A SURVEY OF ENVIRONMENTAL ^{14}C LEVELS IN HONG KONG

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ABSTRACT. As an industrialized city, Hong Kong annually consumes a large amount of fossil fuel. In addition, the Daya Bay Nuclear Power Plant in Shenzhen, Guangdong Province, has just begun operation 20 km from Hong Kong. These factors suggest that it may be appropriate and significant to examine the variation of atmospheric ^{14}C levels in Hong Kong. We have collected and tested a variety of samples from different parts of Hong Kong: terrestrial annual grasses, marine plants and atmospheric CO_2. We measured their ^{14}C activity and compared it with that of cassia oil samples from Guangxi Province, China. The values obtained indicate that environmental ^{14}C levels in the Hong Kong region agree with those found in Guangxi, both of which are significantly higher than the levels predicted by Povinec, Chudý and Šivo (1986).

INTRODUCTION

Three ongoing anthropogenic activities are known to alter environmental ^{14}C levels:

1. Since the industrial revolution in the 18th century, much CO_2 has been produced by combustion of fossil fuels, which have no measurable ^{14}C content. This, the "Suess effect", has decreased the average concentration of atmospheric ^{14}C, as measured by its activity, by *ca.* 3% over the period 1850–1950 (Freundlich 1979; Levin, Münnich and Weiss 1980; Levin *et al.* 1989).
2. Nuclear testing since 1945, particularly nuclear weapons tests, has increased atmospheric ^{14}C; indeed, by 1963 ^{14}C from this source amounted to *ca.* 3% of the ^{14}C content in all global reservoirs; the atmospheric ^{14}C concentration in the northern hemisphere approached a peak value of double the natural atmospheric ^{14}C concentration. Since then, the excess atmospheric ^{14}C has diffused into other reservoirs (mainly to the oceans) and, following the Limited Test Ban Treaty of 1963, the excess atmospheric ^{14}C has decreased exponentially with a decay half-life of 7 yr (Nydal, Lövseth and Gulliksen 1979; Povinec, Chudý and Šivo 1986).
3. Nuclear power has become an important world energy source. Although the ^{14}C produced by nuclear reactors is small compared to that from weapons testing, the number of nuclear power installations is increasing rapidly, so that ^{14}C released from this source is not negligible (Obelić *et al.* 1986; Hertelendi, Uchrin and Ormai 1989; Loosli and Oeschger 1989).

These three factors are all relatively recent and have produced fluctuations over a comparatively short time scale. However, although ^{14}C concentration has been decreasing since 1968 and the effect of proliferating nuclear installations is counteracted by the combustion of fossil fuel, the current ^{14}C concentration in the atmosphere is still *ca.* 15% above the natural ^{14}C level. Further, given projected future development of the nuclear power industry, it is difficult to foresee continued decrease in the atmospheric ^{14}C level.

This increased level of ^{14}C may represent a health hazard. ^{14}C and ^{3}H are incorporated into human tissue through the food chain and are combined during metabolic activity. Their nuclides may then be transferred into genetic material as part of DNA or RNA molecules. In this event, the genetic molecules might be harmed by radioactivity or changed to anomalous molecules by ^{14}C decay, in

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either case producing a variable genetic factor. Although this possibility is small, any increase in the environmental ^{14}C level increases the health risk (Stenhouse and Baxter 1979).

The purpose of this study is to investigate environmental ^{14}C in Hong Kong, one of the most developed cities in southeast Asia. Currently, two major factors impact ^{14}C in the Hong Kong region: the large quantity of fossil fuel consumption there, and the new Daya Bay Nuclear Power Plant in Shenzhen, Guangdong Province, just 20 km from Hong Kong.

METHODS AND RESULTS

We collected a variety of samples from different parts of Hong Kong, including terrestrial annual grasses and marine plants. We also collected atmospheric CO_2 samples using static absorption of CO_2 in NaOH solution over a period of 5–7 days. Following traditional procedures for ^{14}C dating, the samples were then prepared and converted to liquid benzene samples (Qiu, Chen and Cai 1990; Radiocarbon Laboratory 1978, 1983). We measured ^{14}C activity after adding scintillator material to the liquid benzene, using a low-background scintillation counter and Chinese sucrose charcoal (modern carbon standard) as well (Qiu *et al.* 1983).

We used a Model DYS-2 low-background scintillation counter (manufactured by the Biophysics Institute of CASS) with a background of *ca.* 4 cpm per 7 ml benzene and a counting efficiency of *ca.* 70%. All measurements were made in the ^{14}C laboratory of the Archaeology Institute, CASS, Beijing. Results are listed in Table 1. For comparison, we also analyzed cassia oil samples from Guangxi (Table 2). Figure 1 plots the results of sample analyses for both groups against predicted future ^{14}C concentrations.

