernobyl and a very aggressive negative publicity campaign against all forms of nuclear development, all work in this project was discontinued. This despite the fact that from its inception and throughout the eighth years of its design and construction, FPMP had cost the Polish government, that is the Polish tax payer, over $8 million. Starved of financial assistance, institutes concerned with the development of nuclear related subjects, have fallen into disuse and neglect, many closing altogether. The Polish Nuclear Society coupled with the Technical University of Warsaw has released an elaborate analysis of the present status regarding education about radiation in the Polish education system. Sadly a sorry picture emerges.

Although in some elementary and high schools various elements pertaining to the science of radiation exists it is generally taught within the framework of related subjects – for example - physics, chemistry and ecological studies. This is therefore the first contact a student will have with atomic science related matters. Because this first point of contact with nuclear subjects is of such great significance, one would expect the subject to be introduced in an easy and objective manner which describes both the positive and negative influence on ecology and human life. What is called for here is a rational balanced approach which explains realistically the types of problems associated with nuclear technology, at the same time stressing both the known and potentential solutions. Therefore it is an absolute necessity that a positive nuclear education program be adopted in the Polish education system. Sadly this is not true of the present climate.

Analysis of this problem is overwhelmingly pessimistic. After 1990 many Universities closed post-graduate studies in nuclear related subjects. During the same period large numbers of nuclear specialists and experts rejected their profession, finding new positions in jobs that were more profitable and acceptable to "public opinion". Several scientists have fled the country to seek meaningful employment in less paranoid countries, where their highly skilled educational qualities are appreciated and not scorned.

Also since 1990 the amount of students applying for studies in nuclear related subjects has collapsed. Only a handful of Polish Universities continue to offer courses in the field of nuclear sciences (Table 1) most of the others having capitulated to the irrational demands of political and public “anti-nuclear sentiment”.

Fig. 1 shows the number of university students completing nuclear science and technology related subjects in the period 1985 - 1994. As a direct consequence of the Polish Governments decision to abandon construction of F.P.N.P. we are able to observe a catastrophic decline in the number of students involved in the nuclear field. Fig. 2 and Fig.3 show clearly how this has also decimated the number of students receiving honors at the highest levels (i.e. doctorate and professorial level) and a number of the post-graduated thesis finished in nuclear science and technology (before and after 1990).

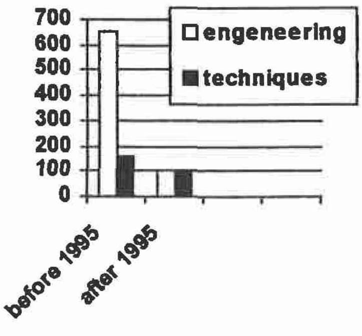
2. CONCLUSIONS

The shortsighted political decision to halt construction of the First Polish Nuclear Plant has all but destroyed nuclear science education in the country, both in regards to its commercial use and its non-energy-related applications.

The political about-face by both the Polish Parliament and Government to revive a Polish nuclear program will require a "Manhattan Project " type program in both educational reform and public awareness if it is to have a chance of success. We will need to use the expertise of all nuclear scientists and professionals to help to create, as rapidly as possible, a new generation of nuclear experts.

Tab.1. Universities and scientific laboratories in Poland involved in "atomic area".

Place	Department
University of Metallurgy and Mine Krakow	Nuclear Physics and Techniques; Electronics and Electrotechniques; Energy;
Technical University Bialystok	Mechanical
Technical University Gdansk	Electric
Technical University Lodz	Institute of Radiation Techniques
Technical University Gliwice	Environmental and Energy Engineering
Technical University Poznan	Radio- and Photochemistry; Physics Institute; Institute of Chemistry and Electrochemistry;
Poznan University	Physics Institute; Institute of Chemistry – Radiochemistry;
Technical University Warsaw	Electric; Electronic; Energetic and Aviation; Land Engineering;
Technical University Wroclaw	Institute of non-organic Chemistry; Rare Earth; Physics Institute; Mechanical Energetic; Experimental Physics Institute;
Nuclear Energy Institute Swierk Institute of Nuclear Problems Swierk	full spectrum
Central Laboratory of Radiation Protection Warsaw	Radiation Protection Environmental Science
Chemistry and Nuclear Techniques Institute Warsaw	full spectrum



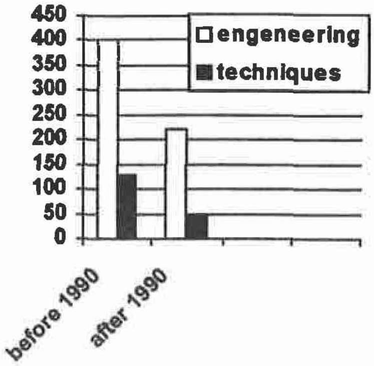


Fig.1.Number of university students finished a nuclear science of technology subjects (before and after 1995).

Fig.2. Number of the highest Universities degree (i.e. doctor and professor's thesis) finished in nuclear science of technology subjects (before and after 1990).

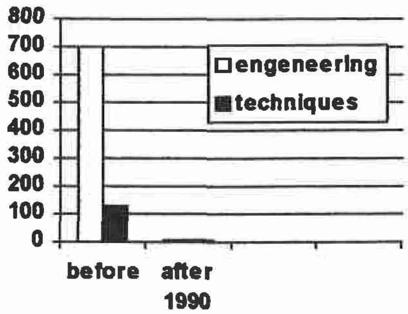


Fig.3.Number of the post-graduated thesis finished in nuclear science and technology (before and after 1990).

Both the Chernobyl incident and the so-called "Hiroshima Syndrome", have had a disastrously negative impact in applied nuclear - radiation studies and subsequently undermined the economic viability of most Polish "Institutes of Radiation R & D".

The sociological impact of years of negative nuclear propaganda is most keenly felt in public attitudes towards both nuclear energy projects and related subjects. The repeated emphasis in the media of the, "negative only", results of nuclear technologies, coupled with unscientific ravings of a few misguided individuals in the scientific community has resulted in a "radio - phobia phenomena" of hysterical proportions.

