STRENGTHENING THE SAFETY OF RADIATION SOURCES & THE SECURITY OF RADIOACTIVE MATERIALS: THE SECURITY OF RADIOACTIVE MATERIALS:

BY ABEL J. GONZÁLEZ

When used as they should be, commercial radiation sources and radioactive materials are useful tools that pose no unacceptable risks to people or the environment. In fact, their applications in fields such as medicine, industry, agriculture, and environmental research help countries achieve sizeable social and economic benefits important to global goals of sustainable development.

For most of the past half century, the IAEA has been instrumental in advancing the application of techniques that constructively make use of ionizing radiation's properties, particularly in the developing world. As importantly, the Agency has spearheaded, along with partner organizations, the attainment of international standards for protection of people against radiation exposure and also for the safety of radiation sources, and the security of radioactive materials. Support for these standards is broadbased, and their periodic review and revision effectively have served to keep them in tune with the latest scientific understanding of radiation effects on human health and the environment, and with technical developments in safety and security.

But though global standards are in place -- and being strengthened -- a disturbing picture is emerging. It is regrettably framed by tragic consequences from accidents that involved unsafe, abandoned, lost, or uncontrolled radiation sources, including cases of illicit trafficking of radioactive materials, notably in the 1990s.

The emerging global picture shows that existing international standards -- albeit endorsed by governments -- are not necessarily being adopted and applied. Events are showing that too many radiation sources are not managed or regulated as they should be; that safety requirements too often are either not being met or not in place at all; and that too many governments, who shoulder the prime responsibilities for regulating radiation safety and security, lack the infrastructure for properly fulfilling them.

A turning point in global awareness of serious problems came in 1998, at an international conference in Dijon, France, that the IAEA cosponsored with the European Commission, the International Criminal Police Organization, and theWorld Customs Organization.

So mobilized, States today are poised to take additional steps for strengthening international cooperation for radiation safety and security. In March 1999, the IAEA's 35-member Board of Governors discussed the issue. A multi-faceted Action Plan now is being submitted to the Board for endorsement and, subsequently, to the Agency's 129 Member States at their General Conference in September 1999. The steps represent timely action against a largely hidden but clearly emerging global challenge.

This edition of the IAEA Bulletin looks closely at the problems and issues the international community is facing, and at the steps States are taking to reinforce the safety and security of radioactive materials.

large number of accidents involving radiation sources and radioactive materials have been reported over the past half century. People have died from causes attributed to excessive radiation exposure, and many more have suffered serious, sometimes disabling injuries. In some cases, the associated environmental damage has been notable, and restoration financially costly.

A common denominator of the major accidents is a breach of safety or security requirements. Another common thread is that for the most part they could have been prevented through the

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SAFETY & SECURITY: DEFINING TERMS

Safety and security - "sûreté' and "sécurité" - are two distinct terms in English and French; in all other major languages, a common word is used for these two concepts. Not surprisingly, therefore, many people wonder what the distinction between safety and security actually is. If they reached for their dictionaries, they would perhaps be none the wiser, because one of the definitions of *security* is *safety* and vice versa. In the context of radiation exposure, both words are used to denote an assembly of administrative, technical and managerial features.
The safety of radiation sources is used to cover the features that diminish the likelihood of something going wrong with a source as a result of which people are overexposed.

■ The security of radioactive material is used to cover the features that prevent any unauthorized possession of radioactive materials by ensuring that their control is not relinquished or improperly transferred.

The **safety** issue covers all types of radiation sources, i.e., radiation generators and radioactive materials.

Generators can produce radiation with enough intensity to cause serious radiological consequences. In the same vein, the activity of radioactive material, and sometimes its activity concentration, can give rise to serious radiological situations.

The security issue is usually limited to radioactive materials alone and not to other radiation sources. This is because generators of ionizing radiation, such as X-ray machines and accelerators, are less likely to be a security threat. Security of radioactive materials is required for two major purposes: on the one hand, to prevent stray radioactive materials causing harm to people; on the other hand, to prevent the diversion of those radioactive materials which are also special fissionable (nuclear) materials, such as uranium-235 and plutonium-239, from legal to illegal, or criminal, uses. Articles in this edition of the IAEA Bulletin concentrate on the first of these two purposes. However, it is to be noted that the IAEA has a full programme dealing with the security of nuclear materials for safeguards purposes.

enforcement of international safety standards that were developed and issued for that purpose.

In normal everyday use, radiation sources and technologies are applied safely as commercially designed, approved, and regulated. They can be in the form of radiation generators, such as X-ray machines and particle accelerators, or instruments and devices containing radioactive materials. Many sources are sealed devices, with the radioactive material firmly contained or bound within a suitable capsule or housing; others consist of radioactive materials in an unsealed form.

If unsafe or unsecured, radiation sources can be detrimental to human health with varying levels of risk, depending on their characteristics. Sealed sources should only present a risk from external radiation exposure. However, damaged or leaking sealed sources, as well as unsealed radioactive materials, may lead to contamination of the environment and the intake of radioactive substances into the human body.

QUANTIFYING PROBLEMS

The terms radiation *safety* and *security* refer to different aspects of the global problems being faced. *(See box above.)* The distinction is important in the context of understanding both the scope and nature of problems and counteractions that can be effectively taken.

Safety of Radiation Sources. Many reported serious accidents are linked to breaches in the safety of radiation sources. Sometimes these occurred because the reliability of equipment was not sufficient. Other times they happened because of managerial or human mistakes. Many of the accidents have underlined problems of regulatory oversight at the national level.

No complete database exists on all radiation-related accidents that have occurred worldwide. The IAEA has compiled a list of major ones, drawing upon those reported in the open literature. (See tables, pages 14-15.) The Agency also has assessed, with the support of local authorities, the causes and consequences of a number of accidents. publishing the findings. The aim is to foster the exchange of experience and the application of lessons learned. (See box, pages 16-17.)

Security of Radioactive Material. Breaches in the security of radioactive materials cause them to be lost, stolen or simply abandoned. There are

1993-98				
BY COUNTRY	Number of cases	Percentage of cases		
Germany	67	28.6		
Russian Federation	52	22.1		
Poland	18	7.7		
Ukraine	17	7.2		
Lithuania	17	7.2		
Turkey	14	6.0		
Bulgaria	10	4.3		
Estonia	8	3.4		
Czech Republic	7	3.0		
Belarus	6	2.6		
Azerbaijan	3	1.3		
Italy	3	1.3		
New Zealand	1	0.4		

Seizures of Radioactive Sources,

BY RADIOACTIVE ELEMENT

	Number of cases	Percentage of cases
Uranium	129	55.1
Caesium	53	22.6
Plutonium	10	4.3
Radium	5	2.1
Americium	3	1.3
Other	34	14.5

Source: World Customs Organization

no data on the number of these events worldwide. However, in the United States alone. the Nuclear Regulatory Commission (NRC) annually receives about 200 reports of lost, stolen or abandoned radioactive sources. These are high levels for a country where regulations for controlling radioactive sources are particularly restrictive and the regulatory authority is particularly efficient. Senior NRC officials think that more cases are going unreported, and that the volume of reports received probably represent only "the tip of the iceberg".

