

History and Present Status of Liquid Scintillation Counting in China

Shou-li Yang

INITIAL STAGES OF LSC IN CHINA

Studies of the liquid scintillation counting (LSC) technique began in 1958 at the Institute of Atomic Energy (IAE), Chinese Academy of Sciences (CAS, also known as Academia Sinica). This work was carried out with an imported liquid scintillation counter with single photomultiplier (PM). At the same time, Professor Shih-Chen Wang, Ph.D., of the Institute of Radiation Medicine (IRM), Chinese Academy of Medical Sciences (CAMS), was preparing to translate *Isotopic Tracers in Biology* (Martin D. Kamen, New York: Academic Press, 1957). While the translation was in progress, he read the revised and enlarged edition of the book which was published in December 1959 and noted immediately the increased number of entries in the appendix on the application of liquid scintillation counting to the major nuclides used in biology. Realizing the importance of LSC in bio-medical research, he not only purchased an Ecko single tube LS counter, but also took on (in 1962) two postgraduate students, Zong-qin Xia and Han Lin, and allowed them to study cholesterol and thyroid hormone metabolism, using LSC for detection of ^3H and ^{14}C .

In 1965, I also went to the Institute and studied extensively the methodology of LSC. Since then, due to extensive interchange of scientific personnel within the country, LSC methods have been spread throughout China. The scientists who worked in the Institute of Radiation Medicine not only have made a great contribution to the development of LSC applications in China, but have also become well-known internationally in the field of nuclear medicine. Professor Shih-Chen Wang held the post of the first president of the Chinese Society of Nuclear Medicine (CSNM) and is now the academic standing member of CAS, the highest honor in Chinese academic circles.

The design and manufacture in China of liquid scintillation counters came later. In 1968, the scientists of IAE, CAS, and Xi'an Nuclear Instrument Factory cooperated in the design of a liquid scintillation counter with two photomultipliers and two single channel analyzers. This counter was called

Model FJ-353 double channel liquid scintillation counter. Only a few were produced in 1970, but actual availability of the counter did not occur until "the National Training Course in Isotopic Techniques and Their Biomedical Applications" in 1973, where it was shown as a demonstration instrument. In 1972, Pei-dong Jiang, Han-ying Jiang, et al., the Institute of Biophysics, CAS, and engineers of the Instrument Factory of Beijing University cooperated to begin the design of the first automatic liquid scintillation system controlled by computer. This instrument, called model YS-1 automatic liquid scintillation spectrometer, was completed in 1976. Then, personnel at Xi'an Nuclear Instrument Factory, Institute of Biophysics, Shanghai Institute of Nuclear Research (SINR), and Beijing Nuclear Instrument Factory (BNIF) designed and successfully produced a variety of LS counters; these became the prototypes for the counters presently made in China.

PROFFESIONAL COMMITTEES

Along with the active development, design, and manufacture of liquid scintillation counters, Chinese specialists have held many meetings for appraising the quality of LS instruments and discussing scintillation methodology. In August of 1979, LS specialists belonging to more than forty units came together in Beijing and drafted a document proposing a national conference on LSC and an LSC committee. The document was submitted to the Preparatory Committee of the Chinese Society of Biophysics (CSBP). At present, the Chinese Professional Committee of Liquid Scintillation Counting (CPCLSC) reports to the Chinese Society of Nuclear Electronics and Detection Technology (CSNEDT) and to the CSNM.

The CPCLSC consists of the ten following members:

1. Han-ying Jiang, Institute of Biophysics, CAS,
2. Pei-dong Jiang, Institute of Biophysics, CAS, general head,
3. Bao-Sheng Liang, BNIF,
4. Zhang-zhi Wang, SINR,
5. Xi-fan Wu, Xi'an Nuclear Instrument Factory,
6. Zhong-qin Xia, Shanghai Second Medical University,
7. Jing-cheng Xiao, IAE, Chinese Academy of Agriculture,
8. Li-ping Yang, an Nuclear Instrument Factory, in charge of contact with CSNEDT,
9. Shou-li Yang, Institute of Clinical Medical Sciences, China-Japan Friendship Hospital, in charge of contact with CSNM,
10. Huai-xin Zhang, IAE, CAS.

