Status and Development of Radioisotope and Radiation Technology in China

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1. Status

The application of radioisotope and Radiation technology has forty years' history in China. In principle it has experienced three historic stages, which are the initiation in the 1950s, the application and development in the 1960s and 1970s, and the fast development in the 1980s. Especially after the 1990s, the application of radioisotope and radiation technology has stepped into the commercialized process and preliminarily formed an industry with certain scale and level. By the end of 2004 the annual total production value (only limited to domestic made) reached about RMB 39.6 billion Yuan (among it, nuclear agriculture about RMB 4.4 billion Yuan ; irradiation chemical industry products about RMB 3.2 billion Yuan ; isotope instrument and meter about RMB 3.5 billion Yuan ; irradiation products about RMB 5.5 billion Yuan ; isotope and its medical products RMB 400 million Yuan ; and ion beam processing RMB 22 billion Yuan). As compared to 1999, the average annual growth rate was 18%. There are more than and 300 units nationwide engaging in R&D and production in association with radioisotope and radiation technology, including 40 scientific institutes, 20 colleges and universities, and some 230 enterprises. Among them there are 40 units in isotope research and production; more than 60 units in producing irradiation cross-linking wires, cables and heat-shrinkable materials more than 140 units in nuclear agriculture and 50 units in nuclear inspection equipment. Over 60 thousand units are using radioisotope and 36 thousand equipments are used,

with 50 thousand employees concerned.

1.1 Medical Application

China has set up the systems of research and development, production and management for radioactive isotopes and its products, including radioactive sources, radioactive labeling compounds and radiopharmaceuticals. There are about 40 related manufacturers and almost 1,000 types of commonly supplied isotopes and products, 80% of them are domestically supplied. More than 4,500 people are engaged in the research and application of nuclearmedicine and more than 15,000 people engaged in radioactive therapy. Center hospitals in big cities have generally established the nuclear medicine sectors. In China there are about 3,300 whole body X-ray tomography scanners, more than 560 medical accelerators, more than 460 cobalt-60 treatment units, about 400 after-loading machines, 67tumor-cutting scalpels, more than 250 X scalpels, more than 100 cameras, more than 500 SPECTs and 63 PETs. 24 cyclotrons are used in combination with PET, among which 10 sets are equipped with positron medicine compound devices. There are more than 2000 RIA analyzers, 300 chemoluminescence immunization analyzers, and 60 fluorescence immunization analyzers nationwide.

The clinical application of 99Tcm perfusion imaging radiopharmaceutical has been popularized. Accelerator-produced radiopharmaceutical is continually used in more and more hospitals. Single photon emission radiopharmaceutical and 18F positron nuclide radiopharmaceutical are promoted. Therapy with 192Ir after-loading source has been widely applied. The 125I seed source has been produced in large quantity and obtained satisfactory curative effect in clinical application, which develops very fast. On the aspect of RIA kit, there are more than 200 applied hospitals, about 90 varieties and the product value closes to RMB 200 million.

131I monoclonal antibody labeling medicine for liver cancer is preliminarily developed. At present, major efforts are made in the R&D on multi-nuclides labeled monoclonal antibody and polypeptide pharmaceuticals, and it has made some progress in small molecule peptide imaging and monoclonal antibody immunization imaging.

1.2 Nuclear Instrumentation

On the aspect of ray testing and control technology and equipment, there are over 25,000 conventional isotope instruments produced domestically. Among them there is an annual pro-

duction of 2,500 nuclear weighing scales, which are basically madein China. Level meter, water content meter, thickness meter and content analyzer have technical breakthroughs on reliability, stability and intelligence, and they play important roles in the technical reform in large and medium scale enterprises (such as iron and steel and coal firms). The annual production value of ionization smoke fire alarm series is about RMB 5 billion Yuan and half of them are domestically made. The "Large container inspection system" with the ray of cobalt-60 (300Ci) and the electronic beam of 9 MeV accelerator as the ray sources has been successfully developed, which is in the leading position in the world and has high market shares in the international market. First set of 2~2.5 MeV (power 1kW~20kW), self shielding, radiation sterilization accelerator, which can be used to kill the biological bacterium such as bacillus anthracic, smallpox and plague germs in the mail and mail package, now has been put into operation. With the increasingly rampant and secret commodity smuggling, drug trade and illicittrafficking of weapons, the customs of all countries call for distinguishing and determining the nature of the goods inside the containers. For example, items such as drugs, plastic bombs, cigarettes and alcohols hidden in goods should be detected. Tsinghua University, Sichuan University and China Institute of Atomic Energy have done many works on this aspect and achieved great progress. With the support of the Ministry of Science and Technology of the PRC, the research work of large-scale industrial CT testing system has been developed. For example, Tsinghua University has successfully developed a 16 MeV electron linear accelerator with the highest X ray dosage rate in China, which is suitable for NDT.

