香港天文台
HONG KONG OBSERVATORY

Environmental Radiation Monitoring in Hong Kong

Technical Report No. 17

Environmental Gamma Absorbed Dose Rate in Air in Hong Kong 1999

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Hong Kong Observatory

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We wish to thank the Radioisotope Unit of the University of Hong Kong for the data of their previous surveys and their efforts in making additional measurements of the indoor gamma absorbed dose rate in air and the radionuclide contents in soil samples.

We would like to record our appreciation to the Planning Department and the Geotechnical Engineering Office, Civil Engineering Department for their courtesy of supplying the updated information on the distribution of the population and the geological formation of Hong Kong respectively.

Abstract

A study of the environmental gamma absorbed dose rate in air in Hong Kong has been carried out to obtain information on the natural radiation levels in Hong Kong. The study combined existing data collected from various sources with results of a territory-wide radiological survey conducted in areas not covered by existing data. The results of this study will be submitted to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

In the survey, gamma absorbed dose rates in air were measured in open field, on street level and indoor. The activity concentrations of natural radionuclides in soil were also assayed. Similar to usual practice in other places of the world, outdoor gamma absorbed dose rates in air were measured in open field areas with underlying surface not affected by human activities. As most of the population in Hong Kong is crowded in heavily built-up areas with busy streets, gamma absorbed dose rates in air were also measured at street levels in built-up areas for comparison purposes.

After cosmic and seasonal corrections, outdoor gamma absorbed dose rates in air (Df) range from 0.051 to 0.123 μGy/h with an average of 0.087 μGy/h. The value is comparable to that of other cities in the neighouring province of Guangdong.

After cosmic and seasonal corrections, gamma absorbed dose rates in air at street level (Ds) range from 0.135 to 0.229 μGy/h with an average of 0.179 μGy/h. The high value of Ds was due to the geometry of the surrounding buildings and the construction materials used.

After cosmic correction, the indoor gamma absorbed dose rates in air (Din) range from 0.141 to 0.267 μGy/h with an average of 0.199 μGy/h. Whether the radioactivity contents in the building material or the geometry (i.e. influence of adjacent buildings) is the more significant factor for the high value of the Din has yet to be determined.

The average activity concentrations of K-40, U-238, Ra-226 and Th-232 in 20 soil samples are 653 Bq/kg, 103 Bq/kg, 72 Bq/kg and 117 Bq/kg respectively. The values are comparable to those for other cities in Guangdong.

Chapter 1

Introduction

1.1 Background

The Hong Kong Observatory (HKO) has recently carried out a study of the environmental gamma absorbed dose rate in air in Hong Kong. The objective of the study is to obtain information on the natural radiation levels in Hong Kong. To complete the study within a short period of time, HKO made full use of existing data, including data collected by the radiation monitoring network (RMN) of the HKO and in previous surveys carried out by the Radioisotope Unit (RIU) of the University of Hong Kong (HKU). In local areas not covered by existing data, HKO conducted a comprehensive territory-wide radiological survey in January to February 1999 to supplement the findings of previous surveys. Survey results were then compiled with existing data to arrive at a more representative picture of the natural radiation levels in Hong Kong.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) will publish a report in the year 2000 which includes, amongst others, the outdoor and indoor radiation levels for various places in the world. The results of this study will be submitted to UNSCEAR so that the natural radiation levels in Hong Kong can be presented in the proper context in the UNSCEAR report and in line with reporting rationale of other places in the world.

1.2 Existing Data

Under the Environmental Radiation Monitoring Programme (ERMP), the HKO continuously monitors the gamma absorbed dose rate in air in Hong Kong by the RMN which is a network of ten fixed field stations at strategic locations over the territory (Figure 1). The gamma absorbed dose rate in air is measured continuously by high pressure ionization chambers (HPIC). The data are transmitted back to the HKO Headquarters once every minute and archived. A summary of gamma absorbed dose rate in air measured by the RMN is published monthly (for example, Hong Kong Observatory 1999) while measurement results of the ERMP are published on an annual basis (Hong Kong Observatory 1998).

Previous surveys refer to those carried out by the HKU since 1987 on terrestrial gamma radiation dose (Tso et al. 1992) and in 1993 on indoor gamma absorbed dose rate in air and its relation to indoor radon concentration in high-rise buildings (Leung et al. 1998). In the HKU study in 1987 (Tso et al. 1992), some indoor measurements were taken in elevator lobbies and hallways as access to private apartments and offices was not always possible. These measurements were thus not representative of the indoor conditions in Hong Kong. For more realistic indoor measurements and in line with usual practice (e.g. He et al. 1992), only those HKU measurements taken in rooms were compiled together with the indoor measurements taken in this supplementary survey.

1.3 The Radiological Survey

The radiological survey was organized in collaboration with the Radiation Health Unit (RHU) of the Department of Health (DH) and the HKU. In the survey, the gamma absorbed dose rate in air was measured in open field, on street level and indoor. The activity concentrations of natural radionuclides in soil were also assayed. HKO was responsible for the outdoor and street level measurements while RHU was responsible for the indoor measurement. HKU was commissioned to assist in the indoor measurement and carry out soil sample measurement.

1.4 The Report

This report gives a detailed account of the study. It describes the strategy, the measurement and the methods used in the radiological survey. It then explains the data compilation and computation to obtain radiation levels representative of Hong Kong.

Chapter 2

Survey Strategy and Criteria

2.1 The Grid

In this survey, the territory of Hong Kong is divided into 42 grid boxes of 5 km x 5 km for open field areas and 61 grid boxes of 2.5 km x 2.5 km for built-up areas according to the population and land use. A map of Hong Kong with the grid boxes and the population distribution is shown in Figure 2. The choice of grid is in line with the practice of similar surveys in the mainland (He et al. 1992). In each grid box, measurements are taken at locations near the centre of the grid box as far as possible. Measurement locations in adjacent grid boxes are separated by at least half of the grid length. Measurement locations are carefully chosen so that the environmental radiation levels are not affected by industrial activities, e.g. electricity power stations, refuse sites, etc.

2.2 Outdoor and Street Level Measurements

Sampling locations must be representative of the environment to be measured. In Hong Kong, the total built-up area is much smaller than the open field areas. In this survey, similar to usual practice in other places of the world, outdoor gamma absorbed dose rates in air are measured in open field areas with underlying surface not affected by human activities, e.g. presence of concrete. The measurement locations are at distances of at least 50 metres from nearest buildings.

As most of the population in Hong Kong is crowded in heavily built-up areas with concrete high-rises closely packed on both sides by busy streets, gamma absorbed dose rates in air are also measured at street level in built-up areas for comparison purposes. Considering the fast moving traffic and that few people stay in the middle of the street for long, street measurements are made at the curbside of pavements at a distance of at least 1 metre from buildings instead of at the middle of the street. A map showing the locations of outdoor and street level measurements is attached as Figure 3.

2.3 Indoor Measurements

As the population stays indoor most of the time, indoor gamma absorbed dose rate in air was studied in order to assess the effective dose received by the public. The HKU conducted a series of surveys on terrestrial gamma radiation dose in 1987 (Tso et al. 1992) as well as on indoor radon and radon progeny in high-rise buildings in 1993 (Leung et al. 1998). With the results of these surveys on hand, indoor gamma absorbed dose rate in air was only measured at those grid boxes in built-up areas not covered by previous surveys. In similar surveys in the mainland, indoor measurements were made in rooms of 15 to 20 square metres (He et al. 1992). However, most dwellings in Hong Kong are very small and rooms of the above sizes are rare. Studies by HKU on stratifying existing data revealed no significant correlation between the indoor absorbed dose rate and the size of the rooms (private communication). Therefore, small rooms are also sampled in the present survey. The area of rooms sampled in the current study ranges from 7 to 20 square metres. Indoor measurements are made at the centre of the rooms and at distances of at least 1 metre from the side walls.

2.4 Soil Sampling

Activity concentrations of K-40, U-238, Ra-226 and Th-232 are assayed in 20 samples obtained from soil representative of the geology of the open fields in the 5 km grid.