The uncertainty is linked to what have come to be known as "*orphan sources*"-- those outside of regulatory control or lost and abandoned altogether. The world's metal recycling industries have been particularly vulnerable to them. Orphan sources can find their way into metal scrap destined for recycling. People who find them, attracted by the prospect of economic gain, sometimes sell the source for its metallic value to scrap dealers who usually are not aware of the radioactive content. Thus, the source enters into the worldwide scrap inventory which, because of the latest global opening of the markets, has became essentially uncontrollable. More than 2300 reports of sources found in scrap metal are stored in the NRC's database. (See table, page 6.) Sometimes, it is known that radiation sources were melted after detection of radiation contamination in imported commodoties. The NRC has detected a number of such cases. (See table, this page.)

In 1998, a case occured in Algeciras, Spain. Radioactive gases, aerosols and particles from the melting were released into the environment and detected over Europe. Although the incident was minor and promptly reported by the Spanish authorities, the airborne contamination aroused public concern. There are no international obligations to report these type of events, and there is no international

Products Contaminated with Radioactive Materials Imported into the United States

Product	Contaminant	Year	Origin
Steel, iron	Cobalt-60	1984	Mexico
Steel	Cobalt-60	1984	Taiwan, China
Steel	Cobalt-60	1985	Brazil
Steel	Cobalt-60	1988	Italy
Steel	Cobalt-60	1991	India
Ferrophosphorus	Cobalt-60	1993	Kazakhstan
Steel	Cobalt-60	1994	Bulgaria
Furnace dust	Caesium-137	1995	Canada
Lead	lead-210, bismuth-210, polonium-210	1996	Brazil
Steel	Cobalt-60	1998	Brazil

Source: US Nuclear Regulatory Commission

registry of cases of suspected melting of radioactive sources, or contaminated scrap, or of detected contaminated commodities. Again, the NRC information may be just the tip of a large iceberg.

In spite of this troubling situation, it is reassuring that the theft and smuggling of radioactive materials for malevolent purposes have historically been rare events. However, the use by terrorists of chemical, biological and -perhaps down the line -radioactive materials as weapons are no longer unimaginable crimes of the future.

Not surprisingly, governments are increasingly concerned about the illicit movement of radioactive and nuclear materials. Some materials are seized by customs officers but others may cross national borders undetected, particularly where customs officers do not know what to look for and lack the equipment to deal with the problem.

The World Customs Organization (WCO) has reported 234 confirmed cases of seizures between 1993-98. *(See table, this page.)* The

International Criminal Police Organization (INTERPOL) has also been active in the field. An analytical study was conducted covering principally the European region during the period 1992-94. As part of its programme, the IAEA also keeps a database of reported incidents. *(See box, page 7.)*

All these data may again be reflecting just part of the total picture, and more research needs to be done.

ROOTS OF CONCERN

The turning point for global interest in radiation safety and security problems was the International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials in September 1998. The roots of problems and concerns began to emerge, as did the seeds of global action to find solutions. (See box, page 10.) For some experts in the field, it is surprising that these issues are rising on the international agenda now. Others believe that is a natural consequence of a stronger international awareness of this issue.

During its 70 years of existence, the International Commission on Radiological Protection (ICRP) has produced about a hundred publications with recommendations for protection against ionizing radiation. National and international organizations have used them for establishing radiation protection standards. However, the ICRP, only very recently, has started to deal specifically with the problem of the safety of radiation sources.

The IAEA has taken the leading role in the United Nations system in establishing standards of safety and has issued more than a hundred documents on the subject. However, until the appearance of the international *Basic Safety* Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (BSS), the safety of radiation sources had been loosely addressed in the IAEA's standards. The security issue was also ignored by international standards until the BSS were was issued. Yet the security requirements now established are general in nature with very little quantification.

A Yardstick For Safety And Security. Solving problems of radiation safety and security requires a yardstick for measuring their scope. Despite shortcomings in the issue of security, the BSS provide that yardstick internationally. Their fundamental purpose is simply to promote coherent and consistent international approaches to radiation protection, radiation safety and the security of radioactive materials. *(See box, page 10.)*

PRESUMPTIONS & REALITIES

Unmet Governmental Responsibilities. It is important to emphasize that the BSS do not (indeed can not) impose responsibilities on governments. Instead, they presuppose that governments have discharged their natural responsibilities on safety and security. The BSS Preamble indicates that the standards are based on the presumption that governments have proper legislation and regulations in place to deal with problems of the safety of radioactive sources and the security of radioactive materials,

and that they have established independent regulatory authorities able to license sources, inspect them and enforce requirements.

The BSS, in fact, assume that every country has a regulatory authority with effective legal independence and with the necessary powers and resources. But resources, in particular, are something that regulatory authorities in developing countries are usually lacking. The BSS also assume that governments can provide, either directly or indirectly, essential support such as technical services (eg. dosimetry and calibration services), information exchange mechanisms and, of course, education and training of personnel.

Apparently, professionals and authorities alike were convinced that all these *a priori* conditions for safety and security were somehow automatically established and implemented. It was presumed, for instance, that all governments had radiation safety infrastructures in place which at least included a system of notification, registration, licensing and inspection of radiation sources.

But most of these assumptions are turning out to have been too optimistic for large parts of the world.

It is not true, for example, that all countries had proper legislation on radiation safety and security. It is not true that all countries have proper regulations in place. It is not true that in most countries there are independent regulatory authorities invested with the necessary powers to perform the work required of them. And, finally, it is not true 5

