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THE SAFETY OF RADIATION SOURCES AND RADIOACTIVE MATERIALS IN CHINA

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Abstract. The report describes the present infrastructure for the safety of radiation sources in China, where applications of radiation sources have become more and more widespread in the past years. In particular, it refers to the main functions of the National Nuclear Safety Administration of the State Environmental Protection Administration (SEPA), which is acting as the regulatory body for nuclear and radiation safety at nuclear installations, the Ministry of Public Health which issues licences for the use of radiation sources, and the Ministry of Public Security, which deals with the security of radiation sources. The report also refers to the main requirements of the existing regulatory system for radiation safety, i.e. the basic dose limits for radiation workers and the public, the licensing system for nuclear installations and for radioisotope-based and other irradiation devices, and the environmental impact assessment system. Information on the nationwide survey of radiation sources carried out by SEPA in 1991 is provided, and on some accidents that occurred in China due to loss of control of radiation sources and errors in the operation of irradiation facilities.

INTRODUCTION

Radiation sources are anything that may cause radiation exposure — for example, by emitting ionizing radiation or releasing radioactive substances. Radiation and radioactive substances are natural and permanent features of the environment, and the risks associated with radiation exposure can therefore only be restricted, not eliminated entirely.

Applications of radiation sources are becoming more and more widespread in China. At present, about 50 000 radioisotope-based and about 100 000 other irradiation devices are being used there in industry, agriculture, medicine and scientific research.

Also, in China, which has had a nuclear industry for over 40 years, there are currently 11 power reactors in operation or under construction, 17 civilian research reactors in operation and six civilian nuclear fuel cycle facilities. In this paper, however, the term "radiation sources" means radioisotope-based and other irradiation devices and does not include nuclear installations.

THE MANAGEMENT INFRASTRUCTURE FOR THE SAFETY OF RADIATION SOURCES IN CHINA

The Chinese Government, which established a licensing system for the regulation of nuclear installations in 1986 by adopting Regulations for the Surveillance and Control of Civilian Nuclear Installations, established a licensing system for the regulation of radiation sources in 1989 by adopting Radiation Protection Regulations for Radioisotope-based and Other Irradiation Devices. Since that time the Chinese Government has issued a number of regulations and safety standards relating to nuclear safety and radiation protection. The management infrastructure for the safety of radiation sources in China is described below.

The National Nuclear Safety Administration (SEPA)

The NNSA/SEPA is the regulatory body for nuclear and radiation safety at nuclear installations in China. Its radiation safety functions are as follows:

- to establish general and specific policies, regulations, standards and technical guidelines for radiation protection and radioactive waste management and to monitor their implementation,
- to carry out environmental radiation monitoring nationwide and monitoring at installations such as nuclear power plants,
- to review the environmental radiation impact reports for all relevant construction projects,
- to maintain radiation protection controls at nuclear installations, at establishments where nuclear techniques are being used and at radioactive ore mines and mills,
- to inspect the on-site emergency plans and monitor the environmental emergency response activities of the operators of nuclear installations,
- to deal with environmental contamination caused by applications of and by losses of control over radiation sources and with disused or spent radiation sources, and
- to carry out monitoring and inspection activities in connection with radioactive waste management.

The Ministry of Public Health (MOPH)

The functions of MOPH are as follows:

- to issue licences for the production, sale and use of radiation sources,
- to register radiation sources, collect data relating to their use and provide information about them to the NNSA/SEPA and the Ministry of Public Security, and
- to investigate, in co-operation with the Ministry of Public Security and the NNSA/SEPA, accidents and other incidents involving radiation sources.

The Ministry of Public Security (MOPS)

MOPS is responsible for:

- the security of radiation sources, and
- investigation and search activities when radiation sources are lost.