Chapter 3

Measurement and Method

3.1 Outdoor and Street Level Gamma Absorbed Dose Rates in Air

In the survey, the portable HPIC (Reuter-Stokes Model RSS-112) was used to measure outdoor and street level gamma absorbed dose rates in air. The ionisation chamber of the HPIC is spherical with a diameter of 25.4 cm and is filled with 25 atmospheres (absolute) of ultra-high purity Argon. The HPIC was mounted with its centre at 1 metre above ground. At each measurement location, data were acquired for a continuous period of 30 minutes. The total uncertainty in this measurement was estimated to be about 5%.

The RMN uses the Reuter-Stokes Model RSS-1013 HPIC Environmental Radiation Monitoring Station to measure outdoor gamma absorbed dose rates in air. The sensor of this HPIC is identical to the one of the portable HPIC. Readings are telemetered every minute back to the HKO Headquarters and archived.

3.2 Indoor Gamma Absorbed Dose Rate in Air

Thermoluminescent dosimeter (TLD) (Harshaw Type 8807 Environmental Dosimeter) was used to measure the indoor accumulated gamma absorbed dose in air in dwellings over a period of approximately two months. Each TLD badge was composed of two dysprosium-doped calcium floride ($CaF2:Dy$) elements and two magnesium and titanium-doped lithium floride (LiF: Mg, Ti) elements. The RHU prepared the TLDs for deployment and subsequently read the recorded gamma absorbed doses in air after exposure.

HKU researchers placed a bundle of two TLD badges at each dwelling within the selected grids in late December 1998 to measure the indoor accumulated gamma absorbed dose in air. The TLD bundle was hung approximately 0.5 metre from the ceiling near the middle of a room. By the end of February, the TLD bundles were collected. Thus, the exposure periods were slightly less than two months. The TLDs were returned immediately to the RHU for readout.

Since the TLD badges were taken from RHU to the HKU and they might not be deployed immediately to the measurement locations, the accumulated gamma absorbed doses in air measured by them were corrected for exposure during transit and the “waiting” period.

3.3 Radionuclide contents in Soil Samples

In the ERMP of the HKO, samples representative of the atmospheric, aquatic and foodchain pathways are collected for detailed radiological analysis. Twenty soil samples from the collection were used for the present study. The samples were selected to be representative in terms of geological and spatial distributions of Hong Kong. The locations of collection of the twenty soil samples are shown in Figure 4.

The samples were dried, ground and sifted to make sure that the grain size was sufficiently small. Grain sizes of all soil samples were checked with a laser particle sizer and confirmed that they were less than 10 μm in diameter. A typical size spectrum is shown in Figure 5. The soil samples were baked dry and filled in 2-litre Marinelli beakers to a volume of 1.6 litre. They were weighed and then sealed for 4 weeks for equilibrium of Ra-226 and Rn-222.

The activity concentrations of K-40, U-238, Ra-226 and Th-232 in the soil samples were assayed by the HKU using gamma spectrometry techniques. A n-type High Purity Germanium Detector (Canberra Model 2002) with 60% relative efficiency was used and all samples were counted for 7 hours. The background was determined by putting an empty Marinelli beaker to the detector and counted for 47 hours. Activity concentrations of Th-234, Pb-214, Bi-214, Ac-228, Pb-212, Bi-212, Tl-208 and K-40 were first measured. The results were then used to compute the activity concentrations of K-40, U-238, Ra-226 and Th-232 with the following assumption:

(i) U-238 was in equilibrium with Th-234,
(ii) Th-232 was in equilibrium with Ac-228, and
(iii) Ra-226 was in equilibrium with Rn-222 and its progeny (Pb-214 and Bi-214).

Chapter 4

Cosmic Contribution

The environmental radiation field is a combination of terrestrial gamma radiation (natural and man-made) and cosmic radiation from space. The cosmic component must be subtracted in order to estimate the net total absorbed dose rate due to terrestrial radiation.

4.1 Outdoor Cosmic Radiation

Estimation of the outdoor cosmic contribution should be made at locations having a low terrestrial component. Following the study by Tsui et al. (1991), the cosmic contribution was determined by the gamma absorbed dose rates in air measured over two large fresh water reservoirs, subtracting the contribution to the total gamma absorbed dose rate in air from other factors.

Outdoor cosmic component was measured at the centre of High Island Reservoir and Plover Cove Reservoir. The HKO took the actual measurements with the assistance from Water Supplies Department on four occasions in the same period of this survey. On each occasion, the actual measurement continued for one hour with the HPIC mounted with its centre one metre above the deck of a fiber glass boat in the reservoir. The boat was at least 1,000 metres from shore and the depths of the water at the locations were about 60 metres so that the contribution from other factors was small. These other factors are the gamma absorbed dose rate due to air and water, K-40 in human bodies and the internal background of the ionization chamber. Their total value is estimated to be 0.004 μGy/h (Tsui et al. 1991). The average outdoor gamma absorbed dose rate in air as measured by the HPIC was 0.043 μGy/h so that the cosmic contribution was about 0.039 μGy/h.

4.2 Indoor Cosmic Radiation

In their previous studies, HKU researchers (Tso et al. 1992 and Leung et al. 1998) used an average transmission factor of 0.7 to determine the indoor cosmic contribution. In this study, both the data in this survey and those obtained by Leung et al. (1998) were compiled together. For the sake of consistency, the same transmission factor will be used in this report to estimate the indoor cosmic absorbed dose rate in air. Using the outdoor cosmic contribution of 0.039 μGy/h obtained in the last section, the indoor cosmic absorbed dose rate in air is estimated to be 0.027 μGy/h.

Chapter 5

Results and Discussion

5.1 Environmental Gamma Absorbed Dose Rate in Air

In total, 152 additional measurements (37 in open field, 61 on street and 54 indoor) on environmental gamma absorbed dose rates in air have been made in the territory-wide radiological survey. Five of the ten RMN stations stand in the open field areas of this survey, namely Kat O, Ping Chau, Sha Tau Kok, Tap Mun and Tsim Bei Tsui. The relevant survey results were compiled together with available data from the five RMN stations above (a total of 42 sites) to give a representative picture of the outdoor gamma absorbed dose rate in air in the territory. After cosmic correction, grid point values of outdoor gamma absorbed dose rate in air in the study period range from 0.053 to 0.127 μGy/h with an average of 0.090 μGy/h.

Seasonal variation of gamma absorbed dose rate in air is significant as exemplified by the monthly mean of that recorded at the five RMN stations under reference from 1992 to 1998 (Figure 6). Since the survey was carried out in the winter months of January and February, the results must be adjusted for seasonal variation to obtain the mean annual level. Using RMN station data from 1992 to 1998 (Royal Observatory 1993 to 1997, Hong Kong Observatory 1998, Hong Kong Observatory 1998 (a-l) and Hong Kong Observatory 1999), the average environmental gamma absorbed dose rate in air of January and February is 1.03 times of the annual figure. Since lower measurement values are expected to be obtained if the survey was carried out all through the year, outdoor gamma absorbed dose rate in air should be adjusted downwards appropriately. After seasonal correction, outdoor gamma absorbed dose rates in air (Df) ranges from 0.051 to 0.123 μGy/h with an average of 0.087 μGy/h. The value is comparable to those of neighbouring cities in Guangdong (Tan et al. 1995). The frequency distributions of Df is shown in Figure 7.

The values of Df are in general higher on the southwestern part of the territory, especially over Lantau Island. The higher values are due to the effect of the underlying geological formation at the measurement locations. This can be visualized more easily when the values of Df are compared on a geological map (Figure 8).

After cosmic correction and similar adjustment for seasonal variation, the values of gamma absorbed dose rates in air at street level (Ds) range from 0.135 to 0.229 μGy/h with an average of 0.179 μGy/h. The average value of the ratio of Ds to Df is 2.06. The average value of Ds in the survey was relatively high. The geometry of the surrounding buildings and the construction materials used at measurement locations contribute significantly to the high Ds levels. Further studies will be needed on the issue. The frequency distribution of Ds is shown in Figure 9. The spatial distribution of both Df and Ds are shown in Figure 10.

