TENORM LEGISLATION - THEORY AND PRACTICE

(A REVIEW OF RELEVANT ISSUES)

Background information for the presentation at the II International Symposium on Technologically Enhanced Natural Radiation
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PREFACE

Activities and work practices in which radiation exposure of workers and members of the public is increased due to the presence of Naturally Occurring Radioactive Material (NORM) are receiving increased attention from regulatory agencies and, to a lesser extent, from the general public.

Proposed national and international radiation protection standards are likely to bring many industries into the realm of regulatory concern.

Attention focused on industries where enhancement of natural radioactivity takes place and radiation exposure of workers and members of the public may be comparable to that for already 'controlled' activities.

However, industries, where technological enhancement of NORM results in only small increases of radiation exposure, could also become 'regulated' in accordance with the provisions of the 'new' radiation protection legislation.
One of such industries is mining and minerals processing in general.

Verbatim adoption of Basic Safety Standards (BSS) of the International Atomic Energy Agency(1) into a national legislation without a full assessment of health, economic and legal consequences could present enormous practical problems.

Therefore, it is appropriate to discuss if these Standards prescribe appropriate control measures for the Technological Enhancement of Natural Radioactivity, especially in mining and minerals processing.

THEORY

DEFINITIONS

There are different definitions for Technologically Enhanced Naturally Occurring Radioactive Material. The one used by Health Physics Society NORM Working Group is, by far, the most comprehensive one:

"TENORM - Naturally occurring radioactive material, not subject to regulations under the Atomic Energy Act, disturbed or altered from natural settings, or present in a technologically enhanced states due to human activities, which may result in a relative increase in radiation exposures and risks to the public above background radiation levels."(2)

Sometimes it is also not very clear what the phrase "technologically enhanced" actually means. Again, a quote from HPS NORM Working Group:

"Technologically Enhanced means that the physical, chemical, radiological properties, and concentrations [of NORM] have been altered such that there exists a potential for:

- Redistribution and contamination of environmental media (soil, water, and air);
- Increased environmental mobility in soils… and groundwater;
- Incorporation of elevated levels of radioactivity in products and construction materials;
- Improper disposal or use of disposal methods that could result in unnecessary and relatively high exposures to individuals and populations via any environmental pathway and medium."(2)

The problems with TENORM are associated with the letter 'R' in the abbreviation: RADIOACTIVE. It will be appropriate, therefore, to discuss general issues of radiation protection before addressing the TENORM issue.

HEALTH EFFECTS OF LOW-LEVEL IONISING RADIATION

The main principle of radiation protection is to keep doses "As Low As Reasonably Achievable, social and economic factors being taken into account". The second half is all too often being misinterpreted and becomes "As Low As Possible, At Any Cost" or "As Low As Technically Achievable"(3) since the Linear No-Threshold dose response model (LNT) remains a 'corner stone' of radiation protection. The LNT model predicts that any dose of radiation, no matter how small, may produce health effects since even a single ionising event can result in DNA damage.

There are two opinions on the subject.

The first one is that "DNA damage of importance in radiogenic diseases occurs at a high rate naturally even in the absence of radiation exposure. Small doses (10 - 100 mSv) increase the spontaneous background rate by a small fraction of 1%, essentially contributing an insignificant increase to the DNA damage which occurs naturally."(4)

On the contrary, another one describes this argument as not sustainable since "it fails to recognise the very low abundance of spontaneous DNA double strand damage and the critical importance of these lesions and their misrepair for cellular radiobiological response."[5] The frequency of an error in the repair of the double-strand DNA damage is much higher than for the single strand damage, which is repaired in a correct manner quite easily.

One can say that the radiation protection community is bitterly divided on the matter of the LNT applicability. I would like to present here views from two ends of the spectrum of opinions:

1. J.W. Gofman "using human evidence exclusively, arrives at risk estimates for acute-low and slow-low exposures which are up to 30-fold higher than the wide range of values provided by UNSCEAR…" and concludes that "the existing human evidence shows, beyond reasonable doubt, that there is no conceivable dose or dose-rate of low-LET [Linear Energy Transfer] ionising radiation which is safe, with respect to producing fatal cancer in humans."[6]

2. Z. Jaworowski states that "numerous results of the experiments at molecular, cellular and organic level, and also epidemiological studies indicate that adaptive and stimulatory (or hormetic) effects occur at low doses of ionising radiation. These effects, often beneficial for the organisms, are in direct contradiction with the linear, no-threshold hypothesis."[7]

An enormous amount of articles is written on this subject. I would like to suggest materials of the 1997 Seville 'Low Doses' Conference[8] for those who are interested in detailed studies. As reported by A. McEwan, "the overall conclusions of the conference are that the rapid advances in studies of molecular mechanisms will aid understanding of the carcinogenesis process, that dose - effect relationships remain dependent on epidemiological evidence, and that the dose response at low doses and dose rates remains uncertain, with some beneficial effect not being able to be excluded. In spite of the uncertainty surrounding risks at low doses, the risks derived from the linear no threshold relationship do not warrant the enormous expenditures on land remediation being pursued in some countries to achieve the very low dose levels."[9]

Another interesting document I would like to mention is the 1998 Report of the OECD Nuclear Energy Agency "Developments in Radiation Health Science and Their Impact on Radiation Protection". Among other subjects, the genetic predisposition of different people to cancer is considered. The following conclusion is made: "genetic predisposition is likely to become an important issue in radiation protection, particularly in case of workers as it might impact national policy in the areas of employability, insurability and compensation"[10].

It is unlikely that these concerns will be realised with the publication of ICRP-79. As reported by J. Valentin, "ICRP Publication 79, Genetic susceptibility to cancer… is now available for sale. The report reviews mechanisms of radiation oncogenesis with respect to gene mutation in man and animals, the spontaneous frequencies of… mutations in man, and the role of genetic factor in radiation induced cancer. Some implications for radiation protection are, of course, reviewed."[11]

"The concluding remarks make direct application of the report's assessment to radiation protection practice: The principle conclusion by the Commission is that, on current knowledge, the presence of familial cancer disorders does not impose unacceptable distortions in the distribution of radiation cancer risk in typical human populations. For individuals with familial cancer disorders, radiation cancer risks relative to the baseline are judged by the Commission to be small at low doses and insufficient to form the basis of special precautions. …At present, and even in the future, genetic testing for familial cancer disorders does not appear to have a major role in radiological protection practice…"(12)

Therefore, the recommendations , which could be made in accordance with NEA Report(10) are not likely to be implemented in practice. Otherwise, it would be very interesting to see this implementation being carried out: It seems that there is no other way except getting a 'genetic fingerprint' from every prospective employee during the pre-employment medical examination.

THE FEAR OF RADIATION

When a new technology is introduced or an existing one is assessed, the following precautionary principle usually applies: in dealing with potentially hazardous technologies the benefit of the doubt must go to the public and not to technologies.

The combination of this principle with the uncertainty about health effects of low level ionising radiation leads to the fact that the idea 'small dose *may* cause harm' is transformed into 'small dose *definitely will* cause harm'.

This interpretation of the facts by mass media and many 'interest groups' has already resulted in public relations nightmare for the nuclear industry. It also leads to its over-regulation resulting in billions of dollars in compliance costs, despite the fact that LNT is a hypothesis, not a conclusively proven fact.

US Senator Pete V. Domenici described the current situation in the United States of America as follows: "Our model forces us to regulate radiation to levels approaching 1 percent of natural background despite the fact that natural background can vary by 50 percent within the United States. We spend over $5 billion each year to clean contaminated DOE sites to levels below 5 percent of background."(13)

It has been estimated that the cost of preventing cancer deaths by UMTRA (Uranium Mill Tailings Remedial Action Project) ranged from $240,000 for Salt Lake City, Utah, to the unimaginable $18,000,000,000 for Slick Rock, Colorado.(14)

As it was rightfully pointed out by Z. Jaworowski: "Each human life hypothetically saved by implementing the US Nuclear Regulatory Commission's regulations costs about $2.5 billion. Such costs are absurd and immoral when compared to the costs of saving lives by immunisation against measles, diphtheria and pertussis, which in developing countries range between $50 and $99 per one life saved."(15)

The adoption of IAEA Basic Safety Standards without consideration of social and economic effects would bring nearly all mining and minerals processing industry under the regulatory control.

Society will be deprived of even more funds that are desperately required to deal with *actual* health problems. These funds will be diverted for the minimising of *theoretical* health effects because of the irrational fear of ionising radiation.

The most obvious example of funds diversion, which has resulted in dire consequences, is the handling of the Chernobyl accident first by the USSR and then by national republics. "Relocation of nearly one million people… was prescribed to avoid exposure to low levels of irradiation; this measure was obviously groundless, both medically and socially. Additionally, four million people… were needlessly included in… legislation; their exposure did not exceed the natural background levels characteristic of many inhabited regions around the world. Three million people were falsely identified as the major victims of the accident."(16) Two 'life-time - dose' concepts were discussed at the time: 350 mSv and 70 mSv, derived from 5 mSv/year and 1 mSv/year, respectively. "Authors of the 350 mSv concept were accused of being traitors to the people, the Soviet minister for Public Health was dismissed from office, and all activity of the Soviet NCRP was halted."(16)

In addition, the statement by some radiation protection 'experts' in the mass media that any radiation dose in excess of 1 mSv/year is a "criminal radiation genocide" was promptly picked up by national politicians in new independent republics. Virtually millions of people were and still are "being subjected to severe psychological stress", which is harming people much more than "hypothetically existing radiation risk due to low levels of radiation in polluted areas."(16)

The fear of radiation is continuously maintained within the former Soviet Union. For example, prominent academician A. Yablokov in his interview with Russian news agency Interfax in 1998 made the following peculiar statements:

- "in the first months following the accident, several dozen thousand children were born dead in Ukraine, Belarus, Russia, and also in Germany, Greece, Austria, Sweden, Norway and Turkey";
- "over nine million people still live on the Chernobyl-contaminated areas where half of the children are born with mental disorders."(17)

It is no wonder then that any 'usual' sickness such as cold or migraine is often immediately attributed to the exposure to 'deadly radiation'.

Errol O'Donovan gives three general reasons for the "inordinate dread of ionising radiation":

1. "The subject of ionising radiation is a particularly difficult one in which to present the quantitative scientific issues to the public";
2. "Human senses cannot detect the presence of ionising radiation"; and
3. "The media, acting possibly with high principles as the protectors of the public, but more likely with an unprincipled eye to business success, often sensationalise and overstate the hazards associated with any event or situation involving ionising radiation."(18)

The fourth one is, probably, the division within the radiation protection community itself. Professor K. Becker asked: "How about the cost/benefit aspects of all our radiation protection programmes relative to our treatment of other risks for our civilization and natural risks? Could it be that elements of self-interest are involved in keeping the 'radiation hazards' alive?"(19)

M. Pollycove states: "Government funds are allocated to appointed committees, the research they support, and to multiple environmental and regulatory agencies. The LNT hypothesis and multi-billion dollar radiation protection activities have now become a symbiotic self-sustaining powerful political and economic force."(20)

The 'low dose' discussion is dominated by deep mistrust between the radiation protection community and the public. With the introduction of more stringent safety standards and the inclusion of TENORM into the regulations this mistrust will be even more enhanced.