Year	Metal	Location	Isotope	Activity (GBq)
since 1910 ^a	Gold	New York	polonium-210, lead-210, bismuth-210	Unknown
1983	Steel	Auburn Steel, NY	cobalt-60	930
1983	Iron/steel	Mexicob	cobalt-60	15 000
1983	Gold	Unknown, NY	americium-241	Unknown
1983	Steel	Taiwan, China ^b	cobalt-60	>740
1984	Steel	US Pipe & Foundry, AL	caeium-137	0.37–1.9
1985	Steel	Brazil ^b	cobalt-60	Unknown
1985	Steel	Tamco, CA	caesium-137	56
1987	Steel	Florida Steel, FL	caesium-137	0.93
1987	Aluminium	United Technology, IN		0.74
1988	Lead	ALCO Pacific, CA	caesium-137	0.74-0.93
1988	Copper	Warrington, MO	Accelerator	Unknown
1988 1989	Steel Steel	Italy ^b Bayou Steel, LA	cobalt-60 caesium-137	Unknown 19
1989	Steel	Cytemp, PA	thorium	Unknown
1989	Steel	Italy	caesium-137	1000
1989	Aluminium	Russian Federation	Unknown	Unknown
1990	Steel	NUCOR Steel, UT	caesium-137	Unknown
1990	Aluminium	Italy	caesium-137	Unknown
1990	Steel	Ireland	caesium-137	3.7
1991	Steel	India ^b	cobalt-50	7.4–20
1991	Aluminium	Alcan Recycling, TN	thorium	Unknown
1991	Aluminium	Italy	caesium-137	Unknown
1991	Copper	Italy	americium-241	Unknown
1992	Steel	Newport Steel, KY	caesium-137	12
1992	Aluminium	Reynolds, VA	radium-226	Unknown
1992	Steel	Border Steel, TX	caesium-137	4.6-7.4
1992	Steel	Keystone Wire, IL	caesium-137	Unknown
1992	Steel	Poland	caesium-137	Unknown
1992	Copper	Estonia/Russian Federa		Unknown
1993 1993	Unknown	Russian Federation	radium-226	Unknown
1993	Steel (?) Steel	Russian Federation Auburn Steel, NY	caesium-137 caesium-137	Unknown 37
1993	Steel	Newport Steel, KY	caesium-137	7.4
1993	Steel	Chaparral Steel, TX	caesium-137	Unknown
1993	Zinc	Southern Zinc, GA	depleted uranium	Unknown
1993	Steel	Kazakhstan ^b	cobalt-60	0.3
1993	Steel	Florida Steel, FL	caesium-137	Unknown
1993	Steel	South Africa ^C	caesium-137	<600 Bq/g
1993	Steel	Italy	caesium-137	Unknown
1994	Steel	Austeel Lemont, IN	caesium-137	0.074
1994	Steel	US Pipe & Foundry, CA	caesium-137	Unknown
1994	Steel	Bulgaria ^b	cobalt-60	3.7
1995	Steel	Canada ^d	caesium-137	0.2–0.7
1995	Steel	Czech Rep.	cobalt-60	Unknown
1995	Steel (?)	Italy	caesium-137	Unknown
1996 1996	Steel Steel	Sweden Austria	cobalt-60 cobalt-60	87 Unknown
1996	Lead	Brazil ^b	polonium-210, lead-210, bismuth-210	Unknown
1996	Aluminium	Bluegrass Recycling, K	•	Unknown
1997	Aluminium	White Salvage Co., TN	americium-241	Unknown
1997	Steel	WCI, OH	cobalt-60	0.9 (?)
1997	Steel	Kentucky Electric, KY	caesium-137	1.3
1997	Steel	Italy	caesium-137/cobalt-60	200/37
1997	Steel	Greece	caesium-137	11 Bq/g
1997	Steel	Birmingham Steel, AL	caesium-137/americium-241	7 Bq/g
1997	Steel	Brazil ^b	cobalt-60	<0.2
1997	Steel	Bethlehem Steel, IN	cobalt-60	0.2
1998	Steel	Spain	caesium-137	>37
1998	Steel	Sweden	iridium-192	<90

Meltings of Radioactive Materials: International Overview

^aMultiple cases reported, earliest circa 1910. ^bContaminated product exported to USA.

^CContaminated vanadium slag exported to Austria; detected in Italy. ^dContaminated by-product (electric furnace dust) exported to USA. *Source:* Pennsylvania Dept. of Environmental Protection, J. Yusko, USA (see USA table, page 23). Reports to the IAEA.

ILLICIT TRAFFICKING OF RADIOACTIVE MATERIALS

As part of its activities for the security of material, the IAEA maintains a database on illicit trafficking of nuclear and radioactive materials. Sixty States participate in the database programme. As of June 1999, the database contained information on more than 320 reported incidents, of which 265 were confirmed by States.

Of all confirmed incidents, most involved radioactive materials or radioactive sources. Nearly half (or 129 cases) involved natural uranium, low-enriched uranium, depleted uranium, or thorium. About 45% (or 119 cases) involved radioactive sources, including caesium-137, cobalt-60, americium-241, and strontium-90.



that when a regulatory authority exists it always has the necessary resources at its disposal.

In the last decade, the IAEA launched a programme -- called the Radiation Protection Advisory Teams (RAPAT) -intended as a diagnostic tool. The IAEA was surprised to learn that of the many countries visited by RAPAT, more than 50 -- nearly half of the IAEA membership then -lacked the minimum radiation safety infrastructure.

In addition, it should be noted that at least 60 countries in the world are not IAEA Member States and experts can only guess that the situation there may be as bad or worse.

In summary, more than 110 States may have no minimum infrastructure to properly control radiation sources, not an encouraging sign. (See map, page 11.) The IAEA's initial response to this situation has been an aggressive, proactive technical co-operation programme that targets the main problems. This Model **Project in Radiation Protection** is one of the largest efforts in the United Nations' history to enhance radiation safety infrastructures in States which need it most urgently. This initiative covers 52 countries. As importantly, the IAEA Board of Governors recently decided that the Agency should also provide for the application

of the BSS in non-Member States, although only with extrabudgetary resources.

The Model Project has highlighted another false assumption, one somehow preserved through illusion. It has been wrongly assumed that a radiation safety infrastructure is equivalent to a legal infrastructure. Many, including experienced experts, sincerely thought that the problem in many countries was the absence of a law or legal regime of obligations for the proper control of radiation sources. It was implicit in this assumption that, given the legal instruments, the problem would be resolved. This was. and still is. a serious mistake.

INTERNATIONAL BASIC SAFETY STANDARDS



Through the IAEA Statute, States have empowered the Agency to develop international safety standards for the protection of health against exposure to ionizing radiation, and to provide for their application. Standards have been in place since the early 1960s.

Early in the 1990s, the full set of basic standards was thoroughly reviewed, revised, and subsequently issued as the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*-- the so-called BSS. (*See IAEA Bulletin, Vol. 36, No. 2, 1994*) They take into account the latest recommendations of the International Commission on Radiological Protection (ICRP), a recognized non-governmental scientific body of senior experts.

Many relevant international organizations joined the IAEA to co-sponsor the BSS, whose present edition the Agency published in 1996 as Safety Series No. 115. They were the Food and Agriculture Organization of the United Nations (FAO), International Labour Organization (ILO), Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (NEA/OECD), Pan American Health Organization (PAHO) and World

After a law is issued in a given country, the radiation safety infrastructure is as good or as bad as it was before. The formal change gives the illusion of a solution. In actual fact, a legal framework is sometimes (not always) a necessary condition but it is certainly not a sufficient condition for the proper control of radiation sources. Conversely, an infrastructure of knowledge (through education and training), resources and, more important, governmental commitment, is not only a necessity but nearly a sufficient element for real progress.

The question thus arises: How strongly should governments be urged to discharge their national Health Organization (WHO). At the time, the issue of radioactive material security was not fully addressed. Had it been, other international organizations, such as the World Customs Organization and International Criminal Police Organization, would have been invited to join the list of co-sponsors.

Broadly, the BSS are intended to ensure:

■ the protection of individuals and the population as a whole against the radiation exposure that they are expected to incur as a result of the normal uses of radiation sources;

 the safety of the radiation sources in order to prevent the occurrence of accidents and, should they nevertheless happen, to mitigate their consequences; and,
 the security of the radioactive materials in order to prevent any relinquishing of control over their use.

On the whole, these international standards have been highly successful. They help ensure that very small radiation doses are incurred by occupationally exposed workers and by the public at large as a result of the normal use of radiation sources. The application of the principle of optimization of radiation protection (that is, to keep doses as low as reasonably achievable, or ALARA), in conjunction with stringent individual dose limitation, are provisions that have achieved large reductions in radiation doses.

responsibilities? An international undertaking of a legally binding nature may be an answer whose time has come. It would underscore that the existence of governmental infrastructures of radiation safety is a precondition for actually ensuring safety of radiation sources and security of radioactive materials.