The provincial radiological hygiene agencies, environmental protection bureaux and public security departments

These bodies are implementing organizations under the instructions of MOPH, the NNSA/SEPA and MOPS respectively. Their radiation safety functions are as follows:

- to implement the policies, regulations, standards and technical guidelines established by the Chinese Government for the safety of radiation sources,
- to carry out environmental radiation monitoring locally and monitoring at nuclear installations, to review environmental radiation impact reports on projects which will result in applications of nuclear techniques and to issue radioactive effluent release permits (functions of the provincial environmental protection bureaux),

- to issue licences for the production, sale and use of radiation sources, to register radiation sources, to investigate accidents and other incidents involving radiation sources and to deal with the resulting environmental contamination (functions of the provincial environmental protection bureaux), and
- to endeavour to ensure the security of radiation sources and, when radiation sources are lost or otherwise escape from regulatory control, to carry out investigation and search activities (functions of the provincial public security departments).

REGULATORY REQUIREMENTS

A preliminary regulatory system for radiation safety has been established in China. Its main features are described below.

Basic dose limits for radiation workers and the public

China's radiation protection regulations (GB8703) are based on three elements: justification of the practice, the optimization of radiation protection and dose limits. The basic dose limit is 50 mSv/year for radiation workers, and 1 mSv/year for the public. These limits are to be changed in the light of the ICRP 60 recommendation and the BSS.

The NNSA/SEPA requests the operators of nuclear installations to work to a conservative dose limit of 0.25 mSv/year for the public, taking account of the overall radiation exposure due to other radiation sources, and also to apply the ALARA principle in the case both of radiation workers and of the public.

Licensing system for nuclear installations

The civilian nuclear installations in China include nuclear power plants, research reactors, critical assemblies and nuclear fuel cycle facilities. The NNSA/SEPA implements a licensing system for nuclear installations which is based on the 1986 Regulations for the Surveillance and Control of Civilian Nuclear Installations.

China has more than one hundred technical standards and safety guides relating to nuclear safety and radiation protection. They describe in detail the technical requirements which must be met in order to maximize nuclear and radiation safety in the siting, construction, operation and decommissioning of nuclear installations and in radioactive waste management; they also describe how those requirements may be met.

Licensing requirements for radioisotope-based and other irradiation devices

Applying the 1989 Radiation Protection Regulations for Radioisotope-based and Other Irradiation Devices, MOPS, in co-operation with the NNSA/SEPA, implements a licensing system for the manufacture, sale and use of radiation sources — i.e. of radioisotope-based and other irradiation devices (in this paper, radioisotope-based irradiation means either simply radioisotopes or devices containing radioisotopes, while "other irradiation devices" means X-ray machines, accelerators and neutron generators).

(a) Authorization and registration of radiation sources

Anyone intending to manufacture, sell or use radiation sources must apply for a licence from the provincial public health department and inform the provincial public security department and environmental protection bureau. If releases of liquid, gaseous or solid effluent are involved, an environmental impact report must be submitted to the provincial environmental protection bureau.

(b) Radiation protection

The owners and users must — for the purpose of complying with the radiation protection regulations and standards — have competent radiation protection staff and install radiation protection shielding, safety interlocks, monitoring instrumentation and alarm systems.

(c) Radiation safety inspections

The local public health departments are responsible for carrying out radiation safety inspections at the premises of radiation source owners and users. The provincial environmental protection bureaux are responsible for monitoring effluent releases and carrying out associated inspections.

(d) Radiological accident management

In China, radiological accidents are divided into three categories, with four classes in each category.