Those who have the knowledge are not trusted by the public to tell the whole truth, since they are seen as being mainly concerned about their posts and funding.

From the other side, the so-called 'lay' public is considered by scientists as not being able to understand ionising radiation and the effects of exposure. The usual argument is that 'logical reasoning will be substituted by emotional reaction at the very moment the word 'radiation' will be mentioned, so why bother?'

Therefore, 'interest groups' and the media fill this vacuum in communications with minimal or no resistance. The balanced and unbiased article in the 'general news stream' such as "Living with radiation" in the National Geographic by Charles Cobb(21) is a rare exception.

In addition to media scare mongering "the lack of a definitive position with respect to individual radiation exposure is being fulfilled by professionals of different areas, not related with radiation, such as jurists and phychologists."(22)

The main stream of information about radiation in fiction, especially in the cinema, is plagued with creatures generated by radiation like killer ants, "giant radioactive squid, giant leeches, giant scorpions, a giant tarantula, monster crabs, and even an army of giant grasshoppers that advanced and attacked Chicago. Indeed, atomic radiation became a common device plot, replacing werewolves and vampires… Comic books and science fiction also joined the trend, impressing millions of young people with tales of radioactive creatures and monsters, contamination and world destruction, all associated with nuclear energy."(23)

And, of course, 'government conspiracies' and 'evil scientists' are usually to blame. The recent re-make of the 1954 Japanese movie Godzilla is the latest example.

At the same time the emphasis of radiation protection professionals is placed on publishing in scientific journals and presenting findings on conferences. This leaves little time for all other forms of communication with the public.

As long as researchers continue to concentrate their efforts on communicating only within the scientific community, they will be seen as a group of socially isolated 'secret' societies in lab coats talking in their own language and using 'devilish' equipment for unknown (and, therefore, 'dark') purpose.

APPLICABILITY OF IAEA BSS FOR TENORM

With the verbatim adoption of IAEA Basic Safety Standards into a national legislation and, consequently, inclusion of TENORM into an area of regulatory control, the worst fears of members of general public would be realised.

It would be deducted by some that government and scientists were proven wrong once more by not recognising the hazard earlier. Indeed, it is quite possible that regulatory agencies might even be accused of 'hiding the vital information from the public'.

Government agencies and science will continue to lose support from the wider community and the TENORM issue may be 'a final blow' or a 'turning point' in the communication link with the public, - depending on the way the issue will be addressed in each country and world-wide.

IAEA Basic Safety Standards propose that a single practice can be exempted from regulatory control if it contributes to individual doses of no more than 10 microSv per year.

Therefore, if a practice causes an individual to be exposed to a dose more than "in order of" 10 microSv/year it becomes a subject of regulatory control. This extremely low dose of ionising radiation is referred to as a 'trivial dose'.

However, the applicability of this dose to TENORM is questionable. European Commission Report EUR 17625 states: "The generic nature of the scenarios reflects, in most cases, small-scale usage of the materials containing the radionuclides. The exemption values are not, therefore, necessarily appropriate for industries processing very large amounts of ores or materials with enhanced levels of naturally occurring radionuclides. …It is left to competent authorities to decide which types of industry deserve attention. There seems to be a consensus, however, that the same radiological criteria as for exemption cannot be applied. The concept of 'triviality' of individual doses does not seem to be so relevant to the natural radiation environment."[24]

The main aim of this presentation is to attract the attention of national regulatory agencies to the fact that IAEA Basic Safety Standards must not be adopted verbatim, without prior assessment of the TENORM issue, particularly in the mining and minerals processing industries.

The IAEA Safety Guide "Provision for Omissions from the Regulatory Control of Radiation: Application of the Concepts of Exclusion, Exemption and Clearance" is currently in the draft form and, therefore, cannot be quoted in this presentation. This publication will provide very useful information for the implementation of the Basic Safety Standards in practice.

It is expected that, apart from the 'trivial dose' exemption criteria, another rationale for exemption may become applicable for TENORM. This rationale would be based on the statement in the BSS that exemption could be granted for a practice if "an assessment for optimisation of protection shows that exemption is the optimum option."[1]

"If individual doses are in excess of trivial levels but are still acceptable, and limited by plant throughput and the natural upper bound on the specific activity of the raw material, such a situation might be considered by the regulator as candidate for exemption from some or all regulatory requirements."[25] The main condition for the exemption would be gaining the confidence of a regulatory authority that radiation protection at a facility processing NORM is optimised, and everything that could be done to reduce radiation exposure of employees and members of the public is being done.

LEGAL ASPECTS OF TENORM REGULATION

It should be borne in mind that estimates of radiation exposure are typically over-conservative.

Dose assessments are usually carried out on the basis of the most conservative assumptions. However, such assessments could be very complex and many pathways of radiation exposure are considered. This results in a risk assessment, which is far from any practical situation since it contains multiple conservative assumptions.

The result of a dose assessment is usually a calculated dose weighted for the several types of ionising radiation and for the sensitivity of various body organs of a 'reference man'. The inclusion of factors such as age and sex of an exposed person complicates the calculation to the point where doses could only be estimated with the help of computer programs.
Pathways of the exposure to NORM and associated processes "can be extremely complex and can vary considerably with the site and method of production."[26]

Over-regulation in the area of 'trivial' doses of radiation exposure (such as remediation of areas which were never associated with any 'nuclear' activities and are currently considered 'safe') will fuel an extreme sensitivity to radiation in mass media, among the general public and in government authorities, which do not have relevant expertise.

The potential legal implications of the combination of the ALARA principle with the LNT hypothesis could be enormous:
"Any exposure, however low, could be analysed and criticised with the benefit of hindsight, and any expert can always show that the dose suffered by the claimant could have been reduced even further.
If ALARA principle is linked to the no-threshold linear hypothesis to prove the irrefutability of the legal reasoning, it is true that the ALARA principle made mandatory under the law becomes an end in itself, which obliges operators to do better than the dose limits…
If ALARA principle is to be considered as a legal standard of care… this could have extremely harmful consequences on the endeavours made by operators to reduce workers' doses, endeavours which would in no case reduce the risk of legal action. Whether the dose was 1 mSv or 10 mSv, the operator could be held guilty of breaching his statutory optimisation obligation."[27]

An interesting suggestion for the reduction of personal dose was made by Mike Malaxos: "…one should live on a plastic yacht moored in the centre of a deep freshwater lake close to sea level. Mantle lamps, auto tint spectacles and other males should be strictly prohibited. Only female crew members should be employed because of their low K-40 body burden. Double beds should not be permitted so that distance between bodies is maximised and the radiation from them is reduced to a level as low as reasonably achievable."[28]

However, it is likely that the operator of this boat could also be held guilty because he did not modify the yacht into a submarine, and did not therefore, pay enough attention to the harmful effects of cosmic radiation at the earth's surface…

Even the 'perceived' risk of radiation exposure could be a reason for litigation. As reported by Sophia Angelini:

"New Mexico Supreme Court in *Santa Fe v. Komis*, 845 P.2d 753 (1992) addressed a claim of diminution of property values based on perceived risks of nuclear waste transportation. The case involved partial condemnation of land taken by the City of Santa Fe to construct a highway for primarily normal public use but also for occasional transportation of nuclear waste from Los Alamos to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. The jury in the District Court awarded $489,582 for the land actually taken, $60,784 for severance damages to the buffer zone and $337,915 for perceived loss due to public perception. The New Mexico Supreme Court affirmed judgement of the District Court and stated:
"If people will not purchase property because they fear living or working on or near a WIPP route, or if a buyer can be found, but only at a reduced price, a loss of value exists. If this loss can be proven to the jury, the landowner should be compensated."[29]

NORM-related legal issues are only partially explored and, "as government warnings about the potential hazards of NORM have increased and regulations designed to control NORM have proliferated, the number of lawsuits alleging property damage or bodily injury from exposures to NORM-containing substances has also increased. This litigation, in turn, has generated disputes between insurers and policyholders over whether standard-form liability policies were meant to provide coverage for such claims… Many companies… are belatedly learning that their insurance policies do not provide coverage for the resulting losses."[30]

As reported in the Mississippi Business Journal:

"Meanwhile oil and gas industry officials have continually maintained that plaintiff's lawyers were overplaying the actual health risks posed by NORM, and that because of litigation surrounding the issue, producers were having a harder time than usual gathering the capital needed to drill a new well. The lawsuit threat and overkill regulations… all but froze land transfers and forced companies to spend more time, effort and money surveying their sites for compliance and arranging for proper NORM disposal."[31]

THE 'CONTROLLABLE DOSE' CONCEPT

Technically Enhanced Natural Radioactivity is usually the major source of radiation exposure of the population. For example, in The Netherlands "…radiation doses due to the regular emissions from non-nuclear industries are more important than those from nuclear industries. Maximum doses due to non-nuclear industries exceed those of the nuclear industries by more than three orders of magnitude."(32)

If IAEA Basic Safety Standards are adopted verbatim, without the consideration of all potential implications, including the legal ones, the economy of a given country may be seriously disrupted. The livelihood of industries, particularly the mining and minerals processing ones outweighs by far any benefits which could be gained from regulating TENR 'to the last millirem'.

It is clear that at the current level of knowledge there is no conclusive answer about the validity of the LNT hypothesis as there is no definite answer at this time to the question about the effects of low level ionising radiation. As correctly pointed out by the ICRP Chairman, Roger Clarke: "…there are no prospects that the existence of a low-dose threshold for tumour induction could be proved or disproved conclusively… Because of the continuing lack of definitive scientific evidence, a new approach to protection could be considered."(33)

The fact that the time has come to change the approach to the regulation of low doses of ionising radiation has been highlighted in many publications, for example, in papers by Al Tschaeche(34), Donald Higson(35) and Werner Burkart(36).