Only an all out educational drive, using popular articles in the written media, TV documentaries and a school educational program, will enable us to redress this imbalance.

Although there exists some governmental and independent organizations that attempt to present nuclear science in a positive light, i.e. bio - positive, human friendly and as an economically indispensable factor for sustainable growth, we cannot rely on the help of such institutions, including the I.A.E.A., to win the battle we are waging.

The fight against ignorance and short-term economic solutions in the field of energy development, against the "Greenies" and "Coal Lobby" respectively, will continue to be difficult.

Finally the following list of points, I hope will enable all of us attending today's conference, to focus our discussions and perspectives for future actions.

a) an increase in the number of nuclear science related subjects at university level is imperative.

b) an increase in funding in this area is needed by the Ministry of Education in Poland.

c) the use of positive coverage in all forms of media is essential for combating public ignorance in the subject.

d) financial assistance, in the form of grants, have to made available to a Science Research Committee.

e) the introduction of pro ecological techniques for the production of energy, such as nuclear energy, must be explored vigorously.

f) financial incentives to industries engaged in nuclear related programs should be encouraged through "Tax Breaks" and low interest credit opportunities.

g) a concerted effort should be made to explain the relationship both historically and presently in the evolution of the universe and the human species.

h) a full frontal attack must be launched to combat superstition and ignorance about nuclear physics. This should also focus on the necessity of exposing unscientific and sensationalistic postulations made by the uninformed. Every piece of misinformation should be challenged wherever it occurs.

i) an international alliance of all persons dedicated to the proliferation of nuclear related science and technologies should be formed and cemented through regular contact and forums of the kind we are attending today.

2 .11 STATUS AND PROBLEMS OF RADIATION EDUCATION IN TAIWAN

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Abstract

In Taiwan, there are few numbers of radiation education, courses this fact makes an impression of insufficiency. This matter is thinkable to be an important problem. There are sets of atomic power stations and 6 atomic reactors are now operating. The electric power production is about 50144MW, which comprises 20% of total electric power in the country. The knowledge for the related to the radiation is not diffuse and there is only frightened impression. The radiation education should be spread to the ordinary citizen, and essential qualities a risk of the radiation should be instructed sufficiently. The radiation literacy of the ordinary citizen is needed to raise the level.

I . Introduction

The country area of Taiwan is nearly 3,6000 sq.km^2 and the population numbered is over 21,000,000.The population density is 585 persons/km^2 which is the secondly crowded in the world, Taipei City has the highest population concentration (2,800,000) of the Taiwan area. The population is greatest along the Taiwan Starct seaboard where the weather is mild and the transportation and industrial facilities are most highly developed. In fact approximately 95% of the nations people live on the strip of coastal plain between Taipei and Kaohsiung. Advancing industrialization has been accompanied by a population shift toward the large cities and a remarkable population decline in the agricultural areas.

The education is available to all citizen over 98%. At the present time, there are about 130 Universities or Academies,[2] while most of student enrollment of university is more than 20,000. The Gross National Produce (GNP) reaches US$13,000. Student enrollment of university or academy at present is 856,186 The numbers of doctoral, master's, undergraduate and academic course students are 10,013, 38,606, 373,702, 433,865 respectively, and corresponding ratio is 1:3.75:36.3:42.2.

II. Education and Training[1)]

There are 79 Universities and Academies; the other Colleges are 60. The number of university, which employs teachers with radiation license, is 18, and the number of these teachers is 77. Which the college with the same qualification is one and the number of teachers is 2.

Number of university and colleges, which provide the course of various radiation education, are 16 and 1 respectively. There are 20 universities that contain the Department of Chemistry, and the number of student is 4,737. Among these 20 universities only 4 provide the course of various radiation education (the ratio is 20%).

Because the various radiation education in university are not enough, ordinary citizen can not understand radiation well. This situation makes people frightened and they are against to the peaceful use of radiation and the building of new Electric Nuclear Power.

In order to redress the deficiency of various radiation education in university, short course training about radiation education is provides in 4 institutes as follows (Table1).

1. Institute of Nuclear Energy Research: To strength the training of employs in institute.
2. Radiation Protection Association: To provide publicly the course of sealed radioactive source.
3. Taiwan Electric Power Co.: To strength the training of employs in company.
4. Yang Ming University: To train the use of Un-Sealed radioactive source in medicine.

III. Nuclear Reactor

1. Nuclear Research Reactor

There have 2 Nuclear Research Reactors in Tsing Haw University and Instituted of Nuclear Research Reactor. They also educate and train for basic science and technology of Radiation, simultaneously, they produce some Radio Isotopes to supply medical use etc.

2. Nuclear Power Generation

The six nuclear units in Taiwan jointly constituted 20 percent of the total installed capacity. The six nuclear units were housed in three nuclear power stations, all of which are owned and operated by the Taiwan Power Company. The first nuclear power began to operation in 1978. The second nuclear power was started in 1983. The third nuclear power began operating in 1984. The two new nuclear units are building now.

Almost all of the nuclear power reactors are located at North part of Taiwan, and another 2 research Nuclear reactors are also in there. So that North part of Taiwan is exposed to higher density of nuclear reactor dosage than South part (Fig. 1).

Ⅳ. The Atomic Energy Council

The Atomic Energy Council, a government supervisory agency under the Excutine Yuan, sets the licensing specification for nuclear power plants and Radiation equipment or users (Table 1,2 and 3) . Numbers of license for Medical and Non-Medical are 13,932 and 7,654 respectively, and the number of license for Radiation protection is 1,360.

CONCLUSION

The discovery of radiation has been beyond 100 years. We still feel it's mystery. Henceforth the education of radiation is strengthened from primary school to university. People will understand the importance of radiation and the way to use well. The radiation literacy of ordinary citizen in Taiwan can be raised in the near future.