Unmet Safety Requirements. The BSS contain a number of requirements which are relevant to safety and security. In the jargon of the BSS, they are known as administrative, technical, managerial and verification requirements.

In the light of what has been learned in recent years, it would now seem that the *administrative requirements* -which were previously thought to be of secondary importance, simply because they appeared to be so obvious -- have become very significant. These requirements are extremely simple: the BSS rely on the existence, in every country, of a system for the notification, registration and licensing of radiation sources, and enforcement mechanisms through regulatory inspection.

As indicated before, what is taken as a self-evident requirement in many developed countries is not met in many parts of the world. Indeed, many countries are not even aware of the need to meet this requirement, and consequently the authorities

STRENGTHENING RADIATION SAFETY & SECURITY

More than 100 countries around the world are known or thought to lack effective control over radiation sources and radioactive materials. Most of them do not have the required infrastructure. Some years ago, the IAEA sent expert missions, called RAPATs, to review national radiation protection problems. Missions were fielded to 62 countries. On the basis of RAPAT findings, the IAEA launched a technical cooperation Model Project covering 52 States -- including many visited by the expert missions -- with the aim to strengthen their national capabilities and infrastructures for radiation and safety and security. It should be noted that about 60 countries are not IAEA Member States.

Model Project & RAPAT Missions

Albania, Bangladesh, Bolivia, Cameroon, Colombia, Democratic Republic of the Congo (at the time, Zaire), Costa Rica, Cote d'Ivoire, Dominican Republic, El Salvador, Ethiopia, Ghana, Guatemala, Jamaica, Lebanon, Madagascar, Mauritius, Mongolia, Myanmar, Nicaragua, Niger, Nigeria, Panama, Paraguay, Saudia Arabia, Senegal, Sri Lanka, Sudan, Syria, United Arab Emirates, Viet Nam

RAPAT

Albania, Bangladesh, Bolivia, Cameroon, Chile, China, Colombia, Costa Rica, Democratic Republic of the Congo (at the time, Zaire), Costa Rica, Cote d'Ivoire, Croatia, Cuba, Democratic People's Republic of Korea, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Ghana, Greece, Guatemala, Hong Kong (1991), Indonesia, Iran, Iraq, Iceland, Jamaica, Kenya, Kuwait, Lebanon, Libya, Madagascar, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Nicaragua, Niger, Nigeria, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Republc of Korea, Romania, Saudia Arabia, Senegal, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Turkey, United Arab Emirates, Uruguay, Venezuela, Viet Nam, Zambia

there do not know how many sources exist within their territory or where they are; it follows logically that sources are not being controlled.

The BSS further placed emphasis on two *technical requirements:* defense-in-depth and good engineering practice. The first refers to a multi-

IAEA Technical Cooperation Model Project

Albania, Armenia, Bangladesh, Belarus, Bolivia, Bosnia & Hercegovina, Cameroon, Colombia, Democratic Republic of the Congo, Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, El Salvador, Estonia, Ethiopia, Gabon, Georgia, Ghana, Guatemala, Jamaica, Jordan, Kazakhstan, Latvia, Lebanon, Lithuania, Former Yugoslav Republic of Macedonia, Madagascar, Mali, Mauritius, Moldova, Mongolia, Myanmar, Namibia, Nicaragua, Niger, Nigeria, Panama, Paraguay, Qatar, Saudi Arabia, Senegal, Sri Lanka, Sudan, Syria, Uganda, United Arab Emirates, Uzbekistan, Viet Nam, Yemen, Zimbabwe Non-Member States

Andorra, Angola, Antigua & Barbuda, Azerbaijan, Bahamas, Bahrain, Barbados, Belize, Butan, Botswana, Brunei Darussalam, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Democratic People's Republic of Korea (since 1994), Djibouti, Dominica, Equatorial Guinea, Eritrea, Fiji, Gambia, Grenada, Guinea, Guinea-Bisseau, Guyana, Honduras (application pending approval), Kyrgystan, Laos, Lesotho, Malawi, Maldives, Mauritania, Micronesia, Mozambique, Nepal, Oman, Palau, Papua New Guinea, Rwanda, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & the Grenadines, Samoa, San Marino, Sao Tome & Principe, Seychelles, Solomon Islands, Somalia, Suriname, Swaziland,

Tajikistan, Togo, Turkmenistan, Trinidad & Tobago, Vanuatu

layered system of safety provisions for the purpose of preventing accidents, mitigating the consequences of accidents, and restoring sources to safe conditions. The majority of the accidents that have occurred show a failure in a proper defense-in-depth. It should be noted that new ICRP recommendations on potential exposures are serving to make the defense-in-depth requirement more quantitative.

Regarding good engineering practices, the BSS presume that sources are always reliable and built to approved engineering standards, with sufficient safety margins, and --

very importantly -- that they take account of research and development results; in other words, that their features are not fossilized in time.

However, particularly in the developing world, there is an absence of good engineering practice. On the contrary, mainly for financial reasons, there is much tinkering and use of "pirate" hardware and software, which increases the chance of accidents.

The BSS *management requirements* include the establishment of a "safety culture". This requirement has proved an elusive one, partly because the expression is difficult to translate into many languages. Basically, the intention of the term is to emphasize that safety should be the highest priority in organizations handling radiation sources, which should be prepared to identify and correct problems promptly; and that clear lines of responsibility should be established, not only for organizations handling sources but in the governmental agencies controlling the use of sources. The lines of authority for decision-making in radiation safety and security should be clearly defined, but this is not normally the case. This is particularly so in the medical field, where the highest authorities in hospitals are often unaware of the safety conditions in their radiology and nuclear medicine services. The problem of safety culture -or lack of it -- is critical in "newly independent States", where there is an obvious lack of regulatory tradition and experience in the control of radiation sources. In these and other countries, shortcomings also are seen in areas of quality assurance, staff training, and safety verification to make sure that requirements are being met.

Light Security Requirements. At the present time, the security requirements in the BSS are minimal. This is not surprising because the BSS reflect international consensus, and in many national regulations the issue is not even addressed. The BSS requirements focus on the prevention of theft. damage and unauthorized use by ensuring that control is not relinquished, that sources are not transferred to unauthorized users and that periodic inventories are conducted, particularly of movable sources.

In the absence of regulatory requirements, recently there has been an emphasis on attacking the effects rather than the cause of non-security. A number of programmes on *illicit trafficking of radioactive and nuclear materials* are being implemented elsewhere, including at the IAEA. The



New ground was broken 1998 in at an international conference in Dijon, France, that raised global awareness of radiation safety and security. The International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials was co-sponsored by the

IAEA, together with the European Commission, World Customs Organization, and International Criminal Police Organization. Major findings -which draw upon the summary by the Chairman of the Conference Programme Committee, Dr. Dan J. Beninson, a former Chairman of the International Commission on Radiological Protection -- include the following points:

A GLOBAL TURNING POINT

Sources of ionizing radiation must have sufficient protection to allow for safe normal operations.