The Main Commission of the ICRP is now proposing a simple approach to radiation protection based on the term 'controllable dose':
"A Controllable Dose is the dose or the sum of the doses to an individual from a particular source that can be reasonably controlled by whatever means."(33)

The focus of radiation protection would be placed on individual doses and not on the 'collective' one: "If the risk of harm to the health of the most exposed individual is trivial, then the total risk is trivial - irrespective of how many people are exposed."(33)
A 'single maximum level' of controllable dose is proposed to be around 20 - 30 mSv in a year and "the management of controllable doses below the Action Level would be individual-related source-specific Investigation Levels."(33)

The main outcomes would be:

- If an Investigation Level of several millisieverts per year is exceeded, the investigation could be carried out to determine if some simple measures can reduce radiation exposure;
- The term 'constraint' would be retained with the principle of optimisation still applicable for each source of radiation exposure;
- As in the IAEA Basic Safety Standards, the dose of several tens of microsieverts per year would be 'below regulatory control';
- The justification principle of radiation protection may be dropped all together;
- The optimisation principle may be recast;
- The confusion between practices and interventions would disappear;

- It would be possible to explain the system of radiation protection to individuals as fractions of the natural background, instead of speaking in terms of becquerels, curies, sieverts, rems, grays and their derivatives, which are confusing for the 'general' recipient of information.

The discussion on the concepts of the controllable dose has commenced and it is likely that results will be seen in several years. For example, the Working Party on Controllable Dose and the Use of Collective Dose (of the OECD Nuclear Energy Agency Committee on Radiation Protection and Public Health) had its first meeting in June 1999. The objective of this working party is to "discuss the ideas and concepts presented in the paper by Professor Roger Clarke… This will include such issues as the use of terminology, as well as the use of collective dose in the justification and optimisation of radiation protection."[(37)]

Several other important documents, which will provide additional information for the practical implementation of TENORM legislation, are currently in draft form and, therefore, could not be quoted or referenced:

- International Atomic Energy Agency Draft Safety Report "Protection from Radiation Exposure due to Thorium in Industrial Operations";
- ICRP documents issued for consultation and available from the ICRP Internet site[(38)]: "Protection of The Public in Situations of Prolonged Radiation Exposure" and "ICRP Committee 4 Task Group on Radiation Protection Recommendations as Applied to the Disposal of Long Lived Solid Radioactive Waste".

The IAEA Basic Safety Standards implementation worldwide is more imminent and further below the possible practical implications of it are discussed.

PRACTICE

DEFINITIONS

The first thing to do is to establish what the term "Natural Radioactivity" actually means and where is the boundary between nuclear and non-nuclear industry.

There is no difference between radiation dose of 3 mSv received by a uranium miner and a dose of 3 mSv for an operator of a tin smelter. The argument that in the case of uranium mining 'radiation is beneficial for the product' and in 'other' mining 'radiation is an unwanted impurity' is, from the general radiation protection point of view, irrelevant. Uranium is the same 'naturally occurring radioactive material', with a concentration being technically enhanced.

Further down the uranium processing chain one may argue that metallic enriched uranium is the same natural substance with the concentration of U-235 technically enhanced. Since radioactive content is in no way beneficial for the depleted uranium, its use, for example, in the manufacture of the armour-piercing munitions also could not be classified as a 'nuclear-related activity', yet.

It is likely that the 'real' boundary between 'natural radioactivity' and 'nuclear activities' is reached when the uranium is already in the form of fuel rods inside the reactor. The next stages like producing isotopes for nuclear medicine, especially ones that are not found in nature (technecium-99, for example) could be already named as 'nuclear activities'.
Linear accelerators, use of radioisotopes in nuclear medicine, industrial use of X-ray equipment, and radiochemistry of isotopes definitely could not be classified as dealing with 'natural radioactivity'.

A SUMMARY OF THE RECENT LEGISLATIVE DEVELOPMENTS

The recent developments in radiation protection legislation could be summarised as follows:

1991: ICRP in Publication No.60[(39)] recognised that the risks of exposure to ionising radiation are greater than had previously been thought.
1996: IAEA published official Basic Safety Standards[(1)] and Transport Safety Regulations[(132)];
2001: Basic Safety Standards will become a basis of radiation protection worldwide with possible exceptions (some countries may adopt more relaxed limits, others - more stringent ones).

In accordance with Basic Safety Standards the exemption from notification, registration and licensing may be available "without further consideration" for:
"1. radioactive substances for which either the total activity… or the activity concentration used in practice does not exceed the exemption levels given in Table I-I.
2. if the following criteria are met in all feasible situations:
(a) the effective dose expected to be incurred by any member of the public due to the exempted practice… is of the order of 10 μSv or less in a year, and

(b) either the collective effective dose committed by one year of performance of the practice is no more than about 1 man.Sv or an assessment for the optimisation of protection shows that exemption is the optimum option."[1]

Virtually all mining and mineral processing could become a subject of a radiation protection legislation due to the following explanation in BSS:
"Unless excluded, exemption for bulk amounts of materials with activity concentrations lower than the guidance exemption levels of Table I-I may nevertheless require further consideration by the Regulatory Authority."[1]

For each individual radionuclide there are two exemption levels: the first one is a concentration in Bq/g, the second one - a total activity of a given nuclide present on the premises. Even if concentrations of 'common' NORM elements uranium or thorium are below the exemption limit of 1 Bq/g, the material could become 'regulated' due to the existence of the 'total activity' limit.

For example, in the case of strict Basic Safety Standards application to NORM the following amounts of quite usual materials (with concentration of radionuclides below the limit of 1 Bq/g) may exceed the 'total activity' limit:

- 1.0 kilogram of phosphogypsum,
- 1.6 kilograms of tin ore,
- 2.5 kilograms of phosphate fertiliser,
- 3.0 kilograms of soil in one of Perth's eastern suburbs,
- 10 kilograms of mineral sands ore,
- 11 kilograms of granite.

These values are obviously ridiculous and explain why Basic Safety Standards could not possibly apply for NORM and TENORM. Of course, exposure from unmodified concentrations of radionuclides in raw materials will be excluded from regulations as 'essentially unamendable to control', similar to potassium-40 in the body or cosmic radiation at the earth surface.

The values above indicate that as soon as any physical or chemical modification of a 'raw' material is attempted, resultant concentrate or waste product would fall under the provisions of the relevant regulation.

UNCERTAINTIES IN THE IMPLEMENTATION OF THE IAEA BSS

It is also unclear what approach national regulatory authorities should take in the implementation of Basic Safety Standards.

1. From one side it is clearly stated that BSS "are not intended to be applied as they stand in all countries and regions, but should be interpreted to take account of local situations, technical resources, the scale of installations and other factors which will determine the potential for application."[1]
But, from the other side, BSS "comprise the basic requirements to be fulfilled in all activities involving radiation exposure. The requirements have the force that is derived from the statutory provisions of the Sponsoring Organisations."[1]

It is very unlikely that an individual 'radiation' regulatory authority in a given country will be able to argue about deviation from the Standards. The possibility of such an argument becomes very remote if we take into account the potential pressure from 'non-radiation' government authorities to implement Standards in full or even 'better' them.

Essentially the situation with the adoption of IAEA Basic Safety Standards is similar to radiation safety guidelines which are issued by the Department of Minerals and Energy of Western Australia: "These guidelines are not a substitute for regulations and compliance with them is not mandatory. Methods and solutions different from those set out in the guidelines may also be acceptable… However, to the extent practicable, industry is encouraged to follow the guidelines to ensure uniformity in radiation safety management."(40)

In other words, if you are going to deviate from a guideline you have to have a very good reason for it. But BSS are 'the *basic* requirements to be fulfilled' and, therefore, it is almost impossible to deviate from them.

2. The division between two types of dealing with radioactive material proposed, for example, in Europe seems to remedy the situation for exposure to TENORM.

The first group of processes is called 'practices' and, if applied to a material, includes all situations where radioactive content is beneficial for the product.

The second group is called 'work activities' and, if applied to a material, covers all other instances of potential radiation exposure, where radioactivity content is treated as an unwanted impurity. Work activities that are "of a concern" are those that may lead to a significant increase in the exposure of employees and members of the public.

But the question "What actually IS a significant dose?" remains unanswered, especially for members of the public. A regulatory authority implementing the Standard has two numbers to work with: the 'trivial dose' "in order of tens of microsieverts per year" and the 'universal' limit for members of the public of 1 mSv per year.
What would the 'significant dose' value be? An individual dose estimate for a 'worst possible case' would include several sources of radiation exposure and it is reasonable to expect that a dose constraint of some fraction of 1 millisievert will be considered a 'significant dose' for one given work practice.

Due to the fact that radiation doses due to the natural background vary within a very wide range and could reach 200 mSv/year(41) it is quite possible that the value used for the 'significant dose' definition will also vary from country to country, sometimes by an order of magnitude.

For example, the value of the 'significant dose' for The Netherlands where natural background radiation is described as "one of the lowest in the world"(42) or for Australia where natural background is also comparatively low(43) would be much lower than for other countries/regions which could be described as 'high dose natural radiation areas'.

Some of these areas are Guaraparí, Poços de Caldas and Araxá in Brazil[44], Kerala State in India[45][46], beaches on the north-east coast of Sri Lanka[47], Ramsar in Iran[48] and Yangjiang county in China[49].

The introduction of the 'controllable dose' concept[33] into radiation protection will hopefully solve the problem or, at least, reduce the inconsistencies.

THE LIST OF TENORM INDUSTRIES

Let us try to compile the list of industries where NORM is found and/or technical enhancement of natural radioactivity takes place. The list is not by any means complete and some industries may be added or subtracted depending on NORM concentrations in relevant processing streams and on the imposed limits:

1. Industries directly associated with mining and minerals processing:

- Uranium mining: concentrates, product and tailings;
- Copper mining and processing: concentrates, mine tailings, smelter dust and fumes;
- Lead processing: smelter dust and fumes;
- Titanium minerals mining and processing: products and tailings;
- Tantalum and niobium mining and processing: ores and concentrates;
- Oil and gas exploration and production: sludges and scales;
- Zirconium minerals mining and processing: products and tailings;
- Tin processing: smelter dust;
- Bauxite mining / alumina production: red mud tailings;
- Phosphate ore mining and processing, fertiliser production: products and tailings;
- Rare earth minerals mining and processing: concentrates, products and tailings;
- Gold mining: tailings, underground exposure to radon;
- Underground coal and other mining: exposure to radon.

2. Other 'non-nuclear' industries:

- Power production from coal: boiler slag, bottom and fly ash;
- Numerous building materials (phosphogypsum, red-slime bricks, glazed tiles, some cement and concrete);
- Elemental phosphorus and phosphoric acid production;
- Waste water treatment;
- Iron and steel production, metal scrap processing;
- Geothermal power generation;
- a number of minor things, such as gemstones, gas mantles, optical glass, thoriated tungsten electrodes, porcelain teeth etc.

3. 'Special' cases:
    3.1. Minor NORM impurities that could affect potential applications of products;
    3.2. Civil aviation industry and space exploration;
    3.3. Exposure to radon which is comparatively well known (at home, at work, in caves visited by tourists and speleologists etc.); and
    3.4. Tobacco smoking.