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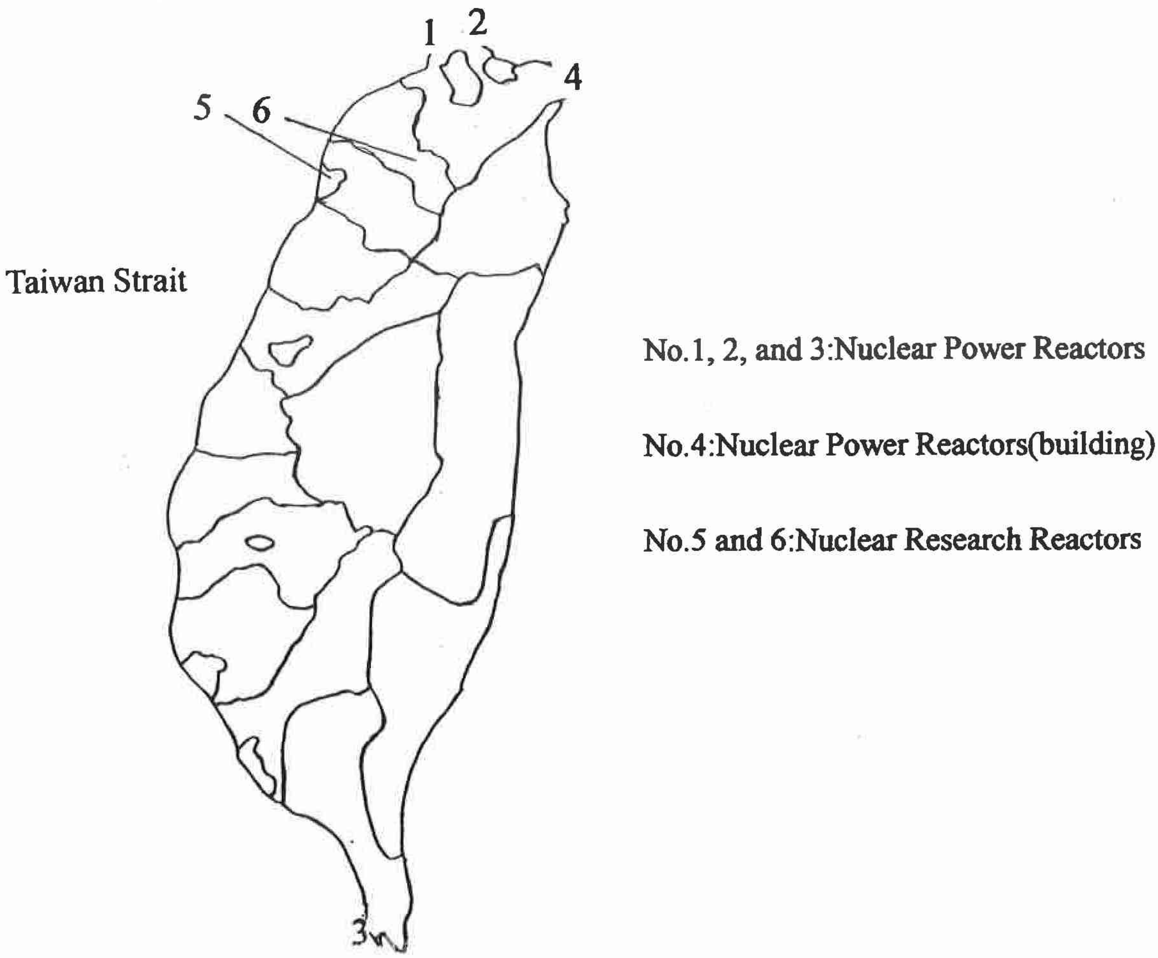

Fig.1 Map of Nuclear Reactors location in Taiwan

Table 1 License for Medical

	To Diagnose	RI	Treatment	Total
Associates Engineers	420	3	12	435
Engineers	2517	148	241	2906
Dentists	6483	0	2	6485
Doctors	3905	85	116	4106
Total	13325	236	371	13932

Table 2 License for Non-Medical

	Sealed Radioactive Material	Un-Sealed Radioactive Material	Ionizing Radiation Equipment	X-ray for Animal	Sealed Radioactive Sources and X-ray	Total
Junior	2266	2707	1812	201	276	7262
Middling	85	190	82	0	3	360
Senior	17	10	5	0	0	32
Total	2368	2907	1899	201	279	7654

Table 3 Number of Radiation Protectors

	Junior	Middling	Senior	Total
Ionizing Radiation Equipment	612	40	1	653
High level Radiation Treatment	44	12	0	56
Radiation irradiation	101	2	0	103
Sealed Radioactive Materials	214	52	3	269
Un Sealed Radioactive Materials	470	63	2	535
Nuclear Reactor	100	40	3	143
Others	28	1	37	66
Total	1569	210	46	1825

Numbers of Licenses : 1360

2.12 STATUS AND PROBLEM OF RADIATION EDUCATION IN THAILAND

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ABSTRACT

Knowledge of radiation and its application and protection have been routinely taught, discussed and transferred to end users and the public. Limited resource and a strategic plan are identified to be the major obstacle to fully implementation of radiation education in Thailand. Current strategic planning on radiation education in Thailand will be discussed.

1. INTRODUCTION

Peaceful applications of atomic energy in Thailand has been the founding principle of atomic energy applications since its introduction to the Kingdom in 1961. It is clear to us that 'peaceful' means benefit with safety. In practice, Thailand commits and adheres to Non-Proliferation Treaty (NPT) of nuclear weapon regime with a comprehensive safeguard agreement with the International Atomic Energy Agency or the IAEA.

The world wide "**Atom for Peace**" program initiated a national peaceful application of atomic energy program in Thailand. Later, an Atomic Energy Commission, so called Thai A.E.C., was established by virtue of the Atomic Energy for Peace Act 1961 with an Office of Atomic Energy for Peace (OAEP) established as its Secretariat. OAEP is an the key organization in Thailand dealing with all matters on peaceful application of atomic energy. Apart from being the Secretariat to the Thai A.E.C., OAEP has been playing key roles to implement the founding principle and its associated policies to control and regulate safe uses of, to promote and coordinate research and development on, and to conduct its own research and development on peaceful utilization of atomic energy. It is also the counterpart institution of the International Atomic Energy Agency (IAEA).