The possibility of accidental exposures involving radiation sources must be anticipated and there must be appropriate safety devices and procedures. In this connection, weaknesses in the design and construction of radiation sources must be corrected; a high level of safety culture in the handling of radiation sources must be promoted; regulatory infrastructures for the control of radiation sources must be supported by governments; and the regulatory authority in each country must maintain oversight of all radiation sources in that country, including those which have been imported, and be able to act independently.

■ Radiation sources should not be allowed to drop out of the regulatory control system. This means that the regulatory authority must keep

problem, however, cannot be tackled by controlling illict trafficking at borders or asking the police to find sources. Rather, it will be solved only when national systems are in place to ensure that control is not relinquished, that sources are not transferred to unauthorized users and that periodic inventories are being conducted.

Since this is not the case right now, greater cooperation with, and assistance to, customs and border officials and police is essential, and is a central element of the Agency's cooperative work in the field.

WAYS FORWARD: TIMELY ACTION

A State that adopts the BSS requirements is taking a necessary, but not a sufficient, step toward ensuring safety and security. The essential issue is not the existence of standards, but their application. In recent years, the Agency has stepped up its efforts to provide for the application of international safety standards in States that need assistance.

Activities are part of programmes covering regulatory infrastructures; peer reviews of regulatory programmes; education and training; a database for unusual radiation events; emergency response and preparedness; and the management of disused radiation sources.

In particular, as part of the Model Project, the IAEA developed a regulatory authority information system (RAIS) for the management of a regulatory programme. It is being implemented in the Member States which are part of the Project. *(See box, page 13.)*

The IAEA's efforts now are being reinforced and new initiatives are being developed. They are designed to respond to the key issues and problems raised at the ground-breaking 1998 international conference in Dijon, France. Both the IAEA General Conference, in September 1998, and the Agency's Board of Governors, in March 1999, have underscored the importance of taking timely action.

On the question of legally binding governmental commitments. IAEA Director General Mohamed ElBaradei proposed to the Board in March the initiation of exploratory discussions related to an international undertaking by States in the area of the safety of radiation sources and the security of radioactive material. The Board expressed no opposition to the proposal, although some members thought that aiming for an international convention would be too ambitious at the present time. They felt that other types of instruments, for

up-to-date records of the person responsible for each source, monitor transfers of sources and track the fate of each source at the end of its useful life.

■ Efforts should be made to find radiation sources that are not in the regulatory authority's inventory, because they were in the country before the inventory was established, or were never specifically licensed or were lost, abandoned or stolen ("orphan" sources).

■ Because there are many "orphan" sources throughout the world, efforts to improve the detection of radioactive materials crossing national borders and moving within countries by carrying out radiation measurements and through intelligence-gathering should be intensified. Optimum detection techniques need to be developed, and confusion would be avoided if international agreement could be achieved on quantitative levels that would trigger investigations at border crossings. ■ The key common element which would have the greatest part to play both in the avoidance of "orphan" sources - with their potential for misuse or accidents - and in the achievement and maintenance of safe and secure operating conditions is effective national regulatory authorities operating within suitable national infrastructures.

■ Governments are urged to create regulatory authorities for radiation sources if they do not exist. The government must provide it with sufficient backing and with sufficient human and financial resources to enable it to function effectively. Only in this way can the problem of the safety of radiation sources and the security of radioactive materials be tackled at its roots and eventually brought under control.

■ Further efforts should be made to investigate whether international undertakings concerned with the effective operation of national regulatory control systems and attracting broad adherence could be formulated.

example, a *code of conduct*, would be more feasible targets.

The Board endorsed major elements of an *Action Plan* that now goes before it and the IAEA General Conference in September 1999 for approval.

The Action Plan. The plan was drafted in late May 1999 by a group of consultants meeting in Prague, Czech Republic. The draft was subsequently considered and further developed by a technical committee meeting in July 1999 in Vienna. The meeting was chaired by Ms. Mary Clark of the US **Environmental Protection** Agency and attended by representatives of Australia, Canada, Czech Republic, Egypt, Finland, France, Germany, Iceland, India, Israel, China, Spain, Turkey, Ukraine, United Kingdom, United States, and an observer from the European Commission.

The proposed initiatives are grouped in seven areas: regulatory infrastructures; management of disused radiation sources; categorization of sources; response to abnormal events; information exchange; education and training; and international undertakings. With regard to timing, activities would be implemented in three phases, starting immediately upon the Plan's approval.

The main activities cover: *Regulatory Infrastructures.*

Setting up services for advising States on establishment of appropriate regulatory programmes.

Management of Disused Radiation Sources.

Preparing documents on particular aspects of the

handling and disposal of disused radioactive sources;
Organizing consultations and workshops on technical, commercial, legal and regulatory aspects of the return of disused sources to manufacturers and on the management of radioactive sources and equipment containing such sources.

Categorization of Sources. ■ Preparing a document on the categorization of sources on the basis of the associated potential exposures and radioactive contamination.

Response to Abnormal Events.

Preparing guidance on national strategies and programmes for the detection and location of "orphan sources" and their subsequent management; and on criteria for the development, selection and use of detection and monitoring equipment at border crossings, ports, scrapyards and other facilities;

 Developing further national response capabilities for dealing with radiological emergencies;

Strengthening the Agency's existing capabilities for provision of assistance in emergency situations.

Information Exchange. ■ Organizing an International Conference on the Control by National Authorities of Radiation Sources and Radioactive Materials and regional workshops on specific topical issues;

Developing an international database on missing and found "orphan sources".

■ Fully developing and maintaining the international database on unusual radiation events and making it available to Member States; Developing a repository of information on the characteristics of sources and devices containing sources, including transport containers, and disseminating the information, with consideration of the advisability of dissemination through the Internet.

Education and Training. Intensifying postgraduate educational course activities, and developing, in a systematic way, syllabuses and training materials for specific target groups and uses of radiation sources and radioactive materials.

International Undertakings. ■ Initiating a meeting of technical and legal experts for exploratory discussions relating to an international undertaking, such as, for instance, a code of conduct, in the area of the safety of radiation sources and security of radioactive materials.

OUTLOOK

Throughout its history, the IAEA has adjusted its programmes to new challenges and opportunities affecting the safe and peaceful development of nuclear and radiation technologies. Initiatives now being developed will help countries strengthen the safety and security of radiation sources and radioactive materials. They focus on measures to upgrade national capabilities for effectively regulating and controlling radiation sources and radioactive materials, giving priority to those that pose the most significant potential risks. One particular focus of

TRACKING PROGRESS: REGULATORY AUTHORITY INFORMATION SYSTEM

As part of its work to strengthen radiation safety and security, the IAEA has developed a computer-based tracking and management system for use by regulatory authorities in its Member States. Called the Regulatory Authority Information System (RAIS), it is composed of five modules that are designed flexibly enough to be suitable for different types of regulatory programmes.