Potential radiation exposures and radionuclides' concentrations in industries listed in points 1 and 2 are more or less known and the information could be obtained from many relevant publications.

'Special' cases of radiation exposure deserve a brief discussion.

3.1. NORM Impurities.

Sometimes a product could contain a very small amount of NORM, which, nevertheless, can affect its final use.

Small amounts of radon in polythene and other polymers, as well as minor NORM impurities in silver-containing photographic emulsions could present problems for high-resolution photography (for example, in astronomy).

Minor NORM impurities in silicon used for computer applications could result in poor performance of the affected equipment.

3.2. Civil aviation industry and space exploration.

Radiation exposure to cosmic rays in the civil aviation industry and, to a lesser extent, in space exploration is comparatively well described in literature.[50,51,52,53] Due to the fact that radiation exposure of air crew is typically exceeding the value of 1 millisievert per year some regulation of radiation exposure would be required.

A separate set of radiation protection regulations is applicable for space exploration. Special '30-day', 'annual' and 'career' dose limits were developed for 'blood-forming organs', eyes and skin[54]. One can guess that, similarly, separate sets of radiation protection regulations were developed by relevant defence institutions for the radiation exposure of the crew of supersonic high altitude military aircraft.

3.3. Exposure to radon.

Radon (decay product of uranium) is present practically everywhere and in some situations (over the stockpile of a concentrate with an enhanced uranium concentration) one can assume that its concentration was also 'technologically enhanced'.

The action levels proposed for radon in IAEA BSS are associated with an annual exposure of about 3 - 5 mSv for a member of the public and 6 mSv for an employee.

These values are extremely high when compared to 0.01 mSv/year "exemption" limit for the exposure of a member of the public proposed in the same document for 'other than radon' radiation exposure. These values are also quite different from the annual limit of 1 mSv per year for a member of the public recommended for practices involving radiation exposure.

The explanation is that practices and work activities are planned and are *adding* to the radiation exposure of a person; radon exposure is *natural*, and if one is going to decrease it, it will be an *intervention*.

At this level a reasonable person trying to understand the subject would be 'lost', since it looks like that there are several different ways of applying the same standards, depending only on the convenience/practicality.

Radon exposure limits of 3-5 mSv/year and the simultaneous promotion of the 'exemption limit of 0.01 mSv/year' coupled with the differences between 'nuclear' and 'non-nuclear', 'normal practice' and 'intervention', 'work activity' and 'practice' are only complicating the issue, which is already complicated sufficiently enough.

Let us consider an example:

> A building contractor is 'enhancing' naturally occurring radioactive material concentrations by putting the granite-containing soil through the mesh to obtain a certain grade (say 5 mm) of granite. Thus, he and his employees are receiving a certain annual dose of ionising radiation, say, about 90 microSv. This work practice may become a subject to a 'radiation' regulation. At least once, it is - to ensure that the doses are as low as reasonably achievable (since they are above 'automated' exemption limit of 10 microSv per year).
>
> From the other side, if the same person receives an annual dose of 5000 microSv per year from the exposure to radon (not counting another 1500 microSv per year from other natural sources) - it is "not of a concern".

If international and national regulatory bodies are to be consistent we should have two options:

- Apply the exemption limit of 0.01 mSv/year for radon exposures for members of the public, which leads to the ridiculous situation when almost everybody on this planet will be 'well above the limit' with an obvious result that the Earth is too hostile and we should move somewhere else, or
- Recognise that there is no point whatsoever in regulating radiation exposure at levels practically indistinguishable from background and either simply lift the limits to more reasonable levels or adopt the 'controllable dose' concept as soon as possible.

3.4. Tobacco smoking.

The discussion of the exemption limit of 10 microsieverts per year is becoming even more interesting if we will take into account radiation exposure of the general public due to tobacco smoking.

Tobacco contains relatively high concentrations of the naturally occurring radionuclide Polonium-210. "When a cigarette is lighted, the polonium is volatilised, inhaled and deposited in lungs."[(55)] Annual effective dose for a 1.5-pack per day smoker would be around 10 millisieverts[(55)]. This value is one thousand times higher than the 'trivial' dose of 10 microsieverts per year.

Health authorities may benefit from this fact significantly. The placement of the warning label similar to the one suggested by P. Gray ("Surgeon General's Warning: Cigarettes are a major source of radiation exposure"[(55)]) on every packet of cigarettes would serve two purposes:

1. reduce the number of smokers and discourage the younger generation to start,
2. inform the public about the existence of natural radioactivity in a manner that will leave a 'permanent mark' in people's minds and then compare the value of the annual exposure from tobacco smoking with the doses received by workers and the public due to 'radiation' activities (no matter, 'nuclear' or 'natural').

POSSIBLE EFFECTS OF IAEA BSS VERBATIM ADOPTION

Before the discussion of different national legislations, let us estimate what effect would be caused by the verbatim adoption of IAEA Basic Safety Standards in a country without a thorough investigation of potential public health, economic and legal consequences.

Such a country would have an immediate need for:

- sufficient amount of suitably qualified and experienced radiation protection specialists in order to ensure that all materials and items which will be classified as 'radioactive' are being handled in accordance with new legislation at the place where they are produced, transported, stored and processed;

- a significant increase in the number of personnel in 'radiation protection' branches of local, state and federal government to deal with 'newly appeared' work activities, issue licences and approvals, read and review numerous monitoring reports and so on;

- numerous 'low-level radioactive waste' storage and disposal facilities for millions of tons of waste which will be generated each year and will require appropriate disposal.

Another item which will require immediate attention is the 'saleability' of the locally mined and processed minerals, 'intermediate' and final products on the international markets. It is quite possible that in case of any competition the 'radioactive content' of a product will become a very important decisive factor in market negotiations.

For example, a local mineral with uranium and/or thorium concentrations in it a little higher than in a similar or same mineral from another region or country would be simply left in the ground.

It would be comparatively difficult to sell products that contain NORM in concentrations higher than, say, a 'world average' unless the price is reduced.

Thus, the TENORM issue ceases to be theoretical. An established mining or mineral processing industry in a given region or country could simply cease to exist due to the perceived risks of radiation exposure from TENORM.

Attempts to remove radioactive impurities from minerals and products could be very expensive and may result in either the alteration of initial properties of the material making it unsaleable, or, in the case of successful removal of impurities, leaving the operator with an 'intermediate-level' radioactive waste product.

SOURCES OF LEGISLATIVE INFORMATION

Some conclusions in the following part, describing country-specific legislation, could be in error due to a simple misunderstanding. All additional information and corrections will be accepted with gratitude. I would like to apologise beforehand for any mistake that was unintentionally made.

It is evident that the most reliable information about country-specific legislation could be obtained from an 'appropriate authority' in this country. The following 'initial points for search' could be suggested:

- IAEA publication "National Competent Authorities Responsible for Approvals and Authorizations in Respect of the Transport of Radioactive Material"(56);
- A very comprehensive studies of 'nuclear' legislation carried out by Nuclear Energy Agency of the OECD both for countries of Central and Eastern Europe(57) and for OECD member countries(58); and
- Internet site 'World Collection of Radiation Links', which is maintained by myself in Western Australia.(59) Currently it contains information and contact details for 830 international and national organisations in 153 countries. General information about TENORM is available from the Phil Egidi Internet site.(60)

NATIONAL APPROACHES TO TENORM

Australia

The Australian Radiation Protection and Nuclear Safety (ARPANS) Bill was introduced into the Australian Parliament in April 1998. The Digest of the Bill contained the following statements: "…the assumption that a dose, however small, carries with it an element of risk has become a key concept in radiation protection… the hereditary malformations and diseases caused by genetic damage take generations to show; it is the children, grandchildren, or remoter descendants of the people originally irradiated who will be affected."(61)

In the beginning of 1999, the ARPANS Agency Act and Regulations, based on the IAEA BSS were promulgated. They are applicable only to facilities under the jurisdiction of the Commonwealth of Australia, but all States and Territories are represented at the National Uniformity Implementation Committee that, among other things, would consider a common approach to TENORM.

ARPANSA Regulations adopt Basic Safety Standards in full, but specific exemption criteria provide for a comparatively easy 'way out' for limited quantities of TENORM:

Firstly, regulation 6 "Prescribed radiation facility", part (1)(d)(ii) increases the 'total activity' value by 1,000,000:
"A prescribed radiation facility is any of the following:…
(d) a facility used for the production, processing, use, storage, management or disposal of:…
(ii) unsealed sources of controlled materials of activity in a quantity greater than 10^6 times that mentioned in column 4 of Part 2 of Schedule 2"(62)

This regulation will allow for the exemption of comparatively large amounts of materials containing thorium and uranium in concentrations below the 'concentration limit' in Regulations (1 Bq/g).

Secondly, if the concentrations of naturally occurring radionuclides exceed those specified, the matter is referred to an appropriate authority (in this case ARPANSA Chief Executive Officer). Then regulation 38 'Prescribed dealings (source licence)', parts (6)(a)(iii) and (6)(a)(iv) could apply:

"…the CEO may declare, in writing, that:

(a) a dealing that is not described in Part 1 of Schedule 2 is a dealing involving:…

(iii) naturally occurring materials; or

(iv) bulk material with a mass of more than 1,000 kg…"[62]

This means that only those 'work activities' which will be identified by an appropriate authority as 'requiring regulation' will be a subject to some or all of the provisions of radiation protection legislation.

No significant legislative change is expected in Western Australia, for example, since the provisions of currently applicable WA Radiation Safety Act and Regulations (1983) specify two ways of rendering material 'radioactive':

1. the numeric limit of 30 Bq/g, and
2. regulation 5(5) states that a material can be classified as radioactive "…if the Council is of the opinion that a radioactive ore which is a natural substance referred to in subregulation (1)(a) may-
   (a) give rise to a radiation hazard; or
   (b) result in an individual receiving a dose equivalent exceeding the dose equivalent limit…"[63]

If the '10^6 times' provision from ARPANSA Regulations is accepted by an Australian State or Territory, it will compensate, at least partially, for a significant decrease in the numeric limit.

The assessment of the impact of new regulations on the mining and minerals processing industry will need to be carried out and some processes, without a doubt, will be 'captured'.

It is not expected, however, that it will be extremely difficult for the industry to 'argue the case' with state appropriate authorities, especially if the regulation 5(5) will be retained in a current or similar form in State or Territory legislation.

Parts of the mining and minerals processing industry where radiation exposure could be 'of a concern' were identified some time ago. They will probably need to make some changes in their reporting and monitoring practices.