TABLE 1. Results of Samples Collected from Hong Kong

Sample no.	Site	Collection date	Material	$\Delta^{14}C$ (‰)
1	Fanling	December 1993	Grass	160 ± 6
2	Kowloon Tong	November 1993	Grass	145 ± 6
3	Chai Wan	December 1993	Grass	148 ± 6
4	Kowloon Tong	January 1994	Atmospheric CO_2	158 ± 12
5	Stanley	March 1994	Seaweed*	247 ± 20
6	Shek O	March 1994	Seaweed	169 ± 6
7	Kowloon Tong	March 1994	Atmospheric CO_2†	222 ± 20

*This sample contains too little carbon and too much silicified plant material, which may be some years old; thus, it exhibits unusually high ^{14}C activity.

†Sample collected after Daya Bay Nuclear Power Plant commenced operation.

TABLE 2. Results of Cassia Oil Samples Collected in Guangxi, China*

Sample no.	Collection date	$\Delta^{14}C$ (‰)
9001115	1990	200 ± 20
910809	1991	180 ± 20
920117	1992	140 ± 20
920727-8	1992	160 ± 20
920818-6	1992	150 ± 20
941072	1994	160 ± 20

*Cassia oil samples were collected by Chinese Shanghai Essence Ltd. from Guangxi. Only a partial listing of the results is included here.

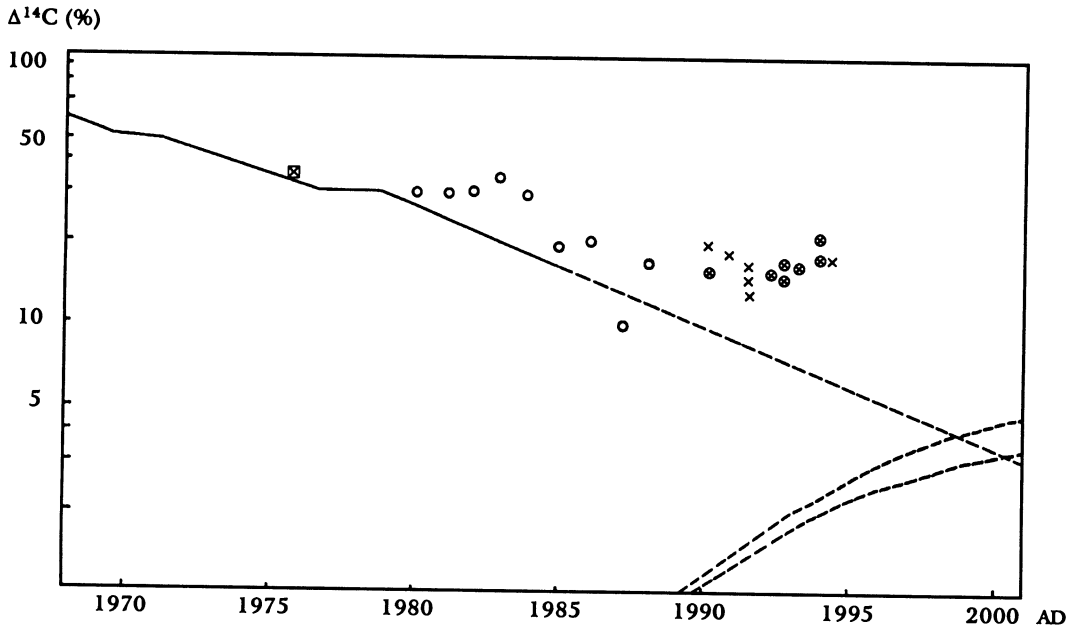

Fig. 1. Recorded (——) and predicted (- - -) atmospheric concentration of ^{14}C (from Povinec 1986: Fig. 2). Lower curves show the boundary ^{14}C level for predicted growth of the nuclear industry. × = cassia oil sample; ⊗ = Hong Kong sample; ⊠ = sugar carbon; O = wheat grains, Beijing (Shen *et al.* 1990)

Discussion

As Hong Kong is situated at a low latitude, far from sites of nuclear weapons testing, one might expect that the environmental ^{14}C concentration would not fluctuate significantly and would match the global average level. Although the data presented cover a short period and cannot show variation over time, the values obtained indicate that environmental ^{14}C levels in the Hong Kong area agree with those found in Guangxi province. However, both sets of values are significantly higher than the levels predicted by Povinec, Chudý and Šivo (1986).