The indoor gamma absorbed dose rates in air obtained in the survey (at 54 sites) were compiled together with the previous survey data measured year-round at 664 sites by HKU (Leung et al. 1998). After cosmic correction, the mean indoor gamma absorbed dose rate in air of the present survey is 0.182 μGy/h, approximately 10% lower than that (0.200 μGy/h) of the HKU. For each grid, data from the two surveys were combined and averaged to give a grid point value of indoor gamma absorbed dose rates in air (Din). Din ranges from 0.141 to 0.267 μGy/h with an average of 0.199 μGy/h. The frequency distribution of Din is shown in Figure 11. The spatial distribution of Din over the territory is shown as Figure 12. Area weighted average and population weighted average for Din are 0.200 μGy/h and 0.200 μGy/h respectively. The average value of the ratio of Din to Df is 2.29.

The relatively high values of Din may again be attributed to the fact that most buildings in Hong Kong are built in concrete and closely packed together. Areas of individual apartments inside the building are very small. However, whether the radioactivity contents in the building material or the geometry (i.e. influence of adjacent buildings) is the more significant factor for the high value of the Din has yet to be determined.

Adopting the conversion factors of 0.7 Sv/Gy and 1 Sv/Gy for terrestrial gamma radiation and cosmic radiation respectively, and an outdoor occupancy factor of 0.2 as recommended by UNSCEAR (1993), the overall annual effective dose from outdoor and indoor terrestrial gamma radiation are 0.11 mSv and 0.98 mSv respectively. The effective doses due to cosmic ray for outdoor and indoor are calculated to be 0.07 mSv and 0.19 mSv respectively.

5.2 Radionuclide contents in Soil Samples

The activity concentrations of K-40, U-238, Ra-226 and Th-232 in 20 soil samples (dry samples) are given in Table 1 below. Area weighted average values of the contents of K-40, U-238, Ra-226, and Th-232 in soil are comparable to those reported in the study by Yu et al. (1992). The Hong Kong values are also comparable to those for neighbouring cities in Guangdong (Zeng et al. 1995).

Grid Reference	K-40 (Bq/kg)		U-238 (Bq/kg)		Ra-226 (Bq/kg)		Th-232 (Bq/kg)	
	Activity concentration	Standard deviation	Activity concentration	Standard deviation	Activity concentration	Standard deviation	Activity concentration	Standard deviation
1	276.7	2.6	159.2	9.0	87.2	0.9	125.9	2.0
6	1242.5	5.1	145.9	10.9	119.6	1.2	195.9	2.6
15	152.9	1.7	38.6	5.8	24.0	0.5	69.7	1.4
19	1327.2	5.2	133.1	10.9	99.3	1.1	219.2	2.8
22	1148.9	5.0	133.8	11.8	131.5	1.2	241.1	2.9
24	436.1	3.1	87.2	8.0	62.0	0.8	102.9	1.9
27	563.5	3.2	94.6	7.0	65.0	0.8	67.0	1.5
30	98.7	1.3	30.6	4.2	28.0	0.4	19.6	0.8
46	852.0	4.1	98.8	7.6	69.9	0.8	88.9	1.8
46	671.8	3.9	95.6	9.0	80.7	1.0	126.2	2.2
61	558.0	3.8	162.4	9.4	120.7	1.1	118.1	2.1
81	1336.2	5.0	110.1	8.7	67.4	0.9	119.1	2.0
88	310.1	2.6	95.1	7.3	58.2	0.8	76.4	1.7
95	237.0	2.4	109.5	8.5	75.9	0.9	116.3	2.0
96	546.1	3.8	73.4	8.8	29.5	0.8	107.7	2.2
100	223.7	2.4	92.4	8.1	63.8	0.8	100.2	1.9
101	643.8	3.6	112.9	8.2	62.2	0.8	105.8	2.0
102	782.7	4.1	108.7	8.6	57.4	0.8	119.8	2.0
103	432.0	3.1	57.0	5.9	39.8	0.6	49.9	1.4
-	1226.1	5.1	126.4	10.2	94.8	1.1	166.3	2.5
Average	653		103		72		117	
Maximum	1336		162		132		241	
Minimum	99		31		24		20	

Table 1. Activity concentrations of K-40, U-238, Ra-226 and Th-232 in 20 soil samples

5.3 Summary

The findings of the present study on the environmental radiation levels in Hong Kong are summarized in Table 2 below.

Outdoor field gamma absorbed dose rate in air (Df)		Street level gamma absorbed dose rate in air (Ds)			Indoor gamma absorbed dose rate in air (Din)		
Year of Survey	1999	Year of Survey	1999		Year of Survey	1993 and 1999	
Number of measurement locations	42	Number of measurement locations	61		Number of measurement locations	718	
Average (μGy/h)	**Range (μGy/h)**	**Average (μGy/h)**	**Range (μGy/h)**	**Ds/Df**	**Average (μGy/h)**	**Range (μGy/h)**	**Din/Df**
0.087	0.051-0.123	0.179	0.135-0.229	2.06	0.199	0.141-0.267	2.29

Table 2 : Summary on the study of environmental gamma air absorbed dose rate in Hong Kong 1999

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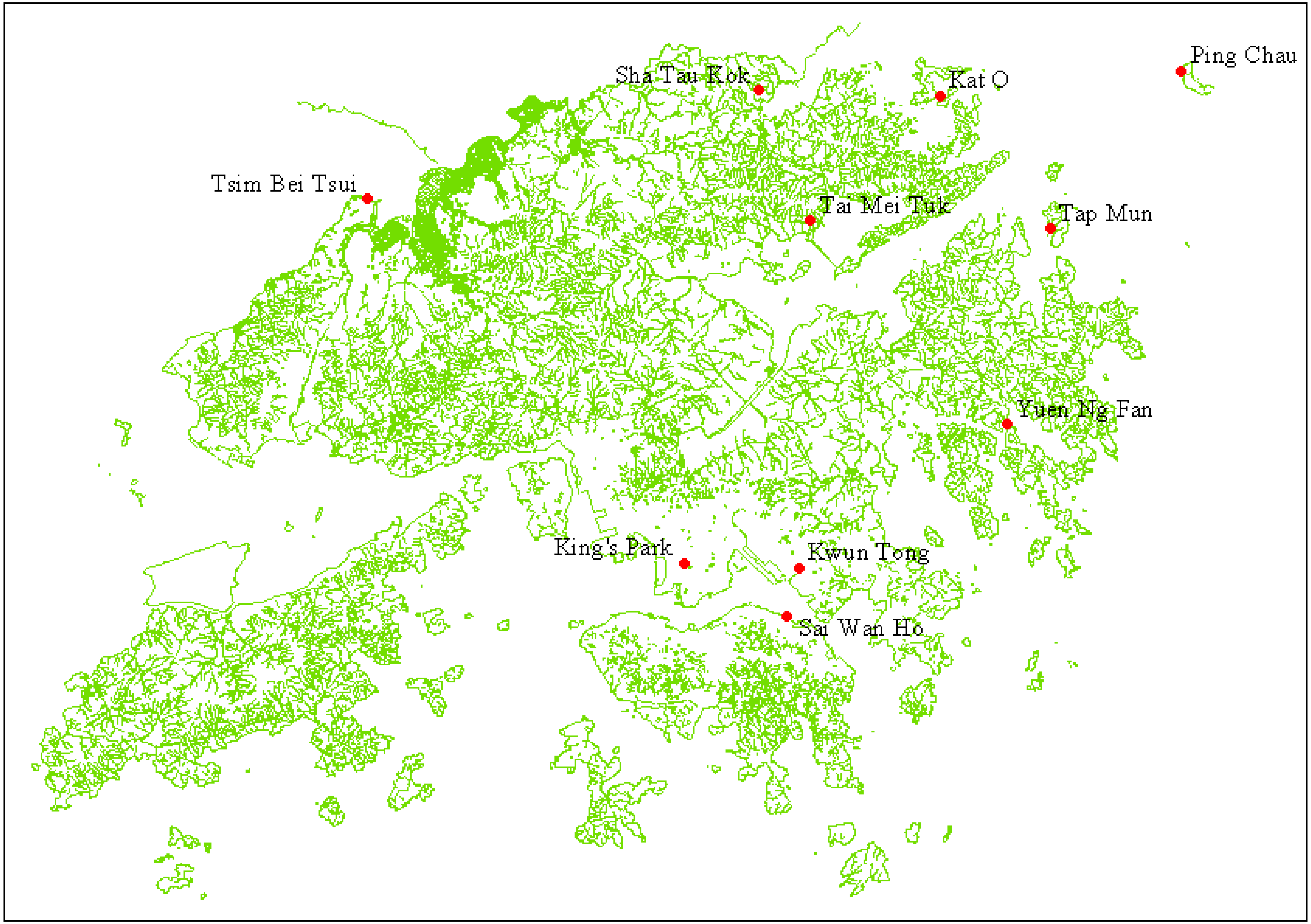