In other parts of the industry, which play a significant role in the Australian economy, levels of radiation exposure are typically very low. Therefore, either 'new' legislation will be applicable to them only partially, or they will be exempted from it all together. These exemptions would be based on the current 'optimisation' principle or on the concept of a 'controllable dose', which, hopefully, will find its way into practical regulations sooner rather than later.

Particular attention should be paid to those parts of the industry, which would not be able to obtain exemptions, and, therefore, new legislation will be applicable to them in full.

EUROPE

The Euratom Council Directive No.96/29 "Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers from Ionising Radiation"[64] adopted IAEA Basic Safety Standards on 13 May 1996. Title VII of the Directive is dedicated to NORM and called "Significant Increase in Exposure Due to Natural Radiation Sources". This 'special NORM part' was absent in the IAEA basic Safety Standards.

All EU Member States must adopt this Directive into their national legislation by 13 May 2000. Switzerland, not belonging to EU, has already introduced ICRP 60/BSS-compatible new legislation by law in 1991 and by regulations in practice in 1994.[65]

The European Commission has supported a program targeting exposure to naturally occurring radioactive materials and a substantial amount of information was collected over several years. The results were collated in a comprehensive study "Materials Containing Natural Radionuclides in Enhanced Concentrations"[24] in 1997. Processes and radiation exposure pathways were analysed and industries that potentially required regulation were identified.

Another study that was carried out is the establishment of reference levels for regulatory control of NORM carried out jointly by the NRPB (UK) and CEPN (France). The study came to the conclusion that "the screening or reference levels for a particular nuclide varies considerably from material to material…" and "it would not be advisable to select a nuclide screening or reference level that would apply to all materials."[66]

The NRPB/CEPN study, at least in one instance, seriously overestimated the potential radiation exposure from one material, namely - zircon sands. This example will be discussed in detail in order to illustrate the need for industry- and even site-specific studies, instead of simply adopting the 'screening' levels in practice. Not only IAEA Basic Safety Standards exemption values, but also all 'general' study results must be interpreted with caution and their application for a local situation with TENORM must be thoroughly examined.

In the above mentioned study thorium-232 has been chosen as an 'indicator nuclide' and the following conclusion made: when contents of thorium-232 in zircon is around 1 Bq/g, in 'normal' circumstances the effective dose for an employee will be less or equal 20 mSv per year. In 'unlikely' circumstances this value will be less or equal 50 mSv per year.[66] Another set of values is 'calculated individual doses' for minimum and maximum activity concentrations in the material, again in conjunction with 'normal' and 'unlikely' assumptions. It is claimed that in the case when zircon contains 'maximum activity concentrations' the annual dose for an employee can reach 270 mSv/year in 'normal' circumstances and 580 mSv/year[67] under 'unlikely assumptions'.

These values seem to be a significant overestimation. For example:

- NRPB broad sheet "Working with Zircon Sands" indicate that the maximum possible dose for a worker is about 6 mSv/year if no respiratory protection is used and about 2.5 mSv/year if it is used(68);
- European Commission Report states that "occupational exposures can reach ~2 mSv/a (zirconia production)"(24) and the maximum possible dose from the use of zircon sands in zirconia production would be 15 mSv/year without respiratory protection and 1.5 mSv/year with respiratory protection(24);
- An Australian study came to the conclusion that "it is not considered possible that doses from zircon, typical of Australian product [which is usually around 4 Bq/g - four times the value of the 'screening level' in the discussed study], could reach 6 mSv per year and probably do not exceed 1 mSv per year."(69);
- Two other NRPB studies estimate the radiation exposure associated with zircon processing as being between 0 and 2.8 mSv per year(70) and, as being on average 2.5 mSv per year with a maximum of just above 5 mSv/year in 1997(71);
- In accordance with a study carried out in the USA in 1991 "from a radiological standpoint working with this material should not represent significant health risks, particularly if rigid industrial hygiene practices are followed and the material is treated properly."(72) However, due to thorium and uranium content, "with respect to licensing, it is apparent that there may be cause for review of this issue…"(72).

It will be possible to apply some degree of flexibility in the process of implementation of Euratom Directive No.96/29 in an individual country.

All EU Member States currently have some provisions for exempting of TENORM from the regulation. However, levels of exemption and activity calculation methods vary significantly.

For example, in the oil and gas industry "The Netherlands, Germany, United Kingdom and Norway… are using different formulas to calculate the total activity of radioactive scales and sludges, due to differences in including daughter radionuclides for the calculations. Not only do the applied formulas differ, also the concentration levels used to qualify scale or sludge as radioactive waste and the disposal options available for the different waste categories vary per country."(73)

It is obvious that a harmonisation at least of some of these differences is necessary and this is the main purpose of the Directive 96/29.

The Directive is only obligatory for processes where natural radionuclides are being processed 'in view of their radioactive or fissile properties'. In all other instances, each Member State must determine what work activities lead to a significant increase in the radiation exposure.

European Commission 1997 Report provides a guideline for the implementation of the EU Directive 96/29 for TENORM:

"It is left to the competent authorities in member states to decide which types of industry deserve attention. The benefits from practices involving natural

radionuclides range from the trivial to the very substantial and the cost of imposing tighter regulatory control range from negligible to very expensive.
Each practice will therefore need to be examined in terms of its overall benefits and detriments on regulation taken in the light of the justification of the practice or activity and the extent to which protection can be considered to be optimised, in accordance with basic radiological protection philosophy."[24]

The question 'What is a substantial dose?' was discussed earlier and it is likely that it will be the main criterion for setting up TENORM regulations in each country.

Some country-specific information is presented below:

The Netherlands

The following proposals were made in 1997:

- for workers: "…a dose criterion of 1 millisievert in one year for workers will be handled. Studies… have shown that… a tenfold of these BSS values in general will not exceed the criterion of 1 millisievert in one year for workers."[74]

- for members of the public: in case of bulk amounts of material "proposed criteria are in the range of 0.3 millisievert per year… up to 1 millisievert per year"[74]

These proposals seem to be a relaxation of the currently applicable dose limit of 0.1 mSv/year for a "source of radiation" (exposure to no more than 10 sources is the supposition).[74]

Even the slight relaxation of the dose limit for a facility will help to solve many potential problems. For example, if during phosphorus production "due to differences in the phosphate ore… the dose can rise to just above the threshold limits"[42] the building of an expensive precipitator dust processing plant or a very high stack will become unnecessary.

In 1998 the following system for TENORM regulation has been proposed for The Netherlands:

- "for different exposure pathways… dose criteria are established;

- exemption and clearance levels for specific activities, discharge and emission levels and surface contamination are derived from the dose criteria;

- if exemption and clearance levels for bulk amounts of NORM are exceeded, then reporting is required. If levels are exceeded 10 times, then prior authorisation is required;

- if clearance levels for emissions to air or discharges to water are exceeded, then immediately prior authorisation will be required."[75]

Industry-specific parameters are being developed and all work activities will be classified according to the potential level of radiation exposure.

Work activities will be 'graded' from category A ("minimal exposure, less than 0.1 mSv per year under normal conditions and less than 1 mSv per year under unlikely conditions"[76]) to category E ("extreme exposure, above 20 mSv per year under normal conditions and above 50 mSv per year under unlikely conditions"[76]).

Finland

The approach to the adoption of Euratom Directive 96/29 in Finland is very simple:

"Application principles of the Finnish radiation protection legislation to natural radiation are consistent with those of the new European Basic Safety Standards Directive. So there is no need for major revisions in Finnish legislation concerning regulatory control of exposure to natural radiation."[77]

United Kingdom

Ionising Radiations Regulations IRR-99[78] and the associated Approved Code of Practice[79] were developed in response to the Euratom Directive 96/29. Regulations 2(1) 'Interpretation' and 3(1) 'Application'[78] give only generic definitions and Schedule 8[78] contains the same values as IAEA Basic Safety Standards.

The Approved Code of Practice, however, is more specific: "In the special case of substances containing naturally occurring radionuclides used in work other than a practice, their activity cannot be disregarded for the purposes of radiation protection where their use is likely to lead to employees or other persons receiving a dose of ionising radiations of 1 millisievert in a year…"[79]

Therefore, if either workers or members of the public will receive a radiation dose in excess of 1 millisievert per year as a result of the NORM technological enhancement, "then it will be considered that the activity of the NORM… will be sufficient to trigger the application of IRR"[80]

As reported by the NRPB, "the processes and specific site situations are many and varied and thus case specific assessments of the radiological hazards are necessary to ensure appropriate protection is instituted."[70]

When Proposals for revised IRR and ACoP were published the following statement accompanied them, among others:
"We intend to make full use of flexibility of the 1996 BSS Directive for generic authorisations… The Commission intends the authorisation process to be as simple as possible, related to the degree of risk involved in the practice."[81]

"Even before the revised BSS Directive was finally adopted, HSE [Health and Safety Executive] issued an informal consultation paper… 11 relatively independent topic areas, such as reporting and authorisation, classification and monitoring of areas and natural radiation"[82] were identified. "Groups were formed and… the conclusions… were brought together for working up draft regulations."[82]

Germany

The following dose levels have been chosen for TENORM:

- "if the annual dose for a worker…(or… for other persons of the general public) arising from a certain practice will remain below 1 mSv/a, no action need to be taken at all; in particular, there is no need for applying the scheme of reporting and authorisation.

- if the annual dose will be in the range between 1 and 6 mSv/a, it is generally considered adequate to apply conventional measures for good health and safety practices… Case-by-case investigations and decisions will usually be required.

- If the annual dose will be above 6 mSv/a, it is usually necessary to introduce an appropriate radiation protection system. …case-by-case investigations and decisions may help to reduce the exposure."[83]

There are three basic options[83] of transforming these dose limits into the numerical criteria for TENORM:

- prescription of dose levels only;

- prescription of dose levels and reference levels (specific activity) for all situations where the dose level could be exceeded, "using a set of values for each type of workplace or industry"[83];

- prescription of dose levels and a single set of reference levels (specific activity) which will "apply simultaneously to all those types of workplaces and industries for which this dose level could possibly be exceeded"[83].

Other Countries

Many case studies of radiation exposure to NORM and of the regulatory implications of the Euratom Directive 96/29 were carried out in other European countries, for example, in Lithuania[84], Sweden[85], Romania[86], Spain[87], Poland[88], Belgium[89], Slovenia[90], Norway[91] and Albania.[92]

AMERICA

Brazil

A TENORM 'case study', called 'The Mining Project', similar to the one conducted in Europe[24] is carried out in Brazil. Radiological impact of mining of minerals where thorium and uranium occur associated with the main ore and their processing is being studied. At the end of the project an assessment of the potential risks associated with these industries will be made and specific regulations will be established.[93]

The study is specific to the Brazilian conditions and it is unlikely that international standards will be adopted without proper evaluation.