Shao-wan Lu, Institute of Biophysics, CAS, is the secretary of the committee.

In addition, the Radiocarbon Dating Professional Group that reports to the Chinese Quaternary Research Committee is also involved in developing LS technology. The head of the group is Shi-hua Chou, Institute of Archaeology, Chinese Academy of Social Sciences.

Table 1. Four National Conferences on LSC Counting

	1st	2nd	3rd	4th
Dates	—	—	Nov. 12–16 1986	Nov. 24–27 1988
Location	—	—	Wuxi	Xi'an
Delegates	—	—	90	118
No. of papers	109	71	98	67
Supported society	CSBP & CSNEDT	CSNEDT	CSNEDT	CSNEDT
Financial support	XNIF, etc.	BNIF, LKB, XNIF, ect.	Beckman, HMIF, etc.	Aloka, Beckman LKB, Packard, XNIF, etc.

NATIONAL CONFERENCES

The CPC LSC has organized four national conferences (one every two years). These are listed in Table 1. The delegate composition of the conferences indicates that more than 50% of the delegates were with various institutes in the fields of biology and medicine. The importance of instrument factories making LSC counters lies not only in the production, but also in the development of new products and financial support of academic exchanges. Table 2 contains a classification of papers in the four national conferences according to their contents. Obviously, sample preparation and its applications, instrument quench correction, and instruments, electronics, and vials are the three main topics studied by Chinese LSC specialists.

I should like to note that LSC specialist Professor C.T. Peng, attended the first national conference at the invitation of the Professional Committee and gave a lecture about distinguishing multi-nuclides in a sample.

The Radiocarbon Dating Professional Group organized four national conferences on ^{14}C dating from 1982 to 1988. The number of delegates and papers in these conferences was fewer than the national conferences on LSC, but the topics discussed were more focused.

BOOKS ON LSC

In 1973, under the direction of the Ministry of Public Health of the People's Republic of China, the Institute of Radiation Medicine, CAMS organized an advanced isotopic technique training course in which the theory and practice of LSC were taught and demonstrated. Drs. Zhong-qin Xia, Shou-li Yang, Pei-dong Jiang, and Ni-na Jiang taught cocktail and sample preparation, quench correction, instrumentation methodology, liquid scintillation counter systems, and absolute activity measurement. The lecture notes were later published as a book, entitled *Isotope Technique and Their Biomedical Applications*, (Beijing: Science Press, 1977 and 1979). Because all the contributors in

Table 2. Classification of the Papers in the Four National Conferences on LSC

Categories	1st		2nd		3rd		4th		Total	
	%	No.	%	No.	%	No.	%	No.	%	No.
Instrument, electronics, vial	18.3%	20	12.7%	9	15.3%	15	17.9%	12	16.2%	56
Instrumental methodology, quenching correction	19.3%	21	22.5%	16	19.4%	19	22.4%	15	20.6%	71
Scintillator, cocktail	6.4%	7	9.9%	7	10.2%	10	10.4%	7	9.0%	31
Sample preparation, and its applications	20.1%	22	23.9%	17	23.5%	23	23.9%	16	22.6%	78
Chem-(bio-) luminescence, B,r,Cerenkov counting	11.9%	13	16.9%	12	9.2%	9	6.0%	4	11.0%	38
Low-level counting	10.1%	11	5.6%	4	11.2%	11	6.0%	4	8.7%	30
Absolute activity counting	9.2%	10	2.8%	2	5.1%	5	9.0%	6	6.7%	23
Others	4.6%	5	5.6%	4	6.1%	6	4.5%	3	5.2%	18
Total		109		71		98		67		345

the book are prominent in Chinese nuclear medicine, the book is widely distributed and well known. It won an award from the National Science Congress in 1979 for excellence in both technical depth and clarity of presentation. At present, the second edition of this book is in press (edited by Shih-Chen Wang, Han Lin, and Chien Chou, Science Press, Beijing).