Figure 1. A map showing the locations of the Radiation Monitoring Network Stations

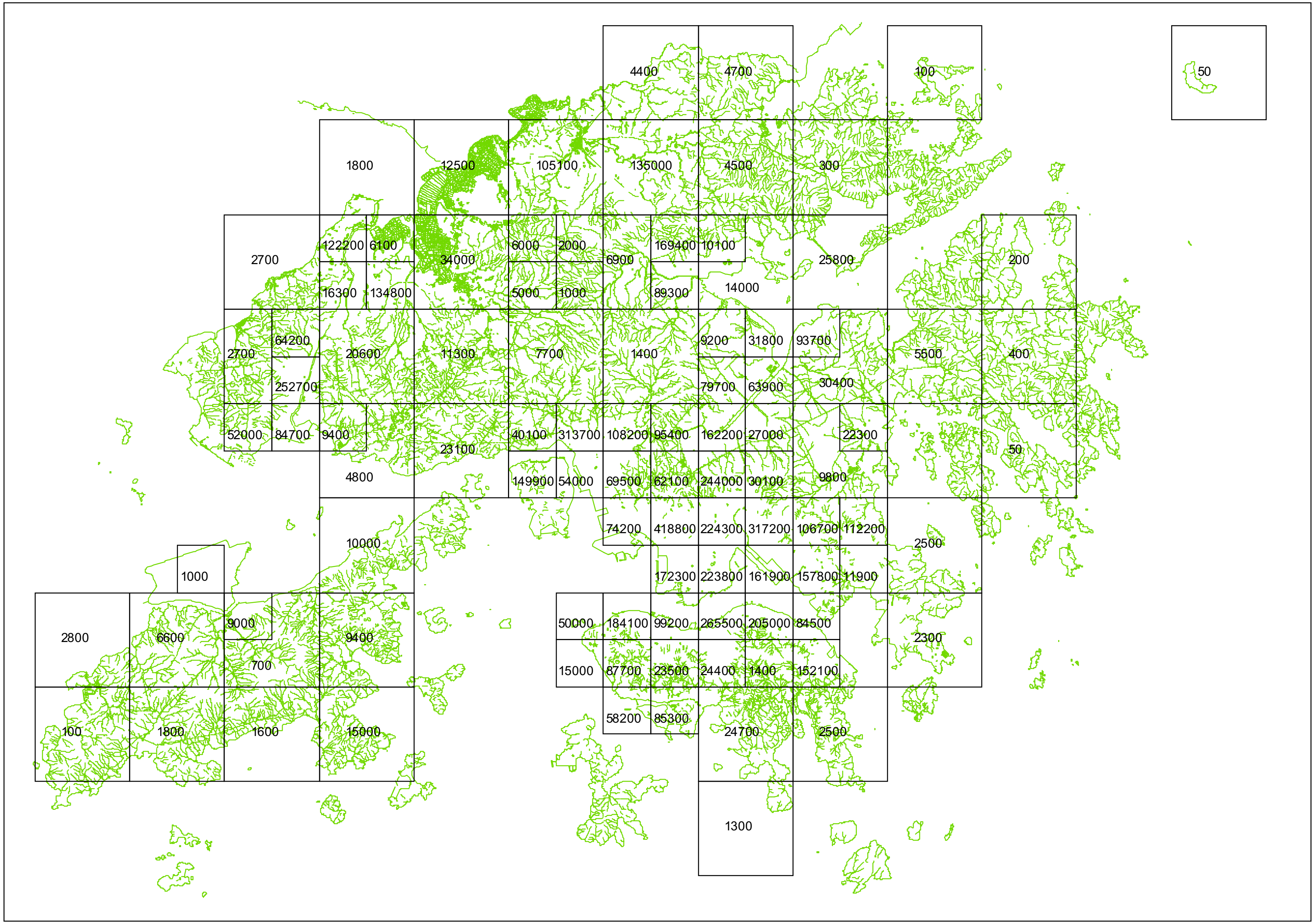

Figure 2. A map showing the grid boxes of the territory-wide radiological survey and the population distribution in Hong Kong

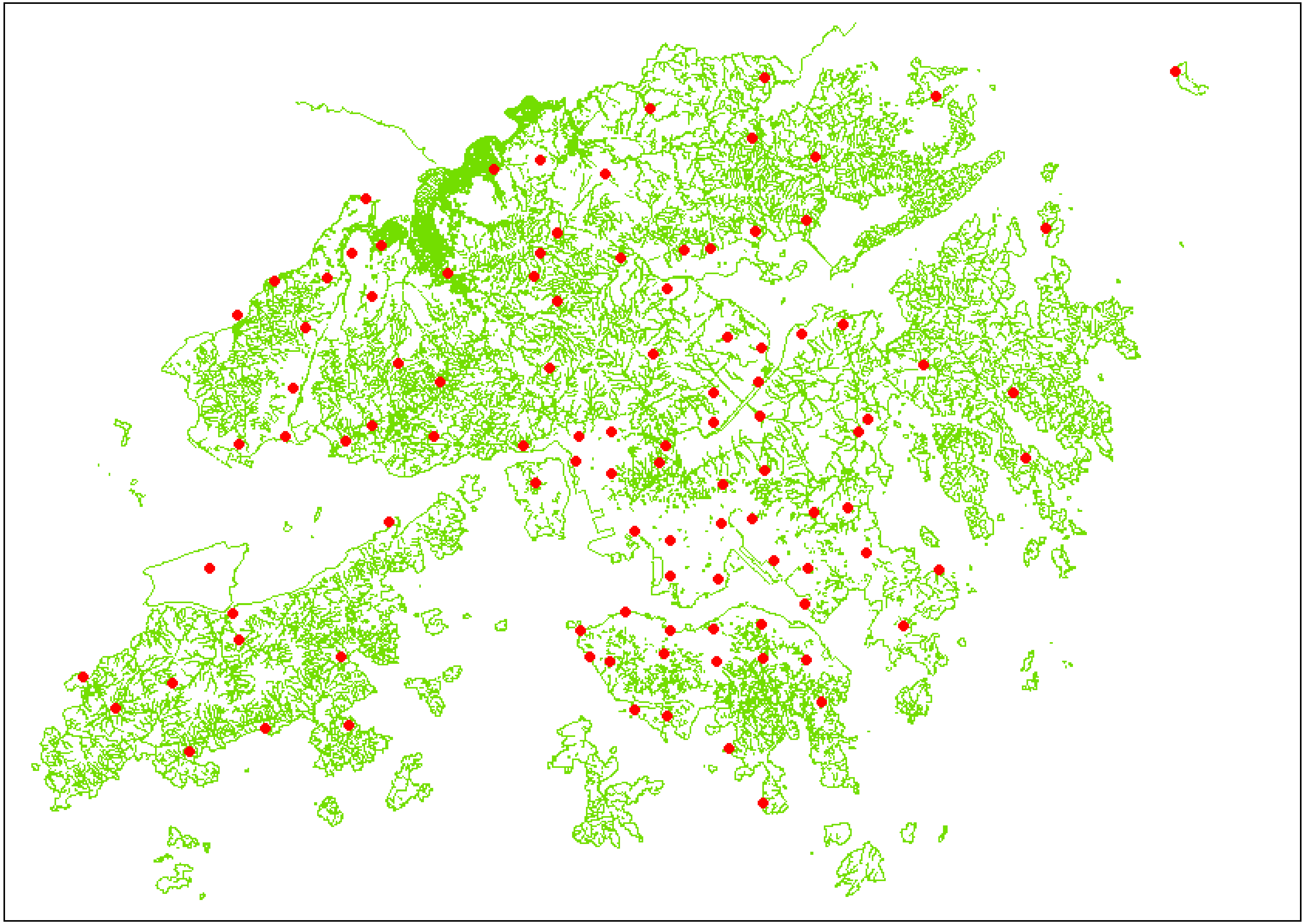

Figure 3. A map showing the measurement locations of outdoor and street level gamma absorbed dose rates in air in Hong Kong