The atmospheric ^{14}C level approached a peak value in 1963 and then began to decrease as an exponential function. Provided there is no further anthropogenic disturbance, the global ^{14}C level would be expected to decrease to the original natural ^{14}C level in time (Povinec, Chudý and Šivo 1986). However, the data obtained in Hong Kong and Guangxi (shown in Fig. 1 alongside Povinec's model) suggest the possibility of additional anthropogenic effects in operation. Whether these involve continued weapons testing, effects from the Chernobyl Nuclear Power Station accident, or the steady increase of global nuclear power plant operations, cannot be determined given the data available. Alternately, the decrease in the environmental ^{14}C level caused by fossil-fuel combustion may be less than expected.

Although more data need to be collected over a longer period, the present data can serve as a base for monitoring any effects from the Daya Bay Nuclear Power Plant, which began operating on 1 February 1994. Normally, the influence of ^{14}C released from nuclear installations may be negligible at a distance beyond 10 km (McCartney *et al.* 1986). Because Hong Kong is 20 km from Daya Bay, its fluctuations in ^{14}C level are apparently due mainly to the influence of nuclear testing.

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REFERENCES

Freundlich, J. C. 1979 Fossil fuel exhaust-gas admixture with the atmosphere. *In* Berger, R. and Suess, H., eds., *Radiocarbon Dating.* Proceedings of the 9th International ^{14}C Conference. Berkeley/Los Angeles, University of California Press: 388–393.

Hertelendi, E., Uchrin, G. and Ormai, P. 1989 ^{14}C release in various chemical forms with gaseous effluents from the Paks Nuclear Power Plant. *In* Long, A., Kra, R. S. and Srdoč, D. eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 754–761.

Levin, I., Münnich, K. O. and Weiss, W. 1980 The effect of anthropogenic CO_2 and ^{14}C sources on the distribution of ^{14}C in the atmosphere. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 10th International ^{14}C Conference. *Radiocarbon* 22(2): 379–391.

Levin, I., Schuchard, J., Kromer, B. and Münnich, K. O. 1989 The continental European Suess effect. *In* Long, A., Kra, R. S. and Srdoč, D. eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31 (3): 431–440.

Loosli, H. H. and Oeschger, H. 1989 ^{14}C in the environment of Swiss nuclear installations. *In* Long, A., Kra, R. S. and Srdoč, D. eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 747–753.

McCartney, M., Baxter, M. S., McKay, K. and Scott, E. M. 1986 Global and local effects of ^{14}C discharges from the nuclear fuel cycle. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 634–643.

Nydal, R., Lövseth, K. and Gulliksen, S. 1979 A survey of radiocarbon variation in nature since the Test Ban Treaty. *In* Berger, R. and Suess, H., eds., *Radiocarbon Dating.* Proceedings of the 9th International Conference. Berkeley/Los Angeles, University of California Press: 313–323.

Obelić, B., Krajcar Bronić, I., Srdoč, D. and Horvatinčić, N. 1986 Environmental ^{14}C Levels around the 632 MWe Nuclear Power Plant Krško in Yugoslavia. *In* Stuiver, M. and Kra, R., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 644–648.

Povinec, P., Chudý, M. and Šivo, A. 1986 Anthropogenic radiocarbon: Past, present, and future. *In* Stuiver, M. and Kra, R., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 668–672.

Qiu, S. H., Cai, L. Z. Chen, T. M. and Yuan, S. X. 1983 Report on Chinese sucrose charcoal standard for ^{14}C dating. *Kexue Tongbao* 28(5): 707–713.

Qiu, S. H., Chen, T. M. and Cai, L. Z., eds., 1990 *^{14}C Chronological Research in China.* Beijing, Science Press: 48–61 (in Chinese).

Radiocarbon Laboratory, Institute of Archaeology, CASS 1978 Report of radiocarbon dates V. *Kaogu* (4): 280 (in Chinese).

Radiocarbon Laboratory, Institute of Archaeology, CASS 1983 Report of radiocarbon dates X. *Kaogu* (4): 646–647 (in Chinese).

Shen, C. D., Jiang, M. T., Huang, R. L., Qian, M. M. and Tao, K. 1990 Variation of ^{14}C in wheat's grain from 1958 to 1988 in the rural region of Beijing. *In* Radiocarbon Dating Society of Chinese Quaternary Research Association, ed., *Special Issue on ^{14}C Dating.* Beijing, Geological Publishing House: 133–136 (in Chinese).

Stenhouse, M. J. and Baxter, M. S. 1979 The uptake of bomb ^{14}C in humans. *In* Berger, R. and Suess, H., eds., *Radiocarbon Dating.* Proceedings of the 9th International Conference. Berkeley/Los Angeles, University of California Press: 324–341.