Eight other books on LSC have been published in China; two of them are written by Chinese scientists, one is translated and edited, and the other five are translations. Among these, two books are widely circulated and well received by the readers: *Advances and Applications in Liquid Scintillation Counting*, (edited by Shou-li Yang, Pei-dong Jiang, and Han Lin, Science Press, Beijing, 1987) and *Liquid Scintillation Counting and Its Application to Biology* (translated and edited by the LSC group of Institute of Biophysics, CAS, Science Press, Beijing, 1979). The former is in the second edition while the latter is taken mainly from *Applications of Liquid Scintillation Counting* by D. L. Horrocks (New York: Academic Press, 1974) and *Biological Applications of Liquid Scintillation* by V. Kobayashi and D. V. Maudsley (New York: Academic Press, 1974).

In addition, the Radiocarbon Dating Professional Group has edited *Proceedings of the First National ¹⁴C Dating Conference* (Beijing: Science Press,

Table 3. Main Journals Published Papers of LSC

Translated English Name	Chinese Spelling Name ^a	Publishing Period	Sponsored Society or Unit	Start Year
Nuclear Electronics and Detection Technology	HEDIANZIXUE YU TANCE JISHU	bimonthly	CSNEDT	1981
Chinese Journal of Nuclear Medicine	ZHONGHUA HEYIXUE ZAZHI	quarterly	CSNM	1981
Science and Technology of Atomic Energy	YUANZINENG KEXUE YU JISHU	bimonthly	CIAE	1964
Nuclear Techniques	HEJISHU	monthly	CNS	1978
Nuclear Science and Engineering	HEKEXUE YU GONG- CHENG	quarterly	CNS	1981
Nuclear Science and Techniques (English)		quarterly	CNS	1990
Radiation Protection	FUSHE FANGHU	bimonthly	CSRP	1981
Chinese Journal of Radiological Medicine and Protection	ZHONGHUA FANGSHE YIXUE YU FANGHU	bimonthly	CSRPM	1981
Progress in Biochemistry and Biophysics	SHENGWU- HUAXUE YU SHENGWUWULI JINZHAN	bimonthly	IBP, CAS	1974
Archaeology	KAOGU	monthly	IA, CASS	1959

^aSome important international abstracts quoted these names.

1984), in which there are 35 papers, including 11 on the methodology of liquid scintillation counting.

PROFESSIONAL JOURNALS

The papers and reviews on liquid scintillation counting are published mainly in professional journals sponsored by the societies of nuclear science (Table 3). They are also disseminated in the journals of other professional societies or learned units. The starting publication dates of the journals listed were mostly in the early 1980s. Before then, the majority of the research papers on LSC were published in informal learned journals, for example, *Radiation Medicine*, *Nuclear Protection*, and *Nuclear Instrument and Methodology*. Although these journals have stopped publication, they have carried many papers and reviews about LSC, nuclear medicine, nuclear instruments, and

methodology, and therefore played an important part in information exchange during the early period. In fact, *Radiation Medicine* and *Nuclear Protection* established foundations for the publications *Chinese Journal of Radiological Medicine and Protection* and *Radiation Protection*, respectively, in 1981.

It must be emphasized that the *Nuclear Science and Techniques*, which is a new professional journal in English, will start as a publication of the Chinese Nuclear Society in 1990. This event shows the increasing growth of information exchanges between China and nuclear scientists around the world.

INTERNATIONAL ACADEMIC EXCHANGES

The first international academic exchange in LSC took place in 1979 at Beijing Normal University, when Dr. C.T. Peng, School of Pharmacy, University of California, gave a series of penetrating lectures on LSC and labeled isotope techniques. The training courses lasted one month and the number present from Beijing and other provinces was about two hundred; it was an exceptional occasion. Since then, Dr. Peng has visited China many times and participated in a variety of publications and discussions.

Dr. J.E. Noakes, Center for Applied Isotope Studies, University of Georgia, U.S.A., has visited China at the invitation of the Institute of Biophysics, CAS, after the conference on "Advances in Scintillation Counting" in 1983. Not long after, Dr. H. Polach, Radiocarbon Dating Research Laboratory, Australian National University, visited the Chinese Institute of Geology. They not only gave special reports but also exchanged low-level counting and instrumentation techniques with the Chinese LSC specialists.

Japanese LSC specialist Dr. H. Ishikawa visited the China-Japan Friendship Hospital, BNIF, and the Chinese Academy of Metrologic Sciences in 1988. He gave an excellent report about the efficiency tracing technique (ETT).