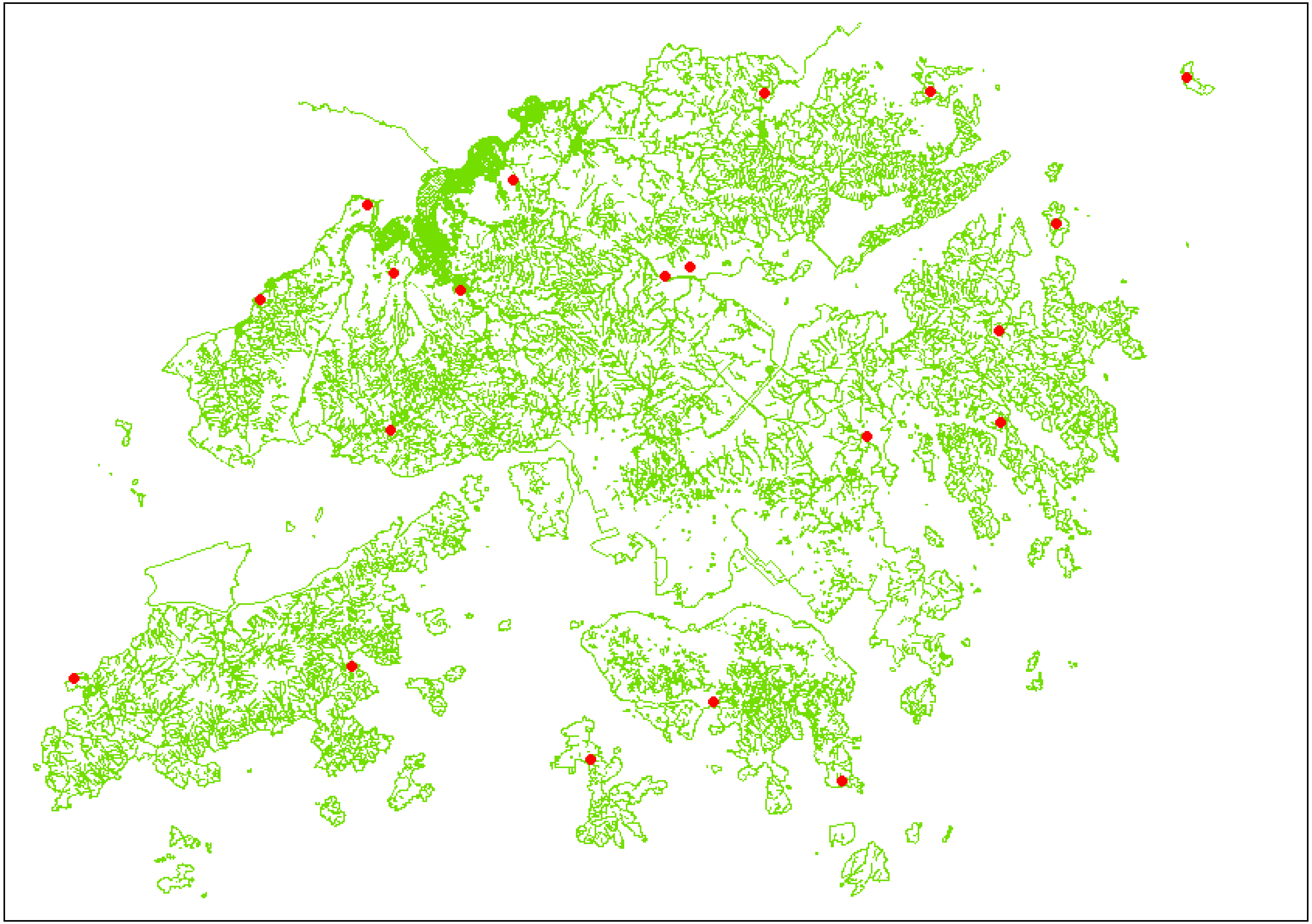

Figure 4. A map showing the collection locations of the 20 soil samples in Hong Kong