MODULE 1: INVENTORY OF RADIATION

SOURCES & INSTALLATIONS Lists all radiation sources within an installation,

classified by practice

Covers installations having a given type of

equipment, or a given practice

Covers multiple radiation sources

Tracks history of a source until returned to the supplier or managed as radioactive waste

MODULE 3: INSPECTION & ENFORCEMENT

Inspections carried out within specified time periods
 Inspections that should be done over a future time period

Assists in monitoring follow-up enforcement actions and deadlines

Allows the regulatory authority to issue inspection reports through RAIS

MODULE 2: AUTHORIZATION

Tracks the administrative status of an installation, from initial application to its authorization, including pre-operational inspections
 Covers authorization related to transfers of radiation sources between installations
 Allows the regulatory authority to issue authorization documents through RAIS

MODULE 4: PERSONAL DOSE MONITORING

 Calculates estimates of the effective dose to workers from measured personal dose equivalent
 Lists doses to workers at each installation
 Computes total doses for workers employed in more than one installation
 Stores the dose histories workers

MODULE 5: PERFORMANCE INDICATORS

REGULATORY AUTHORITY INDICATORS

Lists authorizations processed Displays average time for processing an authorization, classified by practice Lists inspections, by practice, geographic area or inspector; enforcement actions; ongoing

actions with deadlines

LICENSEE INDICATORS

Displays average occupational doses by practice, doses exceeding dose contraints of investigation levels

 Stores history of incidents and non-compliance
 Stores history of enforcement actions OTHER INFORMATION ABOUT NATIONAL ACTIVITIES Lists registered training courses on radiation protection and attendees Lists radiation protection officers and other experts Lists personal authorizations by practice Stores data on emergency arrangements, conventions, etc.

attention is on orphan sources, which could number in the thousands. In many case, countries will need assistance in locating and safely managing them.

Until the 1950s, only radionuclides of natural orgin, especially radium-226, were generally in use. Since then, the picture has changed dramatically and many radionuclides produced artificially have become commercial tools for beneficial applications in industry, medicine, and other fields. Any risks associated with their use must be restricted, and people must be protected from harm, by the *application* of appropriate radiation safety standards.

Global efforts through the multi-year Action Plan under development strengthen the foundation for progress to improve safety. They are designed to provide greater support and assistance into the next century to national authorities responsible for radiation sources and radioactive materials.

As national capabilities are upgraded, the world stands to gain from a stronger global framework for radiation safety and security.

Major Radiation Accidents (1945-99)

Year	Place	Source	Dose (or activity intake)	Overexposures	a Deaths
	Los Alamos, USA	Criticality	up to 13 Gy (mixed ^b radiation		2
1952	Argonne, USA	Criticality	0.1 - 1.6 Gy (mixed ^b radiation)		
1953	USSR Malbaurna Australia	Experimental reactor	3.0 - 4.5 Gy (mixed ^b radiation)		
1953 1955	Melbourne, Australia Hanford, USA	Cobalt-60 Plutonium-239	Unknown Unknown	1	
1955	Oak Ridge, USA	Criticality (Y- 12 plant)	0.7 - 3.7 Gy (mixed ^b radiation)		
1958	Vinca, Yugoslavia	Experimental reactor	2.1 - 4.4 Gy (mixed [®] radiation)		
1958	Los Alamos, USA	Criticality	0.35 - 45 Gy (mixed ^b radiation		
1959	Johannessburg, South Africa	Cobalt-60	Unknown	1	
1960	USA Madison, USA	Electron beam Cobalt-60	7.5 Gy (local)	1	
1960 1960	Lockport, USA	X-rays	2.5 - 3 Gy (to 12 Gy, non-uniform)	6	
1960	USSR	Caesium-137 (suicide)	approx. 15 Gy	1	1
1960	USSR	Radium bromide (ingestion)	74 MBq	1	1 (4 yrs later)
1961	USSR	Submarine accident	1.0 - 50.0 Gy	> 30	8
1961	Miamisburg, USA	Plutonium-238	Unknown	2	
1961 1961	Miamisburg, USA Switzerland	Polonium-210 Hydrogen-3	Unknown 3 Gy	4 3	1
1961	Idaho Falls, USA	Explosion in reactor	Up to 3.5 Gy	7	3
1961	Plymouth, UK	X-rays	local overdosage	11	Ū
1961	Fontenay-aux-Roses, France	Plutonium-239	Unknown	1	
1962	Richland, USA	Criticality	Unknown	2	
1962	Hanford, USA	Criticality	0.2 - 1.1 Gy (mixed ^b radiation		
1962 1962	Mexico City, Mexico Moscow, USSR	Cobalt-60 capsule Cobalt-60	9.9 - 52 Sv 2.9 Cv (pop uniform)	5 1	4
1962	China	Cobalt-60	3.8 Gy (non-uniform) 0.2 - 80 Gy	6	2
1963	Saclay, France	Electron beam	Unknown (local)	2	2
1964	Germany, Federal Republic	Hydrogen-3	10 Gy	4	1
1964	Rhode Island, USA	Criticality	0.3 - 46 Gy (mixed ^b radiation)		1
1964	New York, USA	Americium-241	Unknown	2	
1965 1045	Rockford, USA	Accelerator	> 3 Gy (local)	1 1	
1965 1965	USA USA	Diffractometer Spectrometer	Unknown (local) Unknown (local)	1	
1965	Mol, Belgium	Experimental reactor	5 Gy (total)	1	
1966	Portland, USA	Phosphorus-32	Unknown	4	
1966	Leechburg, USA	Plutonium-235	Unknown	1	
1966	Pennsylvania, USA	Gold-198	Unknown	1	1
1966 1966	China USSR	"Contaminated zone" Experimental reactor	2 - 3 Gy 3.0 - 7.0 Gy (total)	2 5	
1967	USA	Iridium-192	0.2 Gy, 50 Gy (local)	1	
1967	Bloomsburg, USA	Americium-241	Unknown	1	
1967	Pittsburgh, USA	Accelerator	1 - 6 Gy	3	
1967	India	Cobalt-60	80 Gy (local)	1	
1967	USSR Burbank, USA	X-ray medical diagnostic facility Plutonium-239	50.0 Gy (head, local) Unknown	1 2	1 (after 7 yrs)
1968 1968	Wisconsin, USA	Gold-198	Unknown	2	1
1968	Germany, Federal Republic	Iridium-192	1 Gy	1	
1968	La Plata, Argentina	Caesium-137	local, 0.5 Gy (whole body)	1	
1968	Chicago, USA	Gold-198	4 - 5 Gy (bone marrow)	1	1
1968	India	Iridium-192	130 Gy (local)	1	
1968 1968	USSR USSR	Experimental reactor Cobalt-60 Irradiation facility	1.0 - 1.5 Gy 1.5 Gy (local, head)	4 1	
1968	Wisconsin, USA	Strontium-85	Unknown	1	
1969	USSR	Experimental reactor	5.0 Sv (total) non-uniform	1	
1969	Glasgow, UK	Iridium-192	0.6 Gy	1	
1970	Australia	X-rays	4 - 45 Gy (local)	2	
1970	Des Moines, USA	Phosphorus-32	Unknown	1	
1970 1970	USA Erwin, USA	Spectrometer Uranium-235	Unknown (local) Unknown	1 1	
1971	Newport, USA	Cobalt-60	30 Gy (local)	1	
1971	UK	Iridium-192	30 Gy (local)	1	
1971	Japan	Iridum-192	0.2 -1.5 Gy	4	
1971	Oak Ridge, USA	Cobalt-60	1.3 Gy	1	
1971 1971	USSR USSR	Experimental reactor Experimental reactor	7.8; 8.1 Sv 3.0 total	2 3	
1971	Chicago, USA	Iridium-192	3.0 total 100 Gy (local)	3 1	
1972	Peach Bottom, USA	Iridium-192	300 Gy (local)	1	
1972	FRG	Iridium-192	0.3 Gy	1	
1972	China	Cobalt-60	0.4 - 5.0 Gy	20	
1972 1973	Bulgaria USA	Caesium-117 capsules (suicide) Iridium-192	> 200 Gy (local, chest)	1 1	1
17/3	UJA	inuiditi-172	0.3 Gy		