In the past 36 years, there have been substantial progresses made on peaceful and safe utilization of atomic energy in various Thai research institutions including OAEP. Their main contributions have been in areas of education and training, and for agricultural produce development and treatments, nuclear medicine and nuclear oncology, health care and nutrition, and increasing industrial productivity and efficiency. Such progresses are assured by only with sufficient safety measures. Enforcing of radiation and nuclear safety measures has been a major commitment to the public of the safety inspectors and safety officers at OAEP. It has been clearly successful as there has been no record of any major nuclear accident in Thailand since 1962.

2. CURRENT RADIATION EDUCATION PROGRAM

Office of Atomic Energy for Peace, with the research reactor and modern equipment, is the center of associated with radiation education in Thailand, as the promoter and enforcement. Training of radiation safety and radiation safety officer which are the requirement of nation's regulatory function are also provided. All the training course contain basic radiation interactions with matters, the basic knowledge for radiation education. However, it is at rather technical and for scientists. Therefore, it is recently agreed among the trainers that education plan on dedicated radiation education curriculum is needed for expanding correct knowledge of nature of radiation and its usefulness and danger. Hence, the general public are more knowledgeable, and proper use of nuclear technology in the future will increasing on sound basis.

Knowledge of radiation are recently put in school education, starting in secondary school, radiation applications in food irradiation and sterilization of medical products are taught in everyday science courses. In high schools, the topic on radiation and radioactivity are parts of fundamental physics and chemistry. Furthermore, in more than 600 colleges and universities located in all part of Thailand, every major college and university offers courses in fundamental nuclear physics and related topics in Physics Department. Physical-chemistry concerning of radiation and radioactivity in other aspect is taught in Chemistry Department. Reactor theory is a topic existed in Master degree program of Nuclear Technology at Chulalongkorn University. Among universities in Bangkok area, Kasetsart University has a Department of Applied Radiation and Isotopes which offers many undergraduate courses on applications of radiation technology in agriculture and environment. Radiation and research from accelerator is emphasized in the Fast Neutron Research Facility, Institute of Science and Technology Research and Development, Chiang Mai University at Chiang Mai. For medical application, there are numbers of programs on radiation technology studies in medical fields in major cities; Bangkok, Chiang Mai, and Song Khla. The program produces radiologist for hospitals. Three level programs consist of a program for X-rays technician, a program for overall radiologist and a program for advance radiation physicist, who is a person assisting oncologist in radiation dose calculation and treatment of patients.

OAEP's major roles in above curriculum are:

- giving lecturers for many courses in colleges and universities, providing assistant for laboratory exercises and researches;
- delivering lectures for interested groups and associations, arranging in house courses in radiation technologies and radiation protection; and
- cooperating with IAEA in arranging national or regional training in some special related topics, etc.

Figure 1 shows number of academic courses given by lecturers from OAEP, **Figure 2** shows number of persons doing laboratory exercises and researches, and **Figure 3** shows number of lectures given to groups and associations. In addition, since 1990, OAEP has organized 11 courses on radiation aplications and 59 courses on radiation protection.

It is therefore advisable to say that, except for nuclear power, the utilization of nuclear technology in Thailand is willingly accepted. They are widely used in nuclear medicine, industry, agriculture, research and education.

Besides the 59 courses arranged by OAEP and some courses offered in universities, there seems to be inadequate for increasing needs of the technology. OAEP also negotiate with JAERI, under the bilateral OAEP-JAERI Cooperative Research Agreement, two courses on Radiation Protection for Radiation Safety Supervisor, and on Nuclear Technology and Its Diverse Applications. Course for the two topics will organized twice in the course of three years. JAERI also supports number of essential instruments necessary to conduct the courses. Distance Learning for Radiation Protection training is another approach being planned together with planned certification for radiation protection personnel to be enforced by OAEP.

Currently, simplified and short courses on radiation and radioactivity have been organized for school teachers at Ongkharak Distric, Nakon Nayok Province, where a new nuclear research center is to be established. The courses are simplified and associated with simple laboratories such as radioactive materials in everyday-life products, radioactivity in air, autoradiography, column scan demonstration, etc. The courses proved to be successful, and there are numbers of suggestions such as organization of the nuclear related youth camp, the public information center located in schools in the vicinity, and granting students to further study in nuclear science.

3. CURRENT PROBLEM

As radiation education is recently start in school, there are still lacking of experienced teachers to provide appropriate guidance to students. Many educational colleges are inadequately equipped with laboratory accessories, especially materials for physics experiments. Another major concern is to encourage teaching statistics of probability and risk assessment within the radiation measurement techniques. Many people are not knowledgeable enough to make use of the subjects and, hence, do not know status of risks from natural radiation being experienced in everyday life. Majority of university students refuse to take statistics courses if they can avoid.

4. FUTURE PERSPECTIVES

There are world wide effort to educate general public on peaceful applications of nuclear energy including that of nuclear power. Traditionally, public information officers, most likely being familiar with perception of nuclear scientists, tend to jump to disseminating all available information close to our routine technical work and acquainted environments. It is assumed that the public have certain degree of scientific background sufficient to comprehend the available information. After so many efforts for a long period of time, the public often complain of complexity of nuclear science for them to readily comprehend. They need some simpler reference than scientific terms and formulae. Therefore, some rethinking is necessary to clearly identify how general public perceive events around them, what influence their decision making process, and what kind of personality they respect, listen and follow. It is a huge and difficult task.

Public perception of what explained to them seems to be the origin of all misperceptions. The long standing perception of nuclear energy is destructive while perception on daily exposure to radiation from the origin of mankind remains unnoticed situation. Radiation education seems to possess strong message to the public to be understood and be aware of true ecology of mandkinds and true meaning (perception) of nuclear energy in daily life. Hence, public acceptance is expected to follow spontaneously.