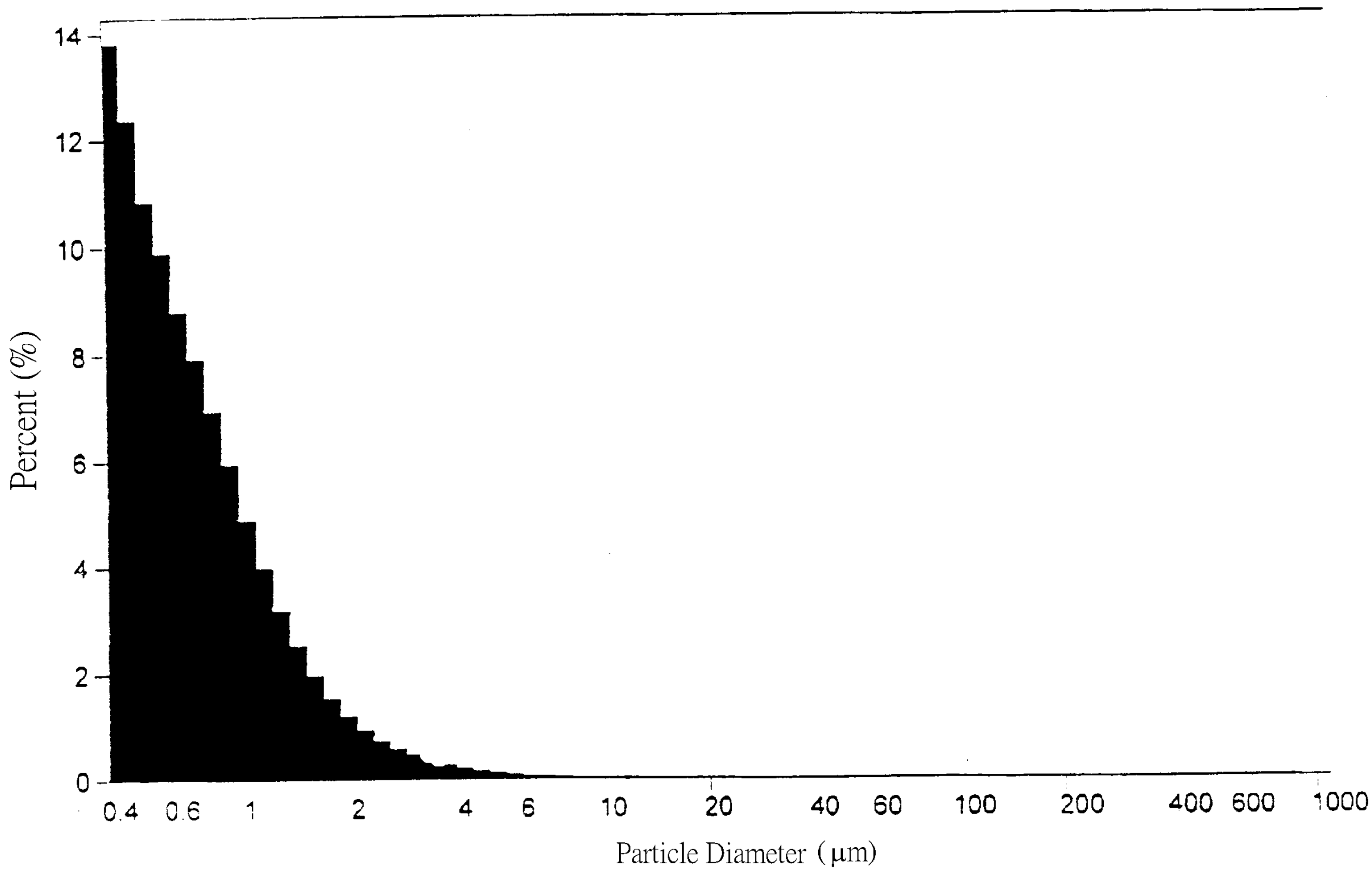

Figure 5. A typical size spectrum of soil samples

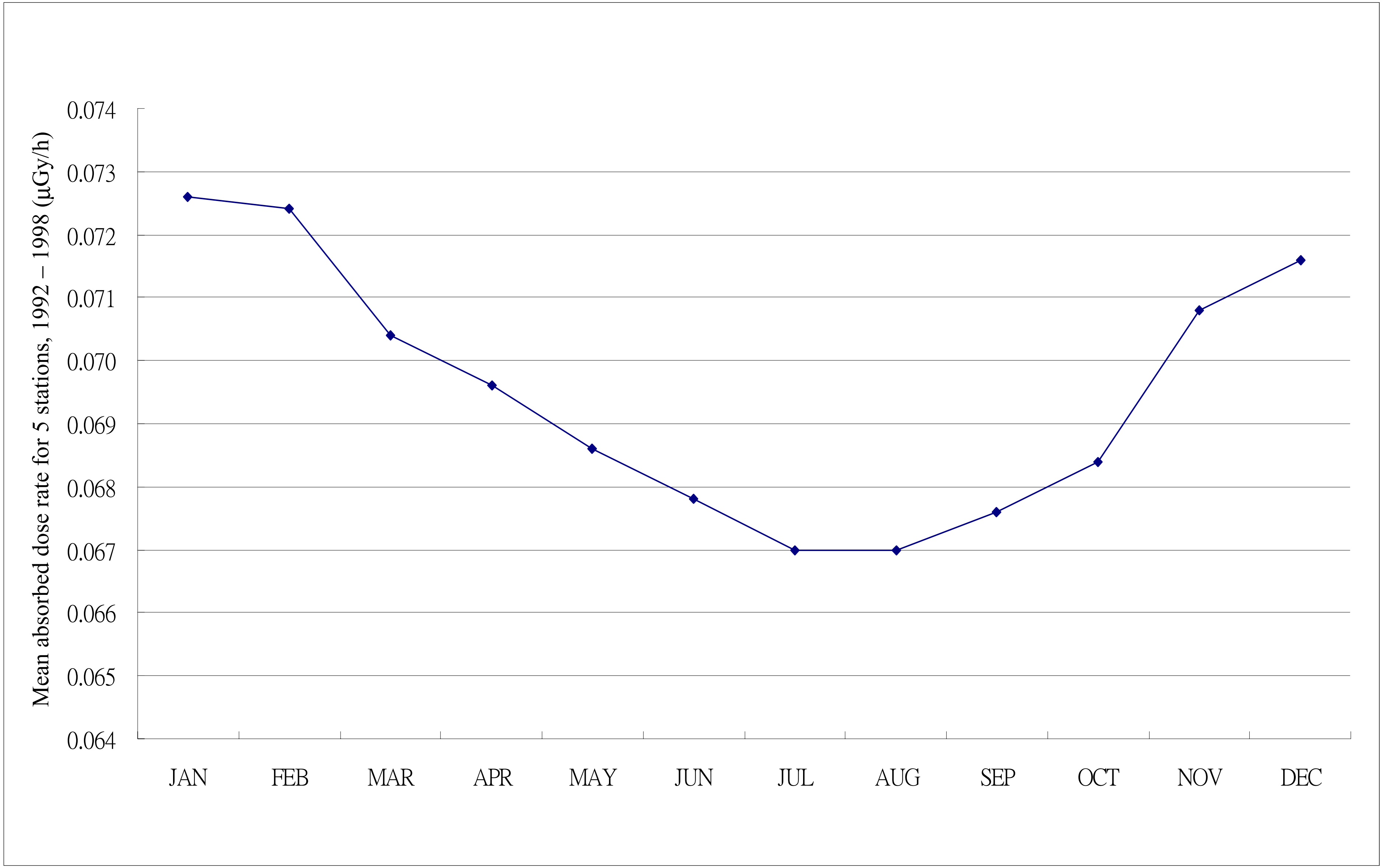

Figure 6. Seasonal variation of outdoor gamma absorbed dose rate in air in Hong Kong

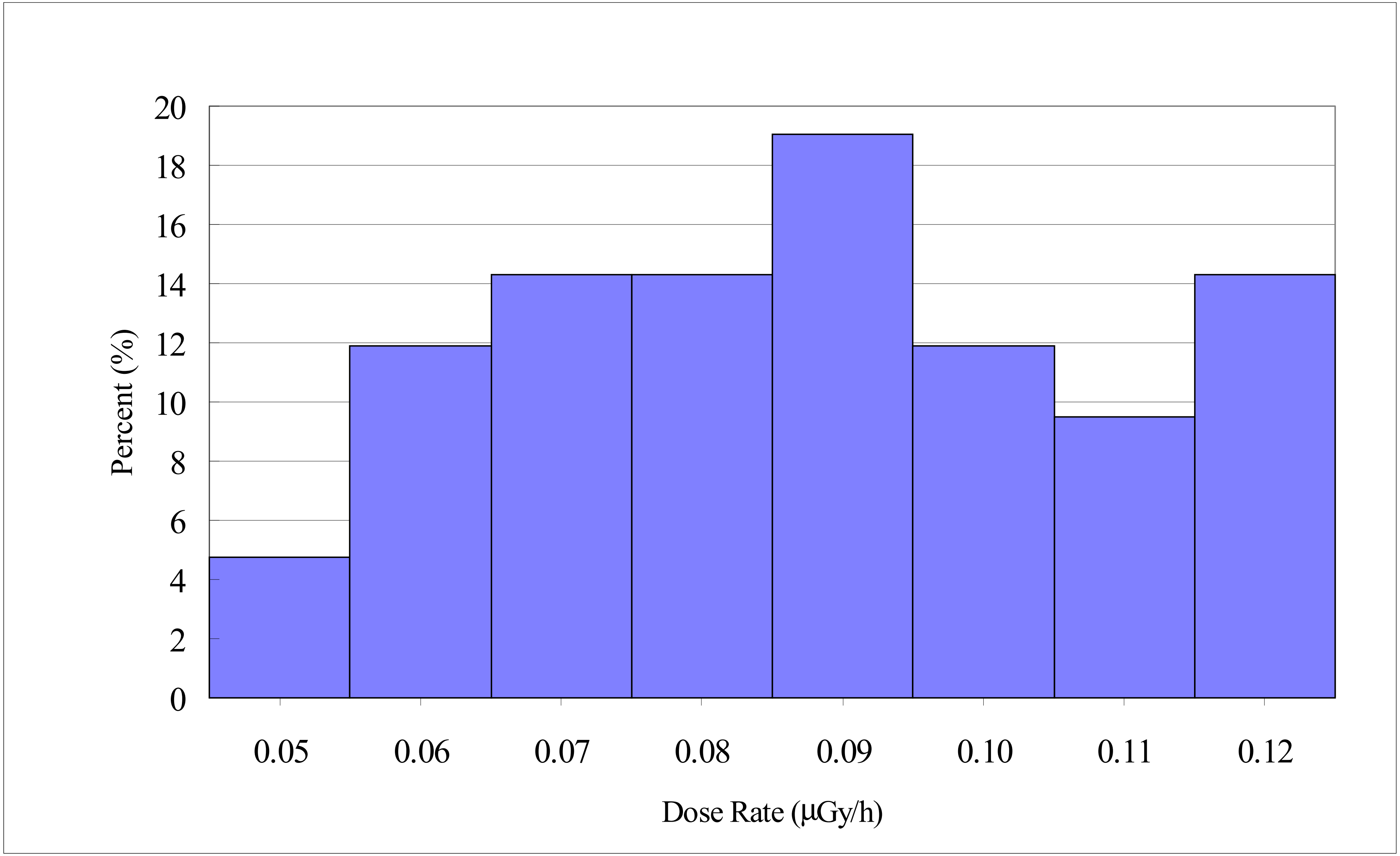

Figure 7. Frequency distribution of outdoor gamma absorbed dose rate in air in Hong Kong