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Year	Place	Source	Dose (or activity intake)	Overexposures ^a	Deaths
1973	UK	Ruthenium-106	Unknown	1	
1973	Czechoslovakia	Cobalt-60	1.6 Gy	1	
1974	Illinois, USA	Spectrometer	2.4 - 48 Gy (local)	3	
1974	Parsipany, USA	Cobalt-60	1.7 - 4 Gy	1	
1974 1 975	Middle East Brescia, Italy	Iridium-192 Cobalt-60	0.3 Gy	1	
1975	USA	Iridium-192	10 Gy 10 Gy (local)	1	
1975	Columbus, USA	Cobalt-60	11 - 14 Gy (local)	6	
1975	Iraq	Iridium-192	0.3 Gy	1	
1975	USSR	Caesium-137/Irradiation facility	3 - 5 Gy (total) + > 30 Gy (hands)	1	
1975	GDR	Research reactor	20-30 Gy (local)	1	
1975	FRG	X-ray	30 Gy (hand)	1	
1975 1976	FRG Hanford, USA	X-ray Americium-241 intake	l Gy (total) > 37 MBg	1	
1976	USA	Iridium-192	37.2 Gy (local)	1	
1976	USA, Pittsburg	Cobalt-60	15 Gy (local)	1	
1977	USA, Rockaway	Cobalt-60	2 Gy	1	
1977	Pretoria,South Affica	Iridium-192	1.2 Gy	1	
1977	Denver, USA	Phosphorus-32	Unknown	1	
1977	USSR	Cobalt-60/irradiation facility	4 Gy (total)	1	
1977	USSR	Proton accelerator	10.0 - 30.0 Gy (hands)	1	
1977 1977	UK Peru	Iridium-192 Iridium-192	0.1 Gy +local 0.9 - 2.0 (total), 160 (hand)	1 3	
1977	Argentina	Iridium-192	12 - 16 (local)	3 1	
1978	Algeria	Iridium-192	up to 13 Gy (for max. exposed person)	7	
1978	UK			1	
1978	USSR	Electron accelerator	20 Gy (local)	1	
1979	California, USA	Iridium-192	Up to I Gy	5	
1980	USSR	Cobalt-60/irradiation facility	50.0 Gy (local, legs)	1	
1980	GDR	X-ray Dediagraphy unit	15-30 Gy (hand)	1	
1980 1980	FRG China	Radiography unit Cobalt-60	23 Gy (hand) 5 Gy (local)	1	
1981	Saintes, France	Cobalt-60/medical facility	> 25 Gy	3	
1981	Oklahoma	Iridium-192	Unknown	1	
1982	Norway	Cobalt-60	22 Gy	1	1
1982	India	Iridium-192	35 Gy local	1	
1983	Argentina	Criticality	43 Gy (mixed ^b radiation)	1	1
1983	Mexico	Cobalt-60	0.25 - 5.0 Sv (protracted exposure)	10	
1983 1984	Iran Morocco	Iridium-192 Iridium-192	20 Gy (hand) Unknown	1 11	8
1984	Peru	X-ray	5-40 Gy (local)	6	0
1985	China	Electron accelerator	Unknown (local)	2	
1985	China	Gold-198 (mistake in treatment)	Unknown, internal	2	1
1985	China	Caesium-137	8 - 10 Sv (subacute)	3	
1985	Brazil	Radiography source	410 Sv (local)	1	
1985	Brazil	Radiography source	160 Sv (local)	2	2
1985/86 1986	China	Accelerator Cobalt-60	Unknown 2 - 3 Gy	3 2	2
			•		28 ^d
1986	Chernobyl, USSR	Nuclear power plant	I - 16 Gy (mixed [®] radiation)	134	
1987	Goiânia, Brazil	Caesium-137	Up to 7 Gy (mixed ^b radiation)	50 ^C	4
1987 1989	China El Salvador	Cobalt-60 Cobalt-60/irradiation facility	1.0 Gy 3 - 8 Gy	1 3	1
1909	Israel	Cobalt-60/irradiation facility	>12 Gy	1	1
1990	Spain	Radiotherapy accelerator	Unknown	27	11
1991	Belarus, Nesvizh	Cobalt-60/irradiation facility	10 Gy	1	1
1991	USA	Accelerator	> 30 Gy (hands & legs)	1	
1992	Viet Nam	Accelerator	20-50 Gy (hands)	1	
1992	China	Cobalt-60	> 0.25 -10 Gy (local)	8	3
1992 1994	USA Estonia, Tammiku	Iridium-192/brachytherapy Caesium-137/waste repository	> 1000 Gy 1830 Gy (thigh) + 4 Gy (whole body	1) 3	1 1
			J. J. J. J.		
1996 1996	Costa Rica Iran, Gilan	Cobalt-60/radiotherapy Iridium-192/radiography	60% overdose 2-3 Gy? (whole body)+	115	13 ^e
1790	iran, olian	indiame 172/18010graphy	100 Gy? (chest)	1	
1997	Russia	Criticality experiment	5-10 Gy (whole body) +		
			200-250 Gy (hands)	1	
1998	Turkey	Cobalt-60	Various doses, up to 3 Gy whole bo		
1999	Peru	Iridium-192/radiography	up to 100 Gy locally; leg amputation	า 1	

Notes: ^a Significant exposures, defined as one > 0.25 Sv to the whole body, blood forming organs or other critical organs; -6 Gy to the skin locally; -0.75 Gy to other tissues or organs from an external source, or exceeding half of the annual limit on intake (ALI). ^b Mixed radiation refers to various types of radiation with different LET values, such as neutrons and gamma rays, or gamma and beta rays.^c The number is probably lower (some of the 50 contaminated persons received doses of less than 0.25 Sv). ^d Deaths attributed to radiation exposure. Two other deaths were non-radiation related. ^e To the end of 1998.

Reference: IAEA/WHO Planning the Medical Response to Radiological Accidents, IAEA Safety Report Series No. 4 (1998).

IAEA REPORTS ON RADIOLOGICAL ACCIDENTS



GOIANIA, BRAZIL In 1985, an accident Goiania involved a caesium-137 source left behind after a private radiotherapy institute moved to new premises. The teletherapy unit containing the radiation source, left unsecured for about two years, was found by two scavengers who took the unit home, tried to remove the source assembly and ruptured the source capsule. In the process, they contaminated themselves, hundreds of other people, and the surrounding city and

environment. Four severely exposed people died, many others were seriously injured, and the emergency response and clean-up effort of houses, buildings, and land lasted six months. All told, more than 100,000 people were monitored for radiation exposure, of whom nearly 300 showed some caesium-137 contamination. Financially, the accident had a major economic impact on the city and region.