It is, therefore, essential to concentrate on using radiation education as the important vehicle to inform general public of nuclear energy in daily life called sun ray, cosmic ray neutrinos and others.

Public understanding of such naturally occurred phenomena will certainly prepared themselves to listen more carefully on subjects of atomic energy, as they realized of its daily association with life on earth.

Therefore, radiation education is indeed an essential instruments for providing good basis for general public to understand atomic energy in daily life. It will certainly be a strategic approach in Thailand for public information program from now onward.

Figure 1 Number of courses given by lecturers from OAEP

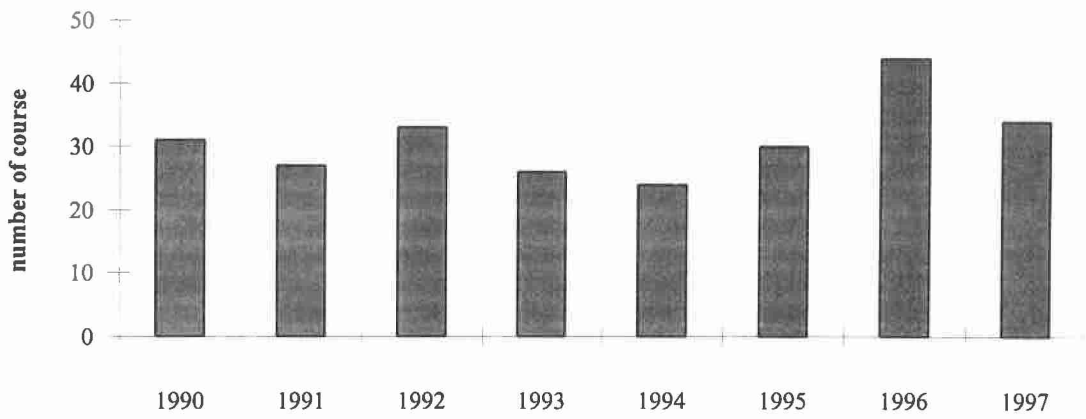


Figure 2 Number of persons doing laboratory exercises and researches

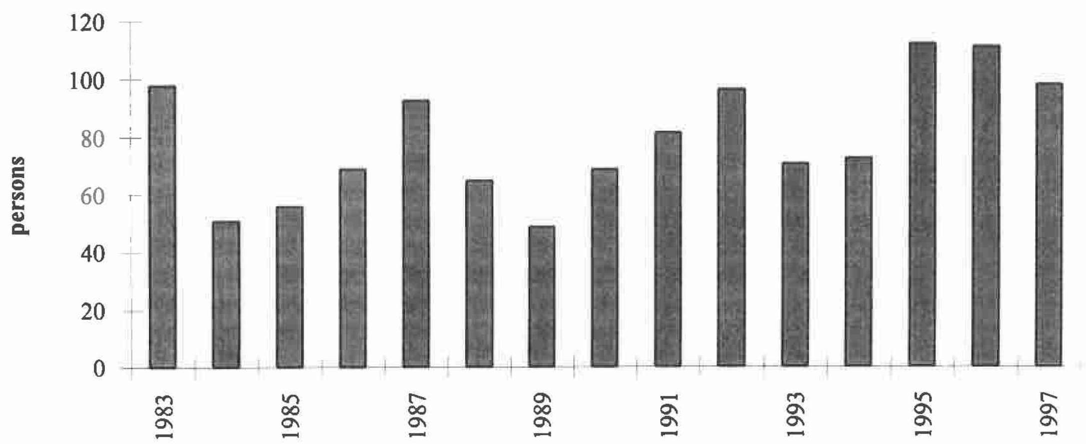
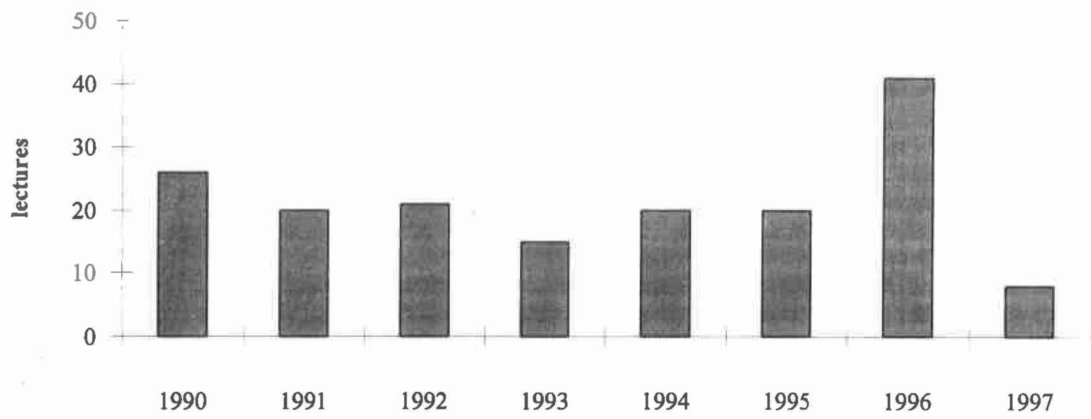


Figure 3 Number of lectures given to groups and associations



2.13 FUTURE PERSPECTIVE OF MEDICAL RADIONUCLIDE PRODUCTION AND RELATED EDUCATIONAL PROBLEMS IN DEVELOPING COUNTRIES

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ABSTRACT

The radionuclide applications are continuously escalation in nuclear medicine. Especially, the development of positron emission tomography (PET) technique has increased very rapidly the use of short-lived radioisotopes in this field, and this has caused the development of compact medical cyclotrons. About 30 cyclotrons operated in the world wide are actually found in the developing countries. In parallel of this progress, the basic nuclear sciences, especially nuclear chemistry and radiopharmaceutical chemistry will probably very important fields in the next new century for nuclear science and technology applications in health care sector. For this reason, the developing countries should eventually revise their academic educational and training programs aiming to ensure the formation of qualified basic nuclear scientists such as nuclear chemist, nuclear physicist, radiopharmacist, etc.