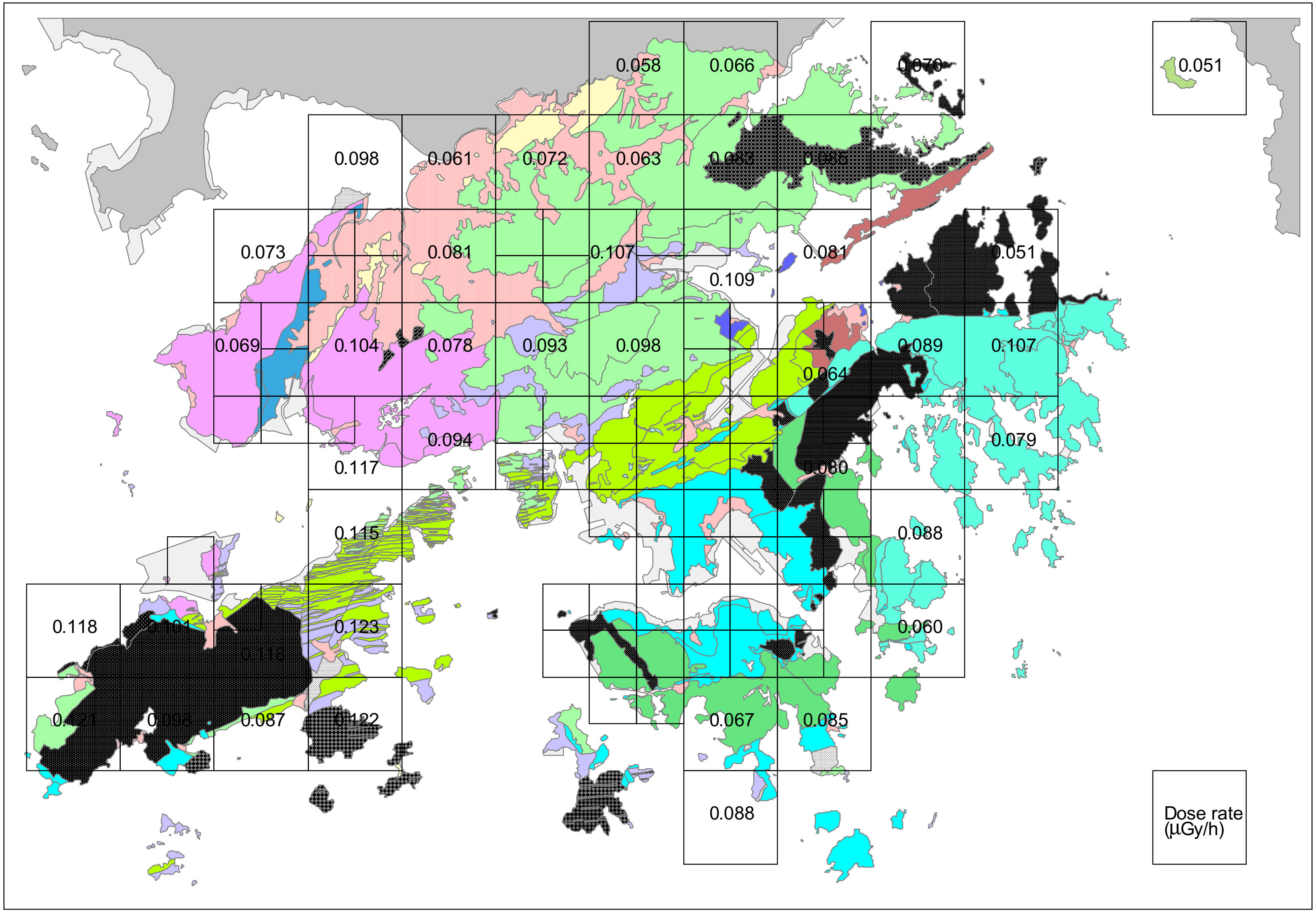

Figure 8a. Spatial distribution of outdoor gamma absorbed dose rate in air and geological formation in Hong Kong

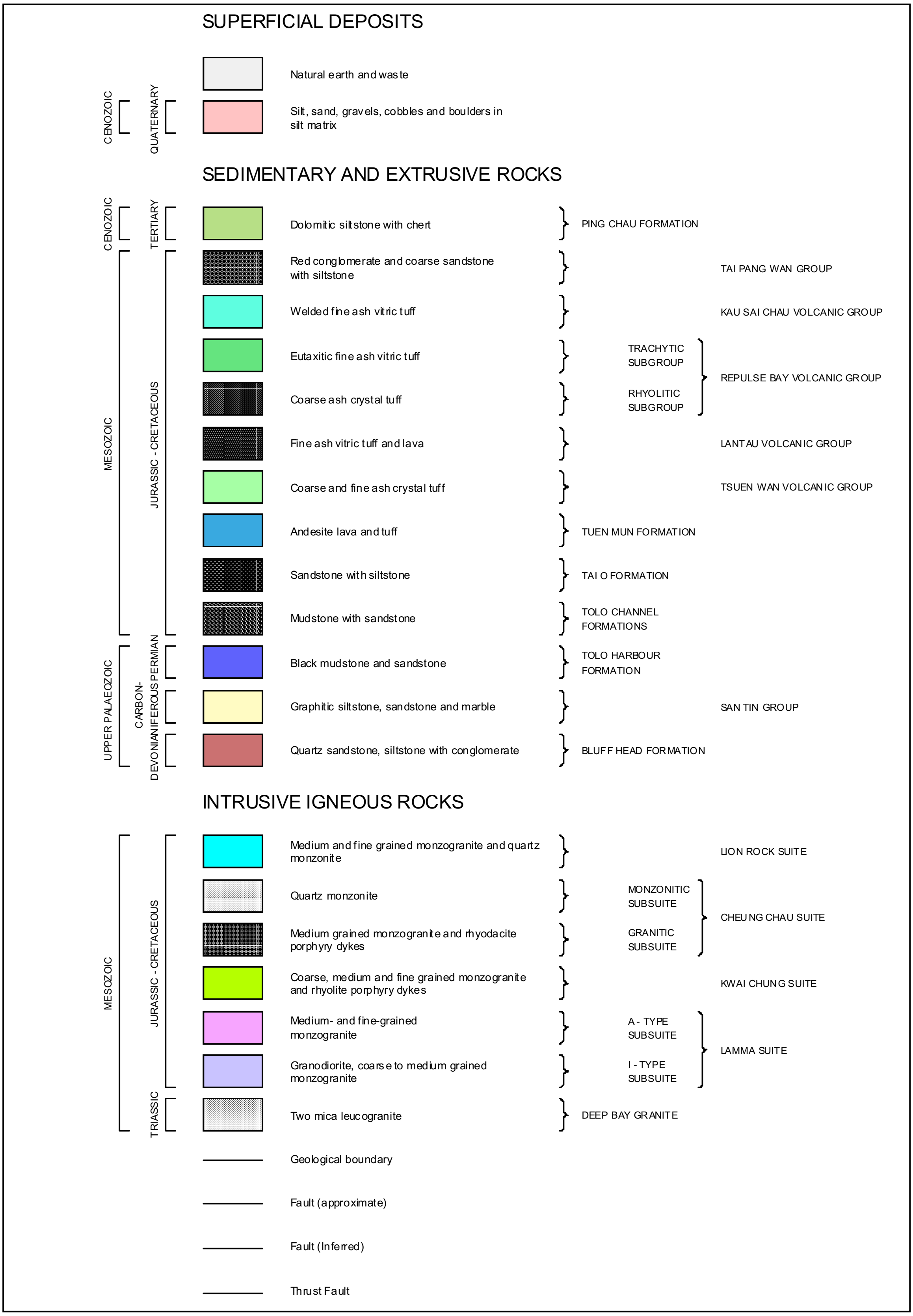

Figure 8b. Legend for geological formation in Hong Kong (Figure 8a)