One suggestion for regulation of NORM in Brazil was made in 1997: "exempt activity concentrations of 10 Bq/g for both, radium-228 and radium-226, can be adopted at least as a starting point for regulating NORM."[44]

Canada

Atomic Energy Control regulations (C.R.C., c.365) do not apply for TENORM:

"2.1. These Regulations… do not apply in respect of naturally occurring radioactive prescribed substances where the substances:

(a) are present in a mineral or other material; and
(b) have not been related to an activity associated with the development, application and use of atomic energy."[94]

Guidelines for the management of NORM, based on the classification of hazards, are being developed. The dose constraint proposed for a single source of exposure is proposed to be set on the level of 0.3 mSv/year.[2]

Other Countries

Other countries are either adopting IAEA BSS or have already proclaimed a radiation protection legislation compatible with them.

There is not too much disagreement between legislation in Argentina (Norma Basica de Seguridad Radiologica - AR 10.1.1)[95] and the BSS or ICRP-60.

The concepts specified in the ICRP-60 and, thus, IAEA Basic Safety Standards, are also adopted into radiation protection legislation in Peru[96], Cuba[97][98] and Mexico[99].

United States of America

The system of radiation protection in the USA is extremely complicated, sometimes to the confusion of all concerned parties, both 'regulators' and 'operators'.

For example, "…a dozen federal agencies have responsibilities for setting nuclear standards. These agencies operate under different laws, which may result in conflicting, duplicative or overlapping regulations to protect the general public."[100]

A good description was also given by the NRC Commissioner Greta J. Dicus: "In the United States, not only have we not adopted the ICRP's latest recommendations, but we are also inconsistent within our own borders due to conflicting standards among our federal agencies. …Different statutory approaches… have resulted… in a patchwork quilt of radiological protection requirements that often conflict with each other. This is a situation that does not engender public and political confidence in our scientists and in our policy makers."[101]

The 'main' agencies that are dealing with radiation protection of workers and the general public are:

- Nuclear Regulatory Commission (NRC);
- Department of Energy (DOE);
- National Council on Radiation Protection and Measurements (NCRP);
- Environmental Protection Agency (EPA);
- Conference of Radiation Control Program Directors (CRCPD) - State Governments.

NRC (Nuclear Regulatory Commission) has no regulatory authority in the TENORM field and when CRCPD developed 'Part N - Suggested State Regulations for TENORM' (see below), the reply from the NRC was that it 'could not give concurrence "since TENORM is outside of NRC's regulatory jurisdiction."(102)
But, despite this, in June 1999 a request for comment on a rulemaking on release of certain materials, such as "steel, aluminium, copper, concrete, soil… sludges, slug, asbestos"(103) by the NRC appeared in the Federal Register.

As described in "Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials" by the National Research Council(104), NRC legislation(105)(106) such as Regulations on Decommissioning of Licensed Facilities and Guidance on Disposal of Residual Thorium and Uranium "are potentially relevant to regulation for TENORM."(104)

DOE (Department of Energy) establishes its own radiation protection legislation(107) and is "responsible for regulating TENORM arising from any of its authorised activities. DOE has regulatory authority over any NARM [Naturally occurring and Accelerator-produced Radioactive Materials] and thus TENORM."(104)

NCRP (National Council on Radiation Protection and Measurements) "is an advisory organisation and it has no authority to establish or enforce any requirements for radiation protection."(104) Its recommendations, however, influence the development of guidelines by other agencies. NCRP "has issued many reports addressing NORM and TENORM"(104) and other reports which may become potentially relevant for the regulation of technological enhancement of natural radioactivity.
One of such documents is NCRP-118 "Radiation Protection in The Mineral Extraction Industry."(108)

Another example is a recent draft report, which evaluated the Linear No-Threshold dose response model.(109) Since this is "draft report for comment", no references will be made. The main conclusion is that there is a linear no-threshold relationship between the risk and the dose.

EPA (Environmental Protection Agency) has complex and varied responsibilities in the field of radiation protection. "They include the development of federal guidance on radiation protection of the public; standards for radioactivity in the environment under authority of the Atomic Energy Act; standards for radioactivity under various laws… and guidance and regulations for indoor radon."(104)

The Committee of the National Research Council has found that:
"the differences between EPA guidelines for TENORM and similar guidelines developed by other organizations are:
- not based on scientific and technical information…
- based essentially on differences in policy judgements for risk management."(104)

A thorough review of EPA Guidances and Regulations for NORM is presented in the chapter 7 of the National Research Council Report.[104]

Other EPA Guidances may also become applicable for TENORM, for example, Federal Guidance Regulations FGR-12[110] and FGR-13.[111]

FGR-13 is of a particular interest since it establishes radiation risk coefficients for 'mortality' and 'morbidity' for about 100 radionuclides to be used in regulatory programs and in the preparation of environmental impact statements.
Tabulated data provide 'mortality' and 'morbidity' coefficients for the 'intake in becquerel'.

A short definition of 'mortality' and 'morbidity':
'Mortality' - you die from radiation-induced illness before you die from something else first;
'Morbidity' - you recover from the radiation-induced illness or you die from something else before radiation will finish you off.

FGR-13 "are not intended for application to specific individuals and should not be used for that purpose, …this document will be used in such activities as preparation of environmental impact statements and development of assessments in support of generic rule making for control of radiation exposure."[111]

EPA maintains that Federal Guidance reports are not legally enforceable. It is, however, quite possible that the FGR-13 Report will be adopted in practice. Then it would be a requirement to calculate the number of cancers that a proposed (or existing) facility will cause in the group of members of general public who are unfortunate to live nearby.

Let us consider an abstract example:

A facility is proposed on the outskirts of a town with a population of 100,000 people and the environmental impact assessment is required.

a) A current environmental impact statement says that due to the processing of a 'NORM-containing material' (containing just natural thorium - for simplicity) at a facility the maximum radiation dose for a member of the public in town will be 0.05 mSv/year from dust inhalation and 0.05 mSv from external radiation.

   The result of 0.1 mSv compares favourably with the annual limit for members of the public (1 mSv) and there is no problem. Local press is unaware of 'NORM' situation and, if it is, the level of exposure will not, probably, generate much criticism.

b) Applying the FGR-13 for levels of radiation exposure described in (a), a 'new' environmental impact statement is written. Annual 'mortality' coefficient is around $3.2*10^{-6}$, annual 'morbidity' coefficient is around $3.6*10^{-6}$. Let's assume that a facility will be operational for 25 years. Then there is a possibility that during this time due to the operation of a facility about 9 people in this town could get a non-lethal cancer and 8 people could die from radiation-induced cancer.

These calculations are very imprecise and are made here only to illustrate the following possibility. After the local press get a copy of the environment impact statement (which is 'a document available for public review') it is very likely that the construction of a facility will simply not go ahead.
Developers facing such environmental impact assessment process will probably not even consider investment in 'NORM-related' activities and, therefore, some parts of industry may be severely affected.

CRCPD (Conference of Radiation Control Program Directors) is developing 'suggested state radiation protection regulations' to be adopted into the legislation by individual States. "Part N - Regulation and Licensing of Technologically Enhanced Naturally Occurring Radioactive Material"(112) was approved by the CRCPD Board of Directors in October 1998 and was issued as a 'suggested state regulation' in April 1999. The implementation of the Part N is currently discussed by the CRCPD E-36 Committee.(113)

The CRCPD regulation does not have any legal authority until it is adopted by the State. However, it is possible that some States could adopt Part N virtually verbatim due, for example, to the limited resources at a State level.

The 'corner stone' of the Part N is the limit of 5 pCi/g (0.185 Bq/g) for radium-228 or radium-226. This value seems to be overly restrictive since it is 54 times lower than the exemption limit for these radionuclides specified in the IAEA Basic Safety Standards(1) (10 Bq/g).

Verbatim adoption of the Part N by a State would result in the requirement for any person handling TENORM (more than 0.185 Bq/g radium by definition) to obtain a 'specific license', which will require radiation protection dosimetry and training programs, statutory reporting, proper warning signs and, probably, posting a site clean-up bond as well.

The need for State-specific TENORM legislation could be illustrated by an another abstract example.

Let us consider a small 'TENORM' enterprise in a country town that, in course of its activity, could potentially expose employees to doses of up to 2 - 3 mSv in a year. Due to the waste disposal from this enterprise doses to members of the public could be up to 0.2 mSv/year. Radium concentration in the processed material could be typically around 100 pCi/g (~3.7 Bq/g), which is definitely above the 'action limit' specified in the CRCPD Part N regulations which were just adopted in this State.

Therefore, both 'operator' and 'regulator' should have a closer look into the practices of this particular small enterprise. And, since exposures associated with this enterprise are comparable with those encountered in the nuclear industry, the answer is simple - this place is to be regulated somehow. The question is: How..?

Should the material used by this enterprise be classified as a "source material" (as per 10 CFR Part 40 and, subsequently, subject to the NRC jurisdiction)? If this will be done, there is a possibility that the local paper will have 5'x5' letters on the front page in a couple of days - something about 'nuclear waste' and 'deadly radiation in our town'.
It is quite possible that the proprietor of the enterprise will realise that he is about to be regulated by "Federal Men In Black" and simply shut the doors and open a bakery or some other 'safe' business.

And right here a friendly State Radiation Control Bureau comes to help with CRCPD Part N adopted into State regulations, LOCAL inspectors and limits for Ra-226 and Ra-228 (adopted for this particular kind of activity), thus avoiding any association with 'nuclear activities'.
Therefore, it is possible for the enterprise to continue its activities, provided that the doses will be kept as low as practicable.

It should be pointed out that National Research Council(104) has recognised that standards developed for one kind of TENORM do not necessarily apply for other materials.

For example, radium-226 is contained in uranium mill tailings, zircon mill tailings and scales from the oil and gas industry.
One of the main sources of the radiation exposure for uranium mill tailings will be exposure to radon-222.

In the case of zircon mill tailings, this exposure pathway will be minimal(114) due to the fact that chemical properties of the original mineral, zircon, remain unchanged and uranium atoms remain embedded in the zircon crystal lattice. For the same reason, environmental mobility of radium-226 in zircon mill tailings will be significantly lower than for uranium mill tailings.

Scales from the oil and gas industry have completely different chemical and physical properties but the same '5 pCi/g' limit may become applicable for all three situations.

It is yet to be seen how CRCPD Part N Suggested State Regulations will be adopted in individual States.

The State of Illinois is currently developing implementation guidance for the CRCPD Part N regulations. The State of Texas is also considering the adoption of regulations for NORM on the basis of CRCPD Part N.

Hopefully, the number '5 pCi/g' will be considered as a 'guideline value' or 'action level', and not as the strict legislative limit. Then the process of exemption or authorisation will be similar to the one, which was described for the adoption of the IAEA Basic Safety Standards in other countries.