1. INTRODUCTION

The imaging techniques based on the detection of nuclear radiations emitted by the radionuclides incorporated into the specific organs are commonly used in today's health care sector. The single photon emission computed tomography (SPECT) and positron emission tomography (PET) are the fastest growing imaging techniques in nuclear medicine and related branches of medical sciences. These techniques principally use the radiolabeled chemical materials that are known as "radiopharmaceuticals". In recent years, many radiopharmaceuticals bearing different kind of radionuclides have been largely used in diagnostic and therapeutic studies, especially of cancer. The basic principle of radiodiagnosis and radiotherapy is ensuring as low as radiation dose absorption by patients. Sometimes, the radionuclides having very short physical half-lives, and very interesting decay characteristics are required for this purpose. The use of short-lived radionuclides necessitates their productions just at the application sites. This necessity has provoked the development of compact particle accelerators. So, the medical cyclotrons were begun to be used in this field. While the oldest running cyclotron was commissioned in 1948 at the University of Birmingham in England, their commonly using was started following 1970's years, and the radionuclides production using medical cyclotrons has became very largely applicable even in the developing countries not haven other nuclear facilities. Consequently, the number of cyclotrons running in the world wide has increased very rapidly. For example, while there were only 3 medical cyclotron and PET centers in the USA in 1975, today this increased up to about 66. In this context, the number of medical cyclotrons actually operated in the world wide is about 206[1]. Table I shows the numbers of medical cyclotrons installed in the period of 1972 - March 1998. As is seen clearly, the use of medical cyclotrons has consideably grown. Table II shows the distribution of these cyclotrons by countries. It is interesting that about 30 cyclotrons running are actually in the developing countries. It seems also very probable that at the beginning of the next new century nearly all developing countries will be able to have, at least, one cyclotron for own medical applications.

2. CYCLOTRON PRODUCED RADIONUCLIDES

The principal purpose of medical cyclotrons is, of course, to produce the short-lived radionuclides at their application sites. Nevertheless, in the case of a productive nuclear reaction can be applied, the charged particles accelerated by cyclotrons such as proton, deutron, triton, and alpha can also be used for production of any radionuclide having whatever half-life. For this reason, in recent years the production of many radionuclides, for example ^{75}Br, ^{124}I, ^{211}At, etc. which have the potential applications in diagnostic or therapeutic studies, have been subjected by several investigators[2 4)]. In this context, some reactor produced radionuclides, as an example ^{99}Mo or directly ^{99m}Tc, have been tried to produce by using cyclotrons[5)]. Consequently, the variety of radionuclides has been considerably grown day by day. Table III shows the principal cyclotron produced radionuclides which have the potential applications in medicine and other fields[1)].

3. BASIC PRINCIPLES OF PREPARATION OF RADIOPHARMACEUTICALS AND FUTURE PERSPECTIVE OF NUCLEAR CHEMISTS

The use of radionuclides in diagnostic and therapeutic studies is depended on the preparation of appropriate radiopharmaceuticals. The first step of preparation of a radiopharmaceutical is to produce the radionuclide, and the next step is the labeling of a chemical compound with this radionuclide. The third step is its sterilization and quality control procedures. For this reason, the nuclear chemistry and radiopharmaceutical chemistry have the principal roles on the preparation and safely using the radiopharmaceuticals in medical applications.

As outlined in the introduction section the growing applications of cyclotron produced radionuclides in medical studies have clearly indicated the importance of qualified nuclear and radiopharmaceutical chemists. This means that in the next new century these professionals will be the key people for radionuclide applications in this field. A report[5)] prepared in 1990 by a group of International Atomic Energy Agency experts (group members : H. Vera-Ruiz, C.S. Marcus, V.W. Pike, H.H. Coenen, J.S. Fowler, G.J. Meyer, P.H. Cox, W. Vaalburg, R. Contineau, F. Helus, and R.M. Lambrecht) also very clearly outlined the important role of these professionals for the preparation and quality controls of cyclotron produced radiopharmaceuticals. It is also interesting to note that in that report the special training of radiochemists and radiopharmaceutical chemists on the specific quality control techniques of radiopharmaceuticals bearing short-lived radionuclides was obviously outlined, and indicated the dangerous role of non-training people to safe and efficacious use of radiopharmaceuticals.

The future perspective of progress envisaged on the application of cyclotron produced radionuclides necessitates the reorganization of academic educational and training programs of basic nuclear sciences, especially of nuclear chemistry.

4. COMMON PROBLEMS ON NUCLEAR CHEMISTRY

As is known well, the public reactions provoked by several politicized groups against to nuclear energy and related technologies influence, of course, the basic nuclear science and technology educational and training academic activities in all countries. In this context, also the nuclear chemistry has been considerably influenced by these negative actions. Surely, this is a common and global serious problem for basic nuclear sciences and related technologies, and particularly for nuclear chemistry. Another important problem of nuclear chemistry is originated from the confusion of "nuclear chemistry", "radiochemistry", and "radiation chemistry" definitions. A careful searching on these three basic definitions in the literature including the main textbooks written by famous authors and published by international press companies clearly shows that there is not an international agreement on these definitions. This means that it is not clear-cut as wished; what is exactly nuclear chemistry, radiochemistry, and radiation chemistry; what relations are exist between them; and exactly what topics should be covered by these chemistry branches related basically to the radioactive materials and nuclear radiations? In addition, what is their place between other chemistry branches? According to some authors, the nuclear chemistry is considered as a principal branch and covers the radiochemistry and radiation chemistry as being two main sub-branches of nuclear chemistry. For example, the textbook prepared by G.R.