SAN SALVADOR, EL SALVADOR In February 1989, an accident took place at an industrial irradiation facility near San Salvador where medical products are sterilized by irradiation from a cobalt-60 source. The accident happened when the source rack became stuck in the irradiation position. The operator bypassed safety systems and entered the radiation room with two other workers to free the source rack manually. They were exposed to high radiation doses and developed acute radiation

syndrome. The legs and feet of two of the three men were so seriously injured that amputation was required. The most-exposed worker died just over six months after the accident.



SOREQ, ISRAEL In June 1990, an accident occurred in a commercial irradiation facility near Soreq that sterilizes medical products and spices by irradiation from a cobalt-60 source. The accident happened after the source rack became stuck in the irradiation position. The operator misinterpreted two conflicting warning signals, bypassed installed safety systems and contravened procedures so as to enter the irradiation room to free the blockage. Exposed to high levels of radiation, he suffered such

severe injuries that he died just over a month later.



NESVIZH, BELARUS In October 1991, an accident occurred in an irradiation facility in Nesvizh, about 120 kilometers from Minsk. Agricultural and medical products are sterilized there using a cobalt-60 source. Following a jam in the product transport system, the operator entered the facility to clear the fault, bypassing a number of safety features. At some stage, the source rack became exposed and the operator was irradiated for about one minute. He was taken for medical care,

first in Nesvizh and Minsk, and then for specialized treatment in Moscow. Despite intensive medical treatment, he died 113 days later.



HANOI, VIET NAM

In November 1992, an accident took place at an electron accelerator facility in Hanoi. An individual entered the irradiation room without the operators' knowledge and unwittingly exposed his hands to the X-ray beam. His hands

were seriously injured and one had to be amputated.



TOMSK, RUSSIAN FEDERATION

In April 1993, an accident took place during the reprocessing of irradiated reactor fuel at the facility of Siberian Chemical Enterprises situated near the city of Tomsk. Although the accident is not

related to the safety of radiation sources, it was assessed as a typical case of bending safety rules. The accident caused damage to both the reprocessing line and the building and resulted in the release of radionuclides including plutonium-239. Parts of the facility's site and a considerable area of the surrounding countryside to the north of the complex, including the village of Georgievka and part of the trunk road linking Samus with Tomsk, were contaminated with radionuclides. Although the level of contamination was relatively low, considerable effort was expended in decontaminating buildings and land.



TAMMIKU, ESTONIA

In October 1994, three brothers entered the radioactive waste repository at Tammiku, without authorization and removed a metal container enclosing a radiation source. They were able to open it, and their actions ultimately resulted in the death of one of the brothers and serious

injuries to the others. The death was not originally attributed to radiation exposure. However, a physician who examined the injuries of the stepson of the dead person realized the radiological nature of the accident and initiated rescue actions that limited the consequences. Estonian authorities requested international assistance to analyse the accident and to advise on remedial actions.



SAN JOSÉ, COSTA RICA A serious accident in Costa Rica involved radiotherapy patients. The initiating event occurred at the San Juan de Dios Hospital, in San José, in August 1996, when a cobalt-60 source was replaced. When the new source was

calibrated, an error was made in calculating the dose rate. This miscalculation resulted in the administration to patients of significantly higher radiation doses than those prescribed. It appeared that 115 patients being treated for neoplasms by radiotherapy were affected. The error was realized in late September 1996, and treatments were stopped. Subsequent measurements on the machine in question and a review of the patients' charts confirmed that the exposure rate had been greater than assumed, by about 50% to 60%. By July 1997, within nine months of the accident, 42 of the patients had died. Among the other patients, many of them showed obvious effects of radiation overexposure, though the full consequences of the overexposure were not evident in the months following the accident. However, it is likely that irreversible radiation effects and complications resulting from the accident will appear in patients in the coming years.

Publications in Preparation:

GILAN, IRAN

On 24 July 1996, a worker at the Combined Cycle Fossil Power Plant, in Gilan was moving insulation materials for the lagging of boilers and pipes in the plant. He noticed a shiny pencilsized piece of metal on the side of the trench and put it into the loose pocket of his overall on the right side above his chest. The metal object happened to be a "pigtail" of a radiograph with an iridium-192 source. It led to severe haemopoetic syndrome (bone marrow depression) and an unusually extended local radiation injury. Plastic surgery was successfully performed at the Curie Institute in Paris. The patient has been in satisfactory general condition since then, though his injuries are debilitating.

ISTANBUL, TURKEY

Old teletherapy sources kept in a firm's warehouse in Ankara were put in lead containers

for shipment to the supplier. They remained there for about five years because of commercial disputes. In December 1998, the firm shipped the containers to another warehouse in Istanbul. But instead of placing the shipment in the deposit yard, workers placed it in a facility next door, where it remained for about nine months. When those premises were sold, the new owners sold the unwanted items, including the containers with the sources inside. The buyer took the containers to an open yard and with another person dismantled them. Ten persons received radiation doses high enough to cause acute radiation syndrome. One of the sources is still missing.

YANANGO, PERU

In February 1999, a radiation accident happened at the construction site of a hydroelectric power station in Yanango, Peru, 300 kilometers east of Lima. The victim was a welder working on the site, who inadvertently picked up an iridium industrial source intended for gammagraphy operations but left uncontrolled. He put it in the back pocket of his trousers. He was initially hospitalized at the Lima Anti-Cancer Centre, suffering from severe radiation burns, and later transferred to the Serious Burns Treatment Centre of the Percy Military Hospital at Clamart (Hauts-de-Seine) in France. He remains there under treatment, and it is expected that he will benefit from a treatment technique used for serious burns which proved effective on Georgian security guards who were victims of a serious radiation accident in 1997.

REPUBLIC OF GEORGIA

Many unsecured radioactive sources have been found in Georgia over recent years. The local authorities first requested international assistance in October 1997, when a group of border frontier guards undergoing training at a centre in Lilo, near Tbilisi, became ill and showed signs of radiation induced skin disease. Eleven servicemen had to be transferred to specialized hospitals in France and Germany. The cause of the exposures was found to be several sources of caesium-137 and cobalt-60 of various activities, abandoned in a former military barracks that used to be under the control of the former Soviet Union. In July 1998 three more abandoned sources with an activity of 50 GBq, 3.3 GBq and 0.17 GBq were found in Matkhoji, an agricultural village about 300 km west of Tbilisi. At the same time, another site of a former Soviet military base close to Kuthaisi was discovered containing an area contaminated with radium-226. Another military base in the city of Poti, close to the Black Sea., was also found to contain two further radioactive sources buried in a sand floor. In October 1998 two other powerful sources were discovered in Khaishi, western Georgia. The sources were part of eight thermo-electric generators placed in the region. These generators used to hold an activity of anything between 740 and 5550 TBq. Since then, four of the generators have been located and are now in safe storage. One was recovered from the bed of the Inguri river which flows through this region in western Georgia. Recently two other discoveries were made: on 21 June 1999, a cobalt-60 source of around 37 GBq was found buried below a road close to the botanical gardens in Tbilisi; on 5 July 1999, two caesium-137 sources were found in the town of Rustavi, close to Tbilisi.