- Category I: accident with exposure in excess of the dose limit
  - Radiological incident: $H_E > 1/2$ of the annual dose limit for the whole body
  - Radiological accident Class I: $H_E > 0.05$ Sv for the whole body
  - Radiological accident Class II: $H_E > 0.25$ Sv for the whole body
  - Radiological accident Class III: $H_E > 1.0$ Sv for the whole body
- Category II: surface contamination accident

  The classification of surface contamination accidents is based on the ratio (F) of the average surface contamination following the accident to the surface contamination limit in China's radiation protection regulations.
  - Radiological incident: F >1
  - Radiological accident Class I: F >10
  - Radiological accident Class II: F >300
  - Radiological accident Class III: F >10 000
- Category III: accident with loss of control of radiation sources
  - Incident: source activity > exemption value, for sealed and unsealed sources
  - Radiological accident Class I: sealed sources:activity > 4×10^6
  - unsealed sources: activity > 4×10^5
  - Radiological accident Class II: sealed sources: activity > 4×10^8
  - unsealed sources: activity > 4×10^7
  - Radiological accident Class III: sealed sources: activity > 4×10^{10}
  - unsealed sources: activity > 4×109

Every radiological accident must be reported immediately to the local public health department and public security department. In cases of environmental contamination, the local environmental protection bureau must be informed. The organization at whose establishment the accident has occurred must take measures to control the accident and protect the public. If necessary, the various governmental agencies will take measures to protect the public and the environment. The NNSA/SEPA has established an emergency centre for responding to nuclear and radiological accidents.

Environmental impact assessment system

Pursuant to the 1999 Environmental Protection Regulations for Construction Projects, China operates an environmental assessment system whereby, before the relevant governmental agencies approve a radiation-related construction project, the NNSA/SEPA (or its agencies at the provincial level) reviews the environmental impact assessment report submitted by the applicant. If satisfied, the NNSA/SEPA (or its agencies at the provincial level) approves the report. In the case of large radiation-related construction projects, the competent governmental department pre-reviews the environmental assessment report.

The design, construction and acceptance of environmental protection systems must proceed in parallel with the design, construction and acceptance of the main facilities, and these systems must be inspected by the NNSA/SEPA.

If there are going to be radioactive effluent releases into the environment, the operator must obtain an effluent release permit from the NNSA/SEPA or the provincial environmental protection bureau. In the siting of a nuclear installation, the possible impact on the public of radioactive releases due to a nuclear accident must be taken into consideration; the long-term impact of the installation must also be considered.

INVENTORY OF RADIATION SOURCES IN CHINA

The licensing system for radiation sources was established in 1989. Some sources which were in use before 1989 have not been registered (most of them are disused sources). Because of the widespread uses of radiation sources, and as some sources have been transferred without registration, it has been impossible to compile an exact inventory of the radiation sources in China. According to data from the Ministry of Public Health, there are now about 50 000 sealed sources (with a total radioactivity of 5×10^{17} Bq) and about 100 000 X-ray machines and accelerators in use in China.

In 1991, SEPA carried out a nationwide survey of radiation sources in China; the results are shown in Tables 1 and 2. However, the survey did not cover all radiation sources; it is estimated that about 30% were not covered. According to the survey, the number of orders for radiation sources was increasing by 20% and that of new users by about 15% annually.

Table 1

Category	Number of users	Number of radiation sources
Sealed sources	4150	16 141 Total activity: 2.66×10^{17} Bq
Unsealed sources	964	Total activity: 2.06×10^{14} Bq
Accelerators	136	219
Neutron generators	20	45
X-ray machines	23 828	Total: 45 279 Medical: 37 955 Industrial: 5921

Table 2. Sealed sources in 1991

	Number of users	Number of sources	Activity (Bq)
Co-60	966	2647	4.90×10^{16}
Cs-137	1663	4520	5.46×10^{14}
Ra-226	341	1471	3.31×10^{13}
Am-241	313	607	5.57×10^{13}
Ir-192	118	202	2.98×10^{14}
Pu-239	76	270	7.72×10^{10}

ACCIDENTS WITH RADIATION SOURCES

In China there have been accidents due to loss of control of radiation sources and to errors in the operation of irradiation facilities.

According to a paper published in 1998 by Fan Shengen, Wang Hongtao et al. in the China Journal of Radiological Health (Vol. 7, No. 2), a total of 1281 radiation accidents occurred in China during the period from 1954 to 1994, with 3393 individuals exposed to radiation (on average, 31 accidents and 83 exposed individuals a year). Four of the accidents resulted in fatalities — see Table 3.