1.3 Application in Agriculture

Application in agriculture is an important field for peaceful uses of radioisotope. It has contributed greatly to the sustainable development of agriculture products. By the end of 2004, using radio-inducing mutationtechnology or coupled with related technologies, China has bred 638 mutation varieties out of 40-odd plants, which has exceeded one fourth of the total number (2252 breeds) of the radioactive breeding worldwide. The annual mutation-breeding planting area exceeds 9 million hectares, which accounts for about 10% of total crop planting area of China. Each year 3.3 billion to 4 billion output of grain, cotton and edible oil were increased. Up to now, the number of breed, planting

area, social and economic benefit yielded as well as the integral technological standard of using mutation breeding technology in China all rank first in the world. It has made important achievements, and yielded fruitful social and economic benefit to use nuclide tracing techniques to researchthe function of various factors in the agricultural production process, and to direct scientifically farming, scientifically fertilization, properly using of agricultural chemicals and water-saving irrigation. In recent 10 years, using isotope tracer method, China has increased 1.9 billion kilogramsof grain production and created RMB 2.8 billion Yuan of economic benefit.

Insect radioactive sterile technology is an important means to kill pestsbiologically. Since the 1960s, China has made radioactive sterile research on more than 10 kinds of pests. Especially the artificial feeding and release test of citrus fruit fly (Tetradacus citri) has made successful achievement. For example, in a citrus orchard of 118 hectares with more than 100,000 trees in Guizhou, after sterile flies released for three years, the harmful rate of citrus fruit fly was reduced from 5.2% to 0.098%.

1.4 Irradiation Device

Irradiation device is mainly used in irradiation chemical industry, disinfection, sterilization and food preservation. Two commonlyused industrial radioactive sources are cobalt source irradiation device and electron irradiation accelerator. In recent ten years, the development speed of irradiation device in China has been evaluated as the fastest in the world. By the end of 2004, there are 72 industrial electron accelerators of 5 kW and above in operation (33 sets of them were imported), 54times increased since 1993 (14 sets). The total power reached over 4400kW,8 times increased since 1993 (469 kW). Another 19 sets are under construction (8 of them are imported) at present, and the total power will come to 5709KW when they are completed. In addition, stack gas desulfurization and denitration are done on three accelerators with a total power of 676 kW in Sichuan Province and one accelerator of 90 kW in Shanghai, which has made a delightful step in the industrialized development.

Since 1998 eleven new cobalt source irradiation devices with the designed source loading capacity above 300,000 Ci (1.11X104TBq) had been put into operation successively. By the end of 2004, a total of 73 devices were put into use, with a total designed source loading capacity of 62 million curies. Another 19 devices are being built with

the total designed source loadingcapacity above 35 million Ci. The actual source loading capacity of cobalt source has increased from 6 million Ci in 1994 to 30 million Ci at present, there has been in serious shortage of cobalt source supply for years.

Three major products in radioactive chemical industry are the radioactive heat-shrinkable products, cross-linking wire and cable, irradiation chemical industrial materials mainly processed by electronic beam. The product value has increased from RMB 250 million Yuan at the end of 1993 to RMB 3.2 billion Yuan at the end of 2004. The application of irradiation cross-linking heat-shrinkable products has been in large-scale. A radioactive chemical industrial material trial base was established with the support of the Ministry of Science and Technology. Some good performance achieved, such as low-smoke halogen-free flame-retardant materials, special radioactive cross-linking material for airport illumination line, high temperature-proof (above 300) radioactive cross-linking cable material and irradiation-proof polypropylene for medical use, has paved the path for further development of radioactive processing. With the accelerating of city network reconstruction, China will need 1~10 mm2 flame-retardant wires for 2 million kilometers annually. In addition, the needs for special wires and cables using in aviation, spaceflight, ocean petroleum exploitation, telecommunication and nuclear power fields will further increase.