Choppin and J. Rydberg and titled as "Nuclear Chemistry : Theory and Applications"[7] has the principal topics of radiochemistry and radiation chemistry. The similar textbook coverage has been also applied by several authors. Other examples are the textbooks written by M. Haïssinsky[8], A. Vértes and I. Kiss[9], H.J. Arnikar[10], and E. Roth[11]. Contrarily, some other authors have considered that the nuclear chemistry and radiation chemistry are basically different, and cover different topics as being not including the radiation chemistry. The textbook written by G. Friedlander, J.W. Kennedy, J.M. Miller[12] is a well known example for this consideration. That textbook was principally covered only the topics related to radioactive materials not including the topics related to radiation chemistry under the title of "Nuclear and Radiochemistry". The nuclear chemistry and radiochemistry have been also very sharply differentiated and very fairly overlopped by R. Guillamont[13]. It is also necessary to outline that the "nuclear and radiochemistry" expression has been also commonly used to refer the discipline of chemistry that relates to radioactive materials including the nuclear transformations. The coverage of radiation chemistry is much more easily distinguished then nuclear chemistry and radiochemistry as being the chemical effects associated on matter with nuclear radiations[14].

If the nuclear chemistry, radiochemistry, and radiation chemistry are considered as well distinguished sub-chemistry branches, it should necessarily be defined a principal chemistry branch that must exactly to cover the nuclear chemistry, radiochemistry, and radiation chemistry, and basically to relate to the chemistry of radioactive materials and nuclear radiations. If so, what definition can be found for this principal chemistry branch? Surely nothing! Nevertheless, in the case of the definition of nuclear chemistry as a principal chemistry branch which covers the radiochemistry and radiation chemistry as its two sub-branches, the problem on the confusion of these definitions will easily be resolved; but, it should eventually be created an international agreement on these definitions. The foundation of the International Nuclear Chemistry Society (INCS) can surely be very helpful for this purpose. If such a society is founded, it may to cooperate with other international scientific organizations such as the International Union of Pure and Applied Chemistry (IUPAC), International Atomic Energy Agency (IAEA), NATO Scientific Committee, American Chemical Society (ACS), etc. In the case of realization of this cooperation, also an international agreement on these definitions can be realized. If not, the confusion will probably continue, and consequently the nuclear chemistry will not seriously be able to into account in international scientific platforms, and to get its real place between other principal chemistry branches. As an actual situation of nuclear chemistry in international platforms, it is not included in the list of principal chemistry branches defined by famous international organizations. As is known well, the principal chemistry branches have been commonly defined as the analytical chemistry, biochemistry, inorganic chemistry, physical chemistry, and organic chemistry. The nuclear chemistry should be included in this list of principal chemistry branches having very different and characteristic application principles and handling techniques as a younger chemistry discipline which basically covers the chemistry related to the radioactive materials and nuclear radiations[14].

5. LOCAL PROBLEMS IN DEVELOPING COUNTRIES

In the next new century, the global energy requirement will probably result the use of nuclear energy with growing intensity in developing countries, too. Actually, the development and advancement of nuclear technologies have been controlled by industrialized countries. As a result of this situation, in that countries the required nuclear engineers and basic nuclear scientists can be formed using the graduate and undergraduate academic programs. In this context, the nuclear chemists, and other nuclear specialists can be formed; but, in the developing countries the situation is much more different than that of industrialized countries. Firstly, while some developing countries has already one or more nuclear power stations, some others have not yet it.

Even the developing countries have the nuclear power station or stations as being already envisaged with the first important step of nuclear technology, this does not means that the formation of nuclear engineers and basic nuclear scientists can be realized in own countries.

The rapid growing of medical cyclotron applications shows clearly that in many developing countries the medical cyclotrons will be grown much more than the nuclear power stations. This means that these countries will eventually need the nuclear chemists and other basic nuclear scientists rather than the nuclear engineers. Table IV shows the distribution of nuclear power stations, research reactors, and medical cyclotrons in some developing countries.

The challenge of nuclear chemists and radiopharmaceutical chemists having special training in medical radionuclide production, radiopharmaceutical preparation, and their quality controls as obviously outlined in the IAEA experts report[5] indicated in the above paragraphs, the quality standards of radiopharmaceuticals which will be used on the patients will not sufficiently be satisfactory and will be able to be dangerous, too. While the easily installation of medical cyclotrons, but the challenge of required qualified experts will probably result the use of non-qualified people for these applications directly related to the health care. Of course, this will cause the envisaging very serious radiation dose problems for patients.

6. SPECIFIC PROBLEMS IN TURKEY

Turkey as a country having very critical geopolitics situation is a political and cultural bridge between Est and West, Russian and Middle-Est, Balkan and Caucasia. The economic potential of Turkey has developed very rapidly, especially in last fifteen years. Also its industrialization has been very considerably realized. Nevertheless, the critic geopolitical situation and earlier economical problems prevented Turkey to have a nuclear power station untill today. Of course, this has had a role negative on the required development of basic nuclear sciences in Turkey, while Turkey has two nuclear research reactors; but, in the first five years of the next new century, Turkey will probably have two nuclear power stations and this will obviously provoke the understanding of importance of nuclear technology and basic nuclear sciences. In addition, at the Ege University a medical cyclotron project has already been started. It is hoped that at the beginning of the next new century it will be able to produce the principal cyclotron produced medical radionuclides used around the Turkey. Of course, these applications will also show clearly the importance of basic nuclear sciences, especially of nuclear chemistry. In spite of these progresses, Turkey has some similar public reactions against to nuclear technology. This is, of course, a serious problem in Turkey, too. Another serious problem in Turkey is originated from the administrative procedures of academic organizations that are controlled by a governmental council. According to regulations determined by this council, a department of chemistry at any faculty of a Turkish University, should be organized by five principal chemistry branches as being analytical chemistry, biochemistry, inorganic chemistry, physical chemistry, and organic chemistry. So, all graduate and undergraduate educational and professional formation programs must be formulated starting from this basic principle. The nuclear chemistry is only considered one of two sub-branches of physical chemistry. Of course, this prevents very seriously the development of nuclear chemistry specialization in Turkey. The complexity of this problem is depended on the difficulty of alteration of governmental high educational council regulations. This means that the problem cannot be resolved neither by an individual University nor by a group interest. As the author of this paper, personally I have been charged since many years to resolve this problem in Turkey; but unfortunately, while the similar problem is not valid neither for nuclear physics nor nuclear medicine and radiopharmacy, a considerable progress could not be obtained for nuclear chemistry. It should be also outlined that the global misconceptions on the understanding of nuclear chemistry has also very seriously influenced the resolving this problem in Turkey.