Each 'concerned' industry should be able to 'present its case' and the decision should be made on the basis of the real estimate of potential radiation exposure. In fact, one TENORM industry has already been exempted from the Part N regulations all together:

"Sec.N4 - Exemptions:
...
c. The distribution, including custom blending, possession, and use of fertilizers containing TENORM, is exempt from the requirements of this Part."(112)
The Rationale gives the following explanation for this exemption: "The agricultural benefit of using these materials is considered to outweigh the health risks associated with their radiological content."(112)

The Health Physics Society has also recognised the potential TENORM legislation problem. Its Standards Coordinating Committee has formed a special working group with the aim of developing American National Standards Institute - Health Physics Society TENORM Standard. "The purpose of the standard is to specify numerical criteria and provide technical guidance regarding the management of radioactivity in products and waste. The focus of the standard is to identify technical and regulatory issues, propose numerical criteria, and outline considerations for evaluating the impact of TENORM on the public and environment."(115)

Disagreements about the applicability of the linear no threshold dose response model based mainly on a personal perception could lead to very interesting situations.

For example, when in June 1999 the National Research Council organised the latest panel on the Biological Effects of Ionizing Radiation, the composition of the committee was criticised by 'both sides' of the 'LNT debate':
Some groups believe that "the panel 'is completely skewed' toward people who favour relaxed standards… Other groups say the panel contains the opposite bias and ignores researchers who believe the LNT model is too restrictive."(116)

In conclusion, it could be said that if radiation protection in the United States of America is not harmonised to some extent, the bringing of TENORM onto a regulatory arena would complicate regulations to the degree where they cease to be practicable.

'Agreements of understanding' between different federal government bodies are required to specify which department has control over which part of radiation protection.

The degree of over-regulation in the USA is nicely illustrated by the recent federal government proposed rules and regulations for the storage and preparation of eggs.
As described in the Editorial of the Investor's Business Daily, "Despite its obvious silliness, the egg proposal is likely to become regulation. …The federal government had been protecting us from ourselves for years. It's given us a society where products ranging from pillows to power tools must have warning labels, air bags that can kill are forced upon the driving public and government regulations cover virtually every facet of life - or try to. …The growth of the nanny state is clear evidence that high taxes and free spending aren't the only ways a government can exceed its legitimate and common-sense limits."(117)
The Editorial comes to the conclusion that the following warning label would be very desirable: "Government regulations can be hazardous to your freedom."(117)

Extremely low limits specified in many 'radiation' legislative acts and guidelines are an excellent illustration for a book "The Death of Common Sense: How Law is Suffocating America" by Philip Howard.[118] (In this book a corporate lawyer shows how rules interfere with common sense and have taken away citizens' power to make decisions.)

It looks like at least some government departments are more concerned about the public opinion and not the actual risks of radiation exposure.

OTHER COUNTRIES

In this part several examples of IAEA Basic Safety Standards adoption in other regions of the world are briefly described.

Current regulations will have to be reviewed and revised"[119] in the Philippines. This will apply in particular to Part 3 'Standards for Protection Against Radiation' and Part 4 'Rules and Regulations on the Safe Transport of Radioactive Materials in the Philippines'.

The updated radiation protection legislation in Korea[120] (Notice of MOST No.96-35) will specify the exemption level exactly as written in the IAEA BSS.

India has "already taken steps to implement the recommendations contained in the ICRP-60 Publication."[121]

In Egypt "the standard of radiation protection adopted by the national centre for nuclear safety and radiation control (NCNSRC) is based mainly on the international basic safety standards… (Safety Series No.115)."[122]

In Malaysia the Atomic Energy Licensing Board "trigger/reporting levels (and sampling plans)" are "stringent to the very high degree, the reporting levels certainly being more conservative than the exemption levels which are to be enacted in the EU in May 2000."[123]

Currently applicable 'Protection from Radiation Act 5, 1983' in Tanzania "needs revision particularly on some administrative and technical issues. …the present law does not address… the more up-to-date International Basic Safety Standards."[124] NORM case study has also been carried out. "Radioactivity and ambient radiation monitoring program in Tanzania is based on geological surveys indicating the existence of uranium, coal and phosphate bearing minerals. The aim is to collect scientific data on safety aspects of the practice on the basis of which decisions or measures can be taken to limit the radiation dose."[124]

IAEA Publications in many cases are adopted in regulations or standards in Indonesia.[125]

The impact of the proposed national policy and strategy on Integrated Pollution Management on TENORM industries in the Republic of South Africa was described in the Report of the Minerals, Energy and Allied Industries Forum on Radiation (IFR) in 1998.[126]

The proposed exemption limit for licensing NORM residues was set at the very low specific activity level of 0.2 Bq/g (with some natural geological formations in the country ranging up to 1.5 Bq/g).
As a result, enormous volumes of tailings from gold and mineral sands mining, phosphate industry and burning of coal would require 'appropriate disposal.'[(126)]

The IFR report (South Africa) raises an issue of physical stability of mine residue deposits, which is very important for the mining industry, but is almost never discussed in conjunction with radiation protection.

A 'large-volume' NORM tailings repository/deposit usually has three types of hazards associated with it, which could be lined up in the order of importance as follows:

physical hazards > chemical hazards > radiation hazards

But due to the irrational fear of ionising radiation this order is often reversed.
Statistical data indicates that, in the period between 1962 and 1994, at least six hundred and thirty four people lost their lives due to the failures of mine residue deposits in Chile, UK, Zambia, USA and South Africa.[(126)]

And, nevertheless, mining and minerals processing companies are forced to comply with more and more restrictive (and, therefore, expensive) radiation protection regulations. The protection of a hypothetical member of the general public from hypothetical health effects of ionising radiation cause the spreading of available human and financial resources thinner and thinner.

The following analogy could be made:

> One could instruct employees about the safe use of a radiation density gauge, make everybody pass tests on the associated guidelines, place all the radiation warning signs around etc. But this will not help at all if the 120-kilogram device will fall on somebody's head because it was attached to the pipe incorrectly…

PRACTICAL SUGGESTIONS

LEGISLATIVE INCONSISTENCIES

As it was pointed out earlier, the TENORM issue may be either 'a final blow' or 'a turning point' in communicating radiation protection issues to the general public.

The association of TENORM industries with anything 'nuclear' is being consistently avoided. For example, 'Oil and Gas Industry' in publications dealing with radiation issues became 'E and P [Exploration and Production] Industry'. Similar trend is characteristic not only for mining and minerals processing. For example, 'Nuclear Magnetic Resonance' became 'Magnetic Resonance Imaging'.

The explanation for the reluctance of TENORM industries to be associated in any way with the word 'nuclear' is obvious.

For example, large amounts of NORM waste "will be in need of treatment, storage and disposal because of the dose limitations in the EC Directive 96/29/Euratom."(127)
There are many approaches to the management of TENORM waste: "shallow land burial",(128) "interim storage, diluting, spreading, product dependent clearance levels, recycling, separation, decontamination"(129) and immobilisation.(130)

The main problem, however, is an administrative one.

"…The nuclear waste heritage will play an important role in… the coming development of policies that deal with this [NORM] type of waste: not all public actors will be able or will want to make a proper distinction between the two categories. The emphasis will potentially be on 'radioactive', not on the amount of radioactivity."(127)
The following guideline is suggested: "Separate the discussion on natural radionuclides as much as possible from the nuclear energy discussion. In practice that may mean: do not involve the same institutions, people and routines."(127)

Of course, biological and chemical properties of man-made and naturally occurring radionuclides are different. But when the exposure to the same radioisotope is treated differently in 'nuclear' and 'non-nuclear' industries, a reasonable observer could see another inconsistency in a radiation protection legislation. (The first inconsistency in applying different radiation protection standards for 'radon' and 'other than radon' exposure was described earlier.)

L. Scott suggested that radionuclides must be regulated in a uniform and consistent manner on the basis of the following:

- "If a radionuclide is a hazard at a given concentration, it is a hazard regardless of the regulatory environment;
- If an atom of uranium poses a hazard at a licensed site, then the atom of uranium poses the same hazard at an alumina or rare earth production site."(131)

It could be, of course, argued that the 'consistent manner' of regulation is not possible due to the fact that in different situations a particular radioisotope is present in different chemical compounds. Physical properties of materials should also be taken into consideration.

But what about the following example:

Both radium-226 ions that were washed off from the pile of fertiliser on a farm into a stream nearby and radium-226 ions that were discharged from a 'nuclear facility' upstream into the same river are exactly the same.
However, in the first instance radium in water is the result of a 'work activity' and in the second one is the result of a 'practice'. Therefore, radium ions from a 'nuclear installation' are gaining some special magic powers to harm a farmer much more than the ones from the fertiliser.

The third example of 'legislative inconsistency' is the reluctance of appropriate authorities to apply the same limits for the industry and for the general public.

'Blank' exemption of fertilisers from the requirements of the Part N of the Suggested State Regulations for TENORM by the US CRCPD was discussed before. Another case is an application of relevant regulations for 'consumer products'.

For example, in the discussion of the proposed regulations in The Netherlands, when the distinction between 'bulk amounts' and 'smaller sources' was made, consumer goods were not included in the latter type of sources.(74) The proposed USA CRCPD exemption limit of 5 pCi/g radium also "does not apply to consumer and retail products."(112)

THE EXAMPLE OF ZIRCON

Leaving aside an exact definition for a 'consumer product' let us consider the possibility of the same material being 'radioactive' and 'non-radioactive' on different stages of processing:

Mining and concentrating.

The separation of the mineral zircon from mineral sands ore is achieved by purely physical means (gravimetric, electrostatic and electromagnetic separation). Therefore, the product ready for shipping is in exactly the same chemical and physical form as found in the natural environment.

The specific activity of zircon is typically around 4 Bq/g. The material is currently not considered 'radioactive' in Western Australia but could be classified as TENORM in the USA (due to the fact that separation methods described above were included in the CRCPD Part N definition for the enhancement of natural radioactivity).(112)

Transport.

The following provision for 'natural material' is included in the new IAEA Transport Safety Regulations ST-1:(132)
"107. The Regulations do not apply to…

(e) natural material and ores containing naturally occurring radionuclides which are not intended to be processed for use of these radionuclides provided the activity concentration of the material does not exceed 10 times the limit values specified in paras 401-406."[132]

Problem 1: As described before[73], different methods are currently used to calculate specific activity due to the differences in including daughter radionuclides in the calculations. Zircon could be potentially classified as 'radioactive material' due to the simple 'mix-up' of numbers by an operator or an appropriate authority.

Problem 2: As in the case of mining and concentrating, due to the difference between available definitions of a 'natural material' the transport of zircon could also become the transport of 'radioactive' material in some countries.