As China is attaching great importance to the environmental protection and people's health, as well as the successful development of irradiation-proof (above 25 kGy) material for medical use, the radioactive disinfection of medical treatment products has been improved greatly, which has accounted for above 20% of the work of devices by now, and is expected to further increase.

Food preservation is an important aspect for irradiation application. China had approved 18 irradiated foods hygienic standards from 1984 to 1994. In 1996 it issued "Irradiated Food Hygienic Management Regulation". In 1997 it issued the hygienicstandards for six big categories of irradiated foods. In 1998 the quantity of irradiated food was 50,000 tons. In 1999 this number had sharply increased to 86,000 tons. Up to now, the total quantity of annual irradiatedfoods has exceeded 100,000 tons, which ranked first in the world.

1.5 The Treatment of Stack Gas of Coal-fired Power Plant

The SOx and NOx released fromcoal-

fired power plants and other plants are one of the main sources of environmental pollution. In China, coal-fired power plants generate 70% of electricity. The annual release of sulfur dioxide to the atmosphere has resulted in acid rain affecting almost 40% of the country. The application of radioactive techniquein this field has its unique advantage. By using electronic beam (EB) technique, the stack gas can be desulfuration and denitrated at the same time. Its industrial demonstration facility has been established in Chengdu, Sichuan Province. This technique can not only desulfurate and denitrate the stock gas, but also turn waste into agricultural fertilizer. Some research units in Beijing, Lanzhou, Mianyang and Shanghai, together with related enterprises, are developing the industry, which has aroused the attention of competent authorities.

2. Development

In general, there is still a big gap between the application level of Chinese radioisotope and radiation technology and that of the developed country. According to the target worked out by National Development and Reform Commission of China, the economic benefit for application of radioisotope and radiation technology industry will reach RMB 100 billion Yuan per year by 2008. If the related industrial policies can be worked out in support of the above-mentioned target, the radioisotope and radiation technology industry will develop faster and the above-mentioned target is likely realized.

2.1 The Application of Radioisotope and Radiation Technology in the Environmental Protection Industry Met Very Good Opportunity

It has obvious advantage to use the radiation technique to treat pollution, sewage and other biological waste than the traditional treatment methods such asburying, pouring into the sea and incineration, etc. With environmental protection industrial policies coming to light, nuclear application technology will find its important place in the environmental protection field.

The electronic beam stack gas desulfuration and denitration technique adopted aiming at the treatment of SO2 and NOX released from coal-fired power plant tends to replace traditional methods with very broad market prospect.

Comprehensive radioactive treatment technique is very effective to solve the city sewage pollution problem, especially on industrial sewage and organic sewage.

Radioactive mutagenizing technique can be used to treat organic sewage and consumed sewage by breeding effective bacterium variety. It has the advantages of high treatment efficiency, good water quality, low cost, and it does not need large-scale reform on the current facilities.

Treatment of "three wastes" by plasma technology has great advantages and will achieve good economic and social benefits. Hot plasma can be efficiently and safely used to treat many dangerous wastes, without secondary pollution.

2.2 Booming of Radioactive Medicine

2.2.1 Radioactive Pharmaceuticals

Radioactive pharmaceuticals include several categories such as in vitro diagnosis pharmaceutical, in vivo imaging pharmaceutical and in vivo treatment pharmaceutical, etc. In developed countries, one out of three patients receive nuclear diagnosis and treatment. Radioactive pharmaceuticals have become an indispensable part of medical science. In China, RIA kits, 99mTc series, iodine-131 series, iodine-125, samarium-153-EDTMP, strontium chloride [88Sr], rhenium-186-HEDP, phosphor-32series, Y-90 series, etc. as well as the specific therapy medicine "Yunke" for rheumatoid arthritis which developed by biological orientation theory and isotope tracer technology, and the therapy medicine "Lizhu" for bone tumor have been applied with great development prospect.