7. CONCLUSIONS AND GENERAL RECOMMENDATIONS

It is evident that the radionuclide production has became more and more easy by using the compact medical cyclotrons. For this reason, the application of different radionuclides will be able to have an important role in the near future either for scientific and technical applications or medical diagnostic and therapeutic studies. As a consequence of this progress, the basic nuclear scientists, especially nuclear chemists will be seeking professionals in the next new century also in the developing countries. Starting from this point of view, it can easily be understand that the academic formation and in addition the specific training programs aimed to the formation of these qualified professionals should eventually be considered, and all graduate and undergraduate academic programs should be revised as soon as possible starting from the basic principles indicated in the different reports[15-19] by the developing countries which desire to develop their public health care programs. For support these efforts in developing countries the international scientific organizations should similarly support the formation of basic nuclear scientists in industrialized countries, too. In this context, the importance of nuclear chemistry as a principal professional field for radionuclide production, radiopharmaceutical perparation and their quality controls should clearly be shown by everybody who is directly or indirectly related to the application of radioactive materials and nuclear radiations in global science and technology sector. The organization of these actions on nuclear chemistry can be realized by the foundation of the International Nuclear Chemistry Society. All nuclear chemists are invited to support and to realize this idea.

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TABLE I

Number of medical cyclotrons installed in the world wide during the period of 1972 - March 1998[1)]

Years	Number of cyclotrons
1972	4
1973	2
1974	4
1975	3
1976	2
1977	-
1978	-
1979	2
1980	2
1981	4
1982	4
1983	6
1984	3
1985	9
1986	7
1987	10
1988	5
1989	12
1990	15
1991	17
1992	17
1993	6
1994	13
1995	13
1996	8
1997	12
1998 (March)	8 + 12 sold

Total : 195 cyclotrons / 27 years → ≈ 7.2 cyclotrons / year

Last 10 years : 138 cyclotrons → ≈ 14 cyclotrons / year

TABLE II
Distribuition of medical cyclotrons by countries[1]

Country	Number of cyclotron	Country	Number of cyclotron
USA	66	Denmark	2
Japan	33	Poland	2
Germany	20	Spain	2
UK	9	Czech Republic	1
Belgium	8	Egypt	1
Canada	7	Hungary	1
Netherland	7	India	1
Italy	6	Indonesia	1
China	5	Iran	1
France	4	Israel	1
Russion Federation	4	Kazakhstan	1
Australia	3	Norway	1
Brazil	3	Romania	1
Finland	3	Saudi Arabia	1
Republic of Korea	3	South Africa	1
Switzerland	3	Sweden	1
Argantina	2	Syrian Arab Republic	1
		Total number : 206	

TABLE III
Principal cyclotron produced radionuclides having the potential applications in medicine and other fields.

Radionuclide	Half-life	Radionuclide	Half-life
^{11}C	20.3 m	^{123}Xe / ^{123}I	2.1 h / 13.3 h
^{13}N	10. 0 m	^{201}Pb / ^{201}Tl	9.4 h / 73 h
^{15}O	123 s	^{88}Y	108 d
^{18}F	109.7 s	^{7}Be	53 d
^{64}Cu	12.8 h	^{10}C	19.4 s
^{124}I	4.2 d	^{28}Mg	21 h
^{38}K	7.71 m	^{48}V	16 d
^{45}Ti	0.09 h	^{75}Se	120.4 d
^{62}Zn / ^{62}Cu	9.3 h / 9.8 m	^{87}Y / ^{87m}Y	80 h / 14 h
^{73}Se	7.1 h	^{93}Mo	> 100 y
^{75}Br	1.7 h	^{99}Mo	67 h
^{76}Br	16.1 h	^{99m}Tc	6.0 h
^{82m}Rb	1.3 m	^{147}Gd	35 h
^{94m}Tc	5.3 m	^{195}Au	183 d
^{67}Ga	78 h	^{206}Bi	6.24 d
^{111}In	2.81 d	^{186}Re	90 h
^{123}I	60 d	^{211}At	7.21 h
^{201}Tl	73 h	^{57}Co	270 d
^{22}Na	2.60 y	^{139}Ce	140 d
^{67}Cu	59 h	^{81}Rb / ^{81m}Kr	4.7 h / 13 s
^{103}Pd	17 d		

TABLE IV
Comparison of distribution of nuclear power stations, nuclear research reactors and medical cyclotros in some developing countries.

Country	Number of power stations[20]	Number of research reactors[21]	Number of medical cyclotrons[1]
Argentina	2	5	2
Armenia	1	-	-
Bengladesh	-	1	-
Brazil	1	4	3
Bulgaria	6	1	-
Chile	-	2	-
China	3	10	5
Colombia	-	1	-
Congo, Democ. Rep. of		1	-
Czech Republic	4	3	1
Egypt	-	2	1
Ghana	-	1	-
Hungary	4	2	1
India	10	5	1
Indonesia	-	3	1
Iran, Islamic Rep. of	-	4	1
Israel	-	2	1
Jamaica	-	1	-
Kazakhstan	1	3	1
Korea, Democratic Rep.	-	1	-
Korea, Republic of	12	2	3
Latvia	-	1	-
Libyan Arab Jamahiriya	-	1	-
Lithuania	2	-	-
Malaysia	-	1	-
Mexico	2	3	-
Pakistan	1	2	-
Peru	-	2	-
Poland	-	1	2
Portugal	-	1	-
Romania	-	1	1
Russian Federation	29	27	4
Saudi Arab Republic	-	-	1
Slovenia	1	1	-
South Africa	2	1	1
Syrian Arab Republic	-	1	1
Thailand	-	1	-
Taiwan	-	3	-
Turkey	-	2	-
Ukraine	16	1	-
Uzbekistan	1	-	-
Viet Nam	-	1	-
Yugoslavia	-	2	-
Total	**99**	**106**	**31**