We hope that more and more LSC scientists could visit China. At the same time, we also hope that Chinese LSC specialists could be more extensively engaged in the LSC research being carried out in many distinguished foreign laboratories.

INSTRUMENTS

The Xi'an Nuclear Instrument Factory is the major manufacturer of LSC instruments and produces more than 80% of the LSC instruments made in China. Xi-fan Wu was the leader of this factory and Li-ping Yang served as the main LSC electronic specialist. They made great contributions to early LSC instrument manufacture in China. At present, there are about twenty LS counter models made in China; these are detailed in Tables 4 and 5.

In the 1980s, significant LSC interests in China included the development of (1) routine LS counters with multi-channel analyzer capability and software

Table 4. LSC Instruments Made in China

Model	Appeared Year	Features	Designer & Manufacturer
FJ-353	1970	Double channels, 3 discriminators, sample capacity 25, semi-automatic, GDB-52 tube, E (%) of ^3H > 40%, background < 40 cpm	IAE, XNIF
FJ-2101 (G)	1979	NIM system, automatic print, others the same as JF-353	XNIF
YS-1	1976	Controlled by model J30 date processor, 3 + 2 channel system, 100 samples, ^{137}Cs external standard	IBP
YS-2-1	1979	Automatic measurement and date processing, 3 + 2 system, 200 samples, ^{137}Cs external standard	IBP
YS-2-2	1979	No date processing function, rest is the same as YS-2-1	IBP
YS-3	1977	Single sample, manual, 2 + 2 channels	IBP
YS-A	1980	60 samples, manual, 2 + 2 channels	TMIF, IBP
YS-B	1980	200 samples, automatic, 2 + 2 channels	TMIF, IBP
YSJ-76	1976	3 channels, ^{137}Cs external standard, 4 counting models, automatic print, 200 samples	SINR, SSMU
FJ-2100	1979	The main features are the same as YSJ-76	SINR, SNIF
YSJ-78 (YSJ-1)	1978	An improved model of YSJ-76	SINR
FJ-2105	1982	Controlled by Z80 microcomputer, 3 + 2 system, 200 samples	XNIF
FJ-1907	1982	Double channels, 24 samples, manual	BNIF
FJ-2107G	1985	NIM standard, Apple II desk computer, others are the same as JF-2105.	XNIF
FJ-2107	1985	No computer, others are the same as JF-2107G	XNIF
FJ-2108	1986	3 + 2 system, cell grown index measurement, sample chamber with constant temperature and shaking	XNIF
FJ-2112	1986	Apple II desk computer for control and data processing, 300 standard vials or 480 minivials, 3 + 2 system	XNIF
FJ-2115	1987	Controlled by single plate computer rack type conveyer, 10 samples	XNIF
FT-1913	1986	TRS-80 microcomputer, CRT display 2048 channels	BNIF

Table 5. Low-level LSC Instruments Made in China

Model	Appeared Year	Features	Designer & Manufacturer
DYS-1	1980	Single sample, manual, NaI anti-coincidence shield (20 x 150 mm, hole 80 mm), sample volume: 2–100 ml, for 5 mL ^{14}C -benzene, $E = 80\%$, $B = 0$, 54 cpm, $E^2/B > 10,000$, detection limit for ^3H in 50 mL water (add 50 mL Instagel cocktail) is 1 Bq/L. water ($t = 30$ min, $E = 68.3\%$)	IBP
DYS-2	1982	No anticoincidence, sample volume: 5, 10, 20 mL, 10 samples, automatic, 5 mL ^{14}C -benzene $E > 70\%$, $B < 3$ cpm [glass vial]; $\text{FOM}^a > 1700$ (glass vial), > 2000 (Teflon vial); detection limit for ^3H : 40 T.U.	IBP
DYS-3	1981	5 samples, sample volume: 5–100 mL NaI anticoincidence, controlled by Apple II computer	IBP
FH-1915	1982	NaI anticoincidence shield, TP-80 microcomputer controlled, ^{14}C : $E = 76.3\%$; $B = 0.4$ cpm; $\text{FOM} = 14550$; ^3H : $E = 52.6\%$, $B = 1.11$ cpm, $\text{FOM} = 2492$	BNIF
FH-1916	1983	An improved model of DYS-2,	IBP, BNIF
FH-1935	1985	New soft multichannels, TRS 80 microcomputer low-level counting software packages	BNIF
DYS-84	1984	Anticoincidence with cyclic counting tube or matrix of counting tube, 24 samples, controlled by Zijin-II microcomputer	IBP
DYS-86	1986	With soft multichannels, the rest is the same as DYS-84	IBP
DYS-88	1988	Anticoincidence with BGO crystal, the rest is the same as DYS-84	IBP