Table 3

	Location	Accident description	Number of fatalities
1963	Anhui	0.43 TBq ^{60}Co source lost	2
1985	Heilunjiang	3.7×10^{11} ^{137}Cs source lost	1
1990	Shanghai	0.85 PBq ^{60}Co irradiation facility, operating error	2
1992	Shanxi	4×10^{11} Bq ^{60}Co source lost	3

Table 4 gives a breakdown of the accidents which occurred during the period 1954–94 by category; Table 5 gives a breakdown by Class.

Table 4*

Category	Number of accidents	Percentage
Exposure in excess of dose limit	240	18.9 %
Surface contamination accident	53	4.2%
Loss of control of radiation source	866	68.4%
Other	83	8.5%

* Because of the incompleteness of the information relating to them, 15 accidents which occurred in the 1960s have not been included.

Table 5*

Accident class	Number of accidents	Percentage
Class I	665	53.7%
Class II	446	36.0%
Class III	127	10.3%

*Because of the incompleteness of the information relating to them, 23 accidents which occurred in the 1960s have not been included.

RADIATION SOURCE SAFETY CHALLENGES

The Chinese Government, which has paid great attention to radiation safety, is continuing to strengthen the regulations and controls relating to applications of radiation sources and nuclear techniques. The licensing system for civilian nuclear installations and that for radioisotope-based and other irradiation devices have proved their value, but major challenges remain owing to the large number of users, the wide distribution of sources, and the great variety of source and facility types in China. For example,

(a) in the case of a few sources, especially ones which were in use before the establishment (in 1989) of the licensing system, there are no records or the records do not match the sources;
(b) it is necessary to establish an integrated national database for radiation sources, so that basic information regarding numbers, types, radiation characteristics, applications, users, transfers etc. can be collated and analyzed by governmental agencies;
(c) some sources have been lost or stolen as a result of improper or insecure storage;
(d) not enough education and training is being provided for the users.

PROPOSALS FOR ACTION

With a view to improving the safety situation as regards radiation sources, the relevant Chinese governmental agencies are reviewing past activities and considering possible future actions. Chinese experts are calling for:

(a) the establishment of a national database on radiation sources
The NNSA/SEPA and MOPH support the establishment of such a database, and to this end a team headed by the Nuclear Safety Centre has been set up by three SEPA institutions, the MOPH and the China Nuclear Industry Group Corporation. It is hoped that the IAEA will provide support during 2001–2002 through its technical co-operation programme. The project will involve an intensive survey of the radiation sources in China, and it is expected that the resulting database, which will provide governmental agencies with detailed information on radiation sources in all parts of the country, will be a valuable aid to experience feedback and decision-making. The NNSA/SEPA and the IAEA will hold a technical training workshop in China at the beginning of 2001 to introduce the IAEA's Regulatory Authority Information System (RAIS).

(b) improvements in the regulatory system and strengthened enforcement
The relevant governmental agencies will do more to improve the authorization and registration system and the regulations and technical standards relating to the safety of radiation sources. Local public health departments are carrying out inspections to ensure that all owners and users of radiation sources have licences. Local environmental protection bureaux are improving their monitoring systems.

(c) cand steelworks
Chinese radiation protection experts suggest that customs establishments be equipped with radiation monitoring systems to prevent illicit trafficking in radiation sources from other countries and that iron- and steelworks be equipped with such systems to ensure that there are no radiation sources in scrap metal which is going to be melted.

(d) the strengthening of education and training
The NNSA/SEPA has compiled radiation protection teaching material to meet the training needs of technical staff working in the field of environmental protection. The relevant governmental agencies will organize workshops and seminars on radiation source safety for staff of – inter alia – MOPH and its provincial radiological hygiene agencies, SEPA and the provincial environmental protection bureaux, MOPS, the State customs authority, the China Commodity Inspection Bureau, and various technical institutions and universities.