Molybdenum (technetium) -99 is used on various viscera and function imaging to diagnose all diseases and functions of human viscera. It is the main radioactive isotope used for medicine, and accounts for 80% of quantity of the in vivo imaging pharmaceuticals of the nuclear medicine. The domestic demand will further increase in the future.

2.2.2 Radioactive Interventional Therapy

The interventional therapy is a newly arisen technique, which implants the radioactive source withhigh specific activity and small dimension into the cancer organization to cure the diseases such as the prostate cancer. Using I-125, Pa-103 and Ir-192 seed source to develop radioactive interventional therapy will develop fast in China.

2.2.3 Further Application of Radioactive Testing and Treatment Instruments

The applications of computerized positron emission tomography (PET), computerized single photon emission tomography (SPECT) and the small size

cyclotron will be greatly expanded. The treatment instruments using neutron and electrification ionare expected to be applied. The application of BNCT is developing aiming to multiple directions at present, such as liver cancer, lung cancer, prostate cancer, breast cancer and melanoma, and itstreatment fields continues to expand and develop fast with broad perspective.

2.3 Nuclear Testing Technology Further Develops

Nuclear testing technology can realize quick online inspection. It can inspect items within a package or container, which does not need to unpack the package. Besides the container inspection system, the demand for radioactive detection for explosives and drugs in small package will further increase. By using special device and accelerator, NDT for internal defects of large-scale pipe, industrial equipment and bridge structure, etc will also develop quickly.

2.4 Application of Irradiation Device

Due to the perspective quick development of the three mainapplied fields of irradiation devices, the demands for cobalt-60 and irradiation accelerator will increase rapidly. The industrial cobalt source, low-energy large-power irradiation accelerator and high-energetic large-power irradiation accelerator both have broad industrialization prospect.

2.4.1 Radioactive Disinfections and Sterilization

China is one of the contracting states of Montreal Protocol. Radioactive disinfections and sterilization will become the main method for medical treatment product disinfection and sterilization after 2015 when chemical sterilization method (ethylene oxide) is completely diminished. With the increase of import and export trade and domestic attention on food safety, radioactive processing demand will also increase.

2.4.2 Irradiation Chemical Products

The demand for the matured products such as heat-shrinkable material, irradiation wire and cable will further increase. With some developed countries started to restrict the content of sulfur in rubber, rubber cross-linking by irradiation method will also have broad market prospect. There are 800,000 tons of market shares per year only for producing emulsion liquid. The demand for high performance car wheels will also greatly increase along with the development of Chinese automobile industry. The natural high molecule irradiated hydrogel is expected to replace the current materials with very

good prospect, due to its outstanding advantages (non-toxic, non-addictive and degradable). Hi-tech new material by irradiation cross-linking of polyethylene will also be widely used in automobile manufacturing, IT, special packing, construction, agriculture, fishery, daily life, recreation and cultural activities. In addition, flocculant product, silicon carbide fiber and oligomeric chitosan prepared by irradiation scion grafting are also liable to be developed and applied successfully.

2.5 Radioactive Tracer Technology to be Developed Quickly

The radioactive tracer technique still remains in the research stage in China. Many products (such as tracer) are still remaining at the laboratory production scale. Since the radioactive tracer technology can trace the pesticide's distribution and residue in all parts of the crop, soil and water, with the strengthening of environmental protection, there is a great area for application of tracer technique. Researches such as medicine dynamics, pharmacology, medicine selection, receptor analysis in new medicine, cannot go steps without radioactive tracer technique. Tracer technique can also be used to test the leakage of large-scale pipeline network of natural gas and petrol. Adopting thrice backstopping tracer technique to test the saturation degree of the remained oil in the oil field can extend the stable production period of Chinese oil field with important economic benefit.

3. Ending Words

Although the applicationof radioisotope and radiation technology brings great social benefit to us, both the public and the decision-makers do not completely understand this fact. In many cases, radioisotope and radiation technology technologies are always opposed due to misunderstanding. CIRA will pay more attention to the popularization of radioisotope and radiation technology so that the scientific and technological wealth could better serve the mankind. KRIA