^aFOM: figure of merit

sophistication, (2) low-level background liquid scintillation counters for environmental protection and radiocarbon dating, such as Models DYS-86 and FH-1935, (3) economical, simple and convenient LS counters for use in basic hospitals and small research units, such as FJ-2115, and (4) counters that can simultaneously measure both beta- and gamma-emitting nuclides.

The anticoincidence shield method in low-level LS counters is another subject of increased attention in China. Han-ying Jiang, Shao-wan Lu, and Ting-kui Zhang, Institute of Biophysics, reported BGO crystals as an anticoincidence shield and compared it with other anticoincidence methods. Some

authors have studied the cross talk and cross talk discriminator and applied them to the products of the LS counter.

ORGANIC SCINTILLATORS, COCKTAILS, AND SAMPLE PREPARATION

In the 1970s, Nankai University, Shanghai Institute of Pharmacology, and Shanghai No.1 Reagent Works, etc., first produced PPO. Since then, Nankai University has studied butyl-PBD and BZOB. Presently, Shanghai No.1 Reagent Works has produced more than twenty scintillators, such as p-TP, PPO, PBD, butyl-PBD, BZOB, POPOP, DM-POPOP, BBO, DPA, DPH, bis-MSB, etc.

In 1982, Chun-liang Xu prepared a new scintillator, p-TTP [2,5-di(p-tolyl)1,3,4-oxadiazole], an analog of m-TTD [2,5-di(o-tolyl)1,3,4-oxadiazole]. Its luminescence efficiency is the same as butyl-PBD and its optimum concentration is 0.4 to 0.8%. In 1984, Zhen-gue Yang, Shanghai No.1 Reagent Works, synthesized Triton X-100 for LSC. Before then OP-115, an analog of Triton X-100, had been used as an emulsifier, but its background is higher and counting efficiency is lower than Triton X-100.

The counting of substances supported on filter paper or millipore filters is a simple method of sample preparation. Therefore, it has been widely used in the assay of bio-medical samples in China. In the 1960s, Sheng-li Huang et al., used this technique to measure ^{14}C in digested animal tissue. This method was popular up to the late 1970s, when glass filter paper appeared in the Chinese market. The metabolic experiments of a variety of important drugs in that period, such as the male contraceptive drug, gossypol, were also completed using this method. We also analyzed the energy spectrum of ^3H sample supported on millipore filter and described a LSC method for ^{125}I on the supporters. At present, the supports being used are glass filter papers and millipore filters. About half of the total bio-medical samples in China are assayed via this technique.

RADIOCARBON DATING

In the 1970s, the radiocarbon laboratory in China completed the conversion of dating methods from gas phase techniques to LSC. The most famous radiocarbon dating laboratories are parts of the Institute of Archaeology, Chinese Academy of Social Sciences (CASS), Department of Archaeology, Beijing University; Institute of Geology, CAS, etc.. They have made great contributions to Chinese prehistory and archaeology and are widely recognized internationally.

ACKNOWLEDGEMENTS

I wish to thank the conference organizers Drs. H.H. Ross, J.E. Noakes, and J.D. Spaulding for the financial assistance to attend this conference and Prof. C.T. Peng for his encouragement. I also wish to thank Miss Isabel Li for her valuable assistance in polishing up my English and lastly Mr. Ming Hu for typing the manuscript.*

*Note: This manuscript has undergone extensive revision and condensation in order to meet the style requirements and space limitations of the proceedings. We sincerely hope that we have not changed the substance or connotation of any information intended to be conveyed by the author. Eds.