ST-2 "Advisory Material" for the IAEA Transport Regulations ST-1[132] is currently in the draft form. This document is expected to clarify the definition of a 'natural material'.

<u>Processing.</u>

Let us take, for example, a zircon 'micronising' operation[133], where grains of the mineral (150-200 microns in diameter) are milled to produce the product called 'zircon flour' with a fineness of about 3 microns. It must be mentioned that chemical properties of the mineral do not change during the processing.

Due to the potential differences in the interpretation of the term 'natural' and the fact that small 'zircon flour' particles could be more easily inhaled than mineral grains, the following situation may be a result:

A zircon mill will be receiving a 'non-radioactive' raw material from which it will be producing a 'radioactive' product for further applications in other industries.

<u>Manufacture of a 'consumer product'.</u>

Zircon flour is used as an opacifier in ceramic glazes. An interesting situation, which is directly opposite to the one described above may be a result:

A facility manufacturing ceramic tiles will be receiving a 'radioactive' material which will be used in the production of 'non-radioactive' 'consumer products'.

THE MAIN PROBLEM OF THE TENORM REGULATION

The situation with the regulation of TENORM looks like a labyrinth with no exit:

⇒ By separation of radiation protection standards for TENORM from radiation protection standards for the nuclear industry, 'appropriate authorities' are effectively telling the general public that 'technologically enhanced natural' radiation is not as bad as 'nuclear' radiation.

⇒ This leads to further 'regulatory' and 'community' problems for the nuclear industry, its over-regulation and the lowering of statutory exemption limits.

⇒ But this decrease of exemption limits is exactly what has brought the TENORM issue to the surface in the first place!

It seems that the proposal of Roger Clarke to cut the 'Gordian Knot' by introducing the concept of a 'controllable dose'(33) is an excellent solution for the described inconsistency problem.

In the interim, while this concept takes shape, the following practical suggestions may be taken on board by the radiation protection professionals, appropriate authorities and potentially affected industries.

RADIATION PROTECTION PROFESSIONALS

Mutual recognition of radiation protection education and experience

It is expected that the demand for radiation protection professionals will increase because a number of industries where natural radioactivity is technologically enhanced will require radiation monitoring programs, authorisations, notifications and so on. It is likely that the appointment of a 'Radiation Protection Adviser' (as, for example, in the proposed IRR-99 regulations in the United Kingdom(78)) will be required at many facilities.

Therefore, mutual recognition of radiation protection education and experience between different countries will be very desirable. The proposal put forward by the German-Swiss Radiation Protection Association(134) requires attention from other radiation protection societies.

It is proposed "to establish a committee of experts which… [discusses] sets of criteria for education of radiation protection experts and technicians and for radiation protection training for different categories of professionally exposed persons. These criteria should be approved by the Societies and then be made available to the competent authorities in their countries…"(134)

Suggestion 1.1

Regional and international programs relevant to the mutual recognition of radiation protection education and experience, eventually leading to the signing of certain international agreements should be considered by national radiation protection societies.

Communications with the general public

Only about 15% of the human exposure to ionising radiation comes from man-made sources. The remaining 85% (88% in Perth, Western Australia[135]) of the annual dose is the result of the exposure to 'natural' radiation - cosmic rays, natural radioactivity in food we eat, air we breathe, water we drink and soil we live on and, of course, due to the technological enhancement of natural radioactivity.

Suggestion 1.2.

Different ways of communicating information about natural radiation directly to the general public should be examined.

Suggestion 1.3.

Public education initiatives such as Science Teachers' Workshop Program by the Baltimore-Washington Chapter[136] of the Health Physics Society should be encouraged and expanded.

Suggestion 1.4.

The liaison between radiation protection societies and other professional bodies (such as engineering institutions, environmental protection groups and societies, medical associations and unions of journalists) should be encouraged to pass the information about radiation to the general public.

Suggestion 1.5.

Biased reports in mass media should be vehemently opposed and not left to 'die by themselves' as it is often the case.

Professional communications

There are many radiation protection Journals and Bulletins dedicated to the exposure to the man-made sources of ionising radiation. Surprisingly, there is not a one solely dedicated to the TENORM issues.

Suggestion 1.6.

The publication of a special TENORM Journal must be considered in order to provide an opportunity for researchers to communicate their findings and problems' solutions.

Suggestion 1.7.

A special TENORM e-mail listserver similar to the RADSAFE[137] maintained at the University of Illinois or, alternatively, TENORM-related message board should be created on the Internet as soon as possible. Thus informal instant communications between researchers in different countries will become possible.

'Controllable dose' concept

The concept of a 'controllable dose'[33] is so far the most convenient and simple solution for eliminating the inconsistencies in the radiation protection from low doses of ionising radiation.

Suggestion 1.8.

The 'controllable dose' concept should be discussed and results of the discussion implemented in practice without delay. "ICRP would welcome a wide discussion on the concept of controllable dose and the new proposals for a simplification of protection philosophy."[(33)] This simplification represents obvious benefits for radiation protection.

APPROPRIATE AUTHORITIES

The following suggestions may be taken on board by national regulatory authorities.

Adoption of IAEA Basic Safety Standards

As it was described earlier, verbatim adoption of IAEA BSS into a national radiation protection legislation would present substantial problems both for an 'appropriate authority' and for the affected industries.

Suggestion 2.1.

The magnitude of potential problems associated with the local TENORM industries must be assessed by an appropriate authority.

Suggestion 2.2.

If deemed necessary, the creation of a separate task force or divisions within government departments dedicated solely to NORM and TENORM should be considered. A good example is the "National Radiation Protection Department and Center for Research on Elevated Natural Radiation" of the Atomic Energy Agency in the Islamic Republic of Iran.

It is further suggested that a 'TENORM Group' be created in Australia on the federal level. This Group would consider possible radiation protection regulations for TENORM and would consist of experts from both government and industry from different States and Territories.

Suggestion 2.3.

After the draft of the regulations has been completed, the assessment of the possible economical impact and legal implications both for a regulatory authority and for affected parts of the local industry should be carried out.

This assessment must be carried out in co-operation with:

- all industries that may become 'regulated' and different industry committees, such as, for example, a chamber of mines;
- other government bodies, such as, for example, departments of environmental protection, minerals and energy, resources and development and so on.

Suggestion 2.4.

If, after the consultations with the industry and the public, the decision is made to adopt IAEA Basic Safety Standards in full, or they have been already adopted in regulations, two ways of a 'gradual' adoption of the legislation could be considered.

The most sensible approach in applying the legislation in practice would be an introduction of some dose constraints relevant to the 'primary' limit of 1 mSv per year for a member of the public.

Variant A:

If there exists (or will exist) a work activity that could expose a member of the public from a nearby 'critical group' to:

1) a dose "in order of several tens of millisieverts per year", say, less than 40-50 microSv per year (5% of the limit) - no worries at all, work activity continues without any regulation;
2) a dose below 0.33 mSv per year ($^{1}/_{3}$ of the limit) - a brief justification statement is to be prepared by an 'operator' for review by an 'appropriate authority'. The authority then issues a 'licence' of 'authorisation' without any problems, acknowledging the receipt of the application;
3) a dose below 1.0 mSv per year (but higher than 0.33 mSv/year) - a more complex document (a dozen pages or so) is prepared by an 'operator' for an 'appropriate authority'. This document is a subject for review by this authority, which must ensure that the 'best practicable technology' is used and doses are 'as low as reasonably achievable'. Then either the 'licence' or 'authorisation' is issued or the document is send back to the operator for 'improvement';
4) a dose above 1.0 mSv/year - an 'authority' says to an 'operator': "go and fix it", then come back and we'll see what we can do. An exemption could be theoretically obtained but it would need a very good reason.

Variant B:

The implementation of regulations is carried out "in stages".
An immediate attention is given to work activities where the radiation exposure for members of the public close to 1 mSv per year could be expected.
After these work activities are evaluated, there comes a turn of processes where the radiation exposure is expected to be in the range between 300 - 350 microSv and 1 mSv per year.
And only after all these work activities are either excluded, or optimised and regulated, an 'appropriate authority' should take a closer look at the practices in the dose interval 20 - 300 microSv per year.

TENORM INDUSTRIES

The following suggestions may be taken on board by TENORM industries.

Suggestion 3.1.

The potential problems associated with TENORM within an industry should be identified and solutions should be found before the local regulations will come into force. Studies carried out in other countries should be taken into account, as it is quite possible that problems, which seem to be impossible to solve by the local industry, were already rectified some time ago in another country.

Suggestion 3.2.

The potential implications of radiation protection legislation should be communicated within an industry and to appropriate authorities. Workshops, seminars and conferences on TENORM must address not only studies of radiation exposure but also potential economic and legal consequences of bringing natural radioactivity under regulatory control.

Suggestion 3.3.

Co-operation with appropriate authorities in the development of relevant radiation protection regulations should be an aim for industries, which are sometimes just a passive target for the already promulgated legislation.

Suggestion 3.4.

National and international co-operation between producers and downstream processors of NORM-containing products should be encouraged. (Some regulations, as, for example, proposed IRR-99[78][79] in the United Kingdom or Mines Safety and Inspection Regulations[138] in Western Australia make such a co-operation compulsory on a national or local level, respectively.)

The general public is mainly not aware of the presence of naturally occurring radioactive materials in the surrounding environment. Biased reports and claims by different 'interest groups' in mass media could severely damage the sound reputation many TENORM industries enjoy in regards to the safety in the workplace and the preservation of the environment.

Suggestion 3.5.

Industries should be proactive in communications with the general public and try to 'confine' 'extremist' interest groups and to 'open a dialogue' with the 'moderate' ones. The creation of 'media watch groups' and 'public consultation groups' for TENORM industries could be suggested.

Suggestion 3.6.

The co-operation between TENORM industries internationally will result in obvious benefits. For example, if there are several committees dealing with radiation protection in a given TENORM industry, the creation of a working group that will co-ordinate the activities of these committees will be very beneficial for an industry in all countries. Similar guidelines would be streamlined to the practicable extent and the identical research activities would be evenly distributed between experts in different counties.

In some industries, for example in the phosphate industry, the co-operation is very well developed; in others, such as in the mineral sands mining and processing industry, the co-operation is only rudimentary.

Some of the suggestions above could be very practical, other ones possibly would be described as 'out of phase with reality'.

CONCLUSION

The main conclusion made on the basis of the information presented above is:

International Atomic Energy Agency Basic Safety Standards should not be adopted into a national radiation protection legislation verbatim, without a thorough investigation of health, economic and legal implications for the many industries where natural radioactivity is technologically enhanced.

A number of practical examples from different countries were described and several possible solutions were suggested.

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