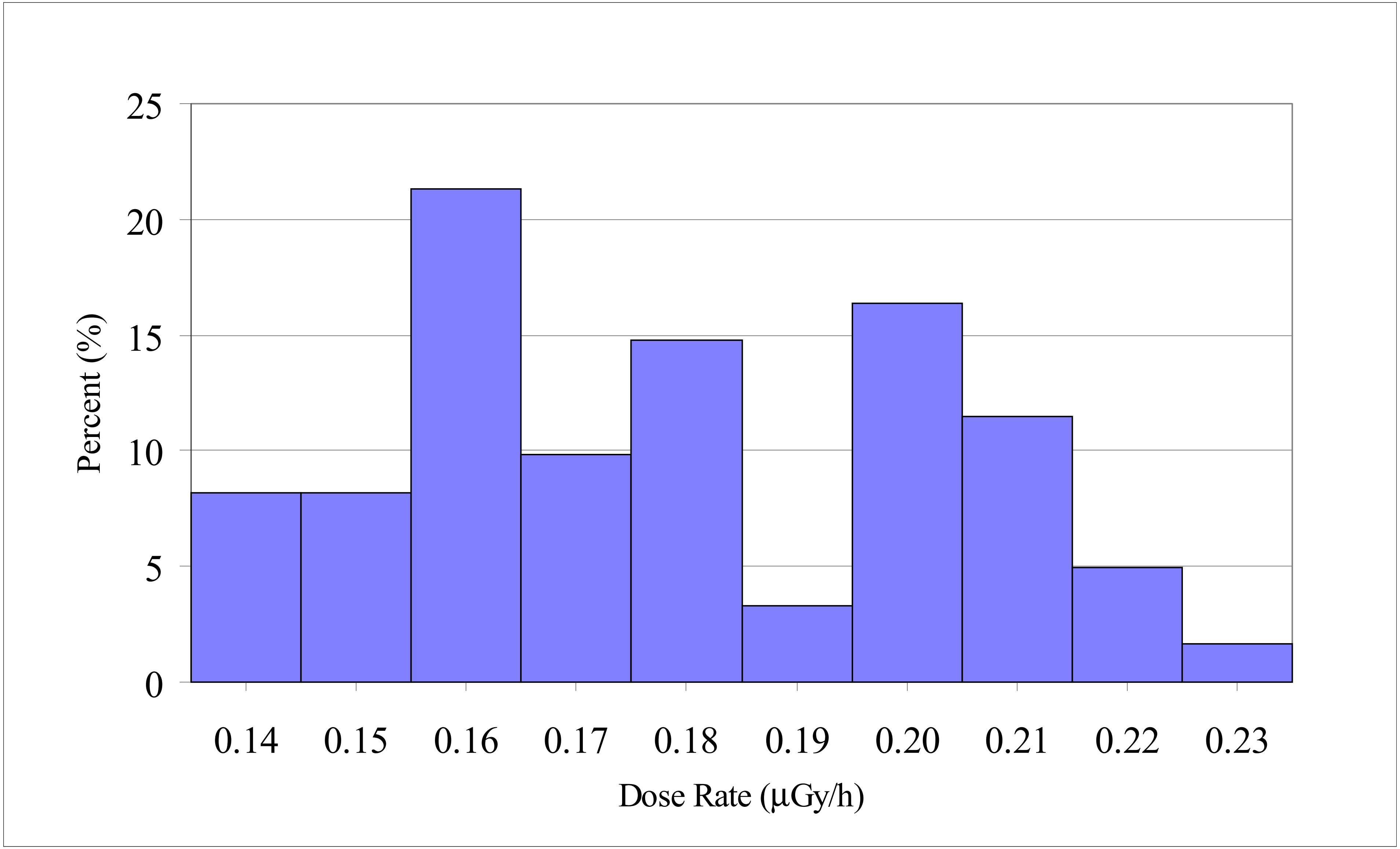

Figure 9. Frequency distribution of street level gamma absorbed dose rate in air in Hong Kong

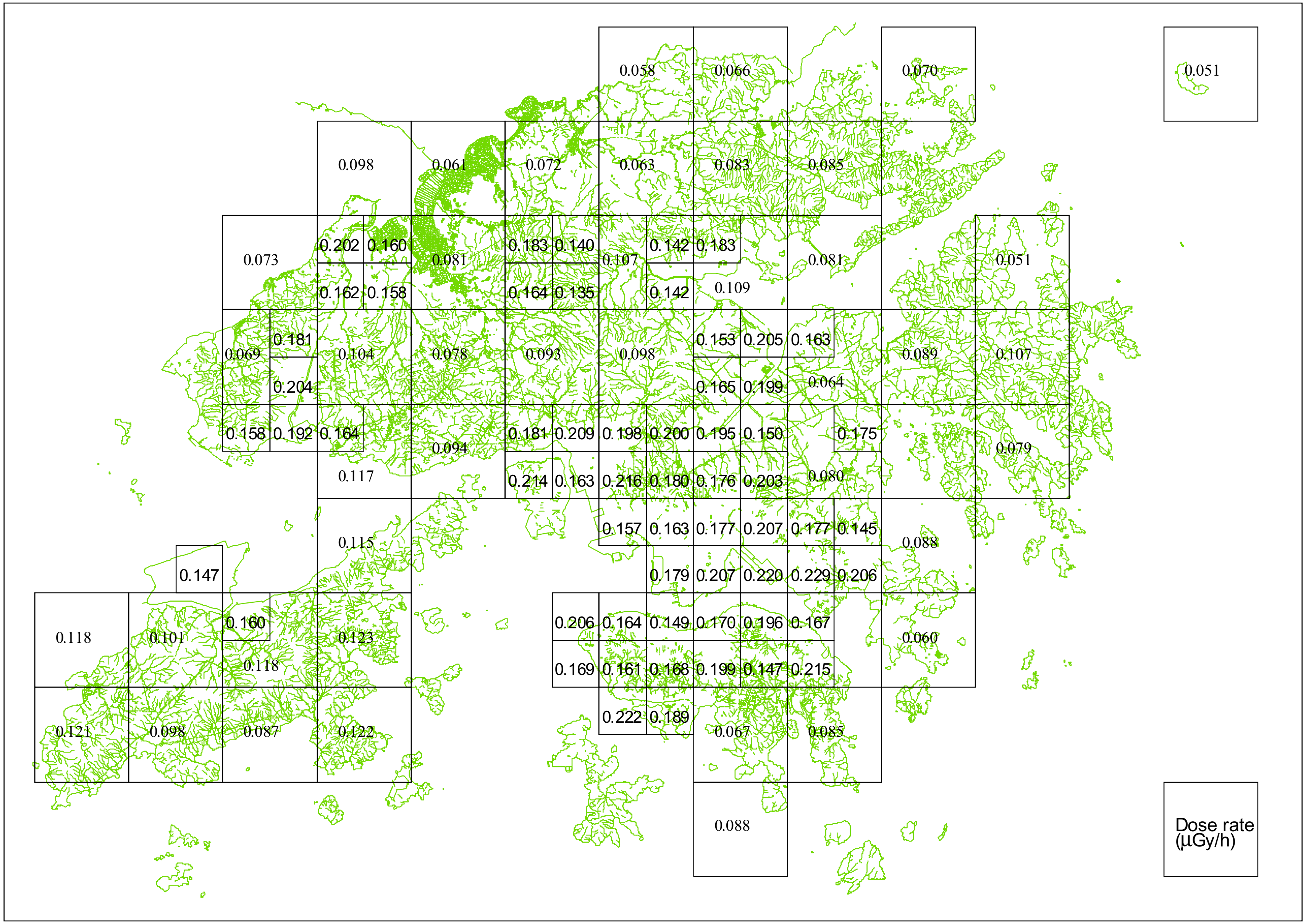

Figure 10. Spatial distribution of outdoor and street level gamma absorbed dose rates in air in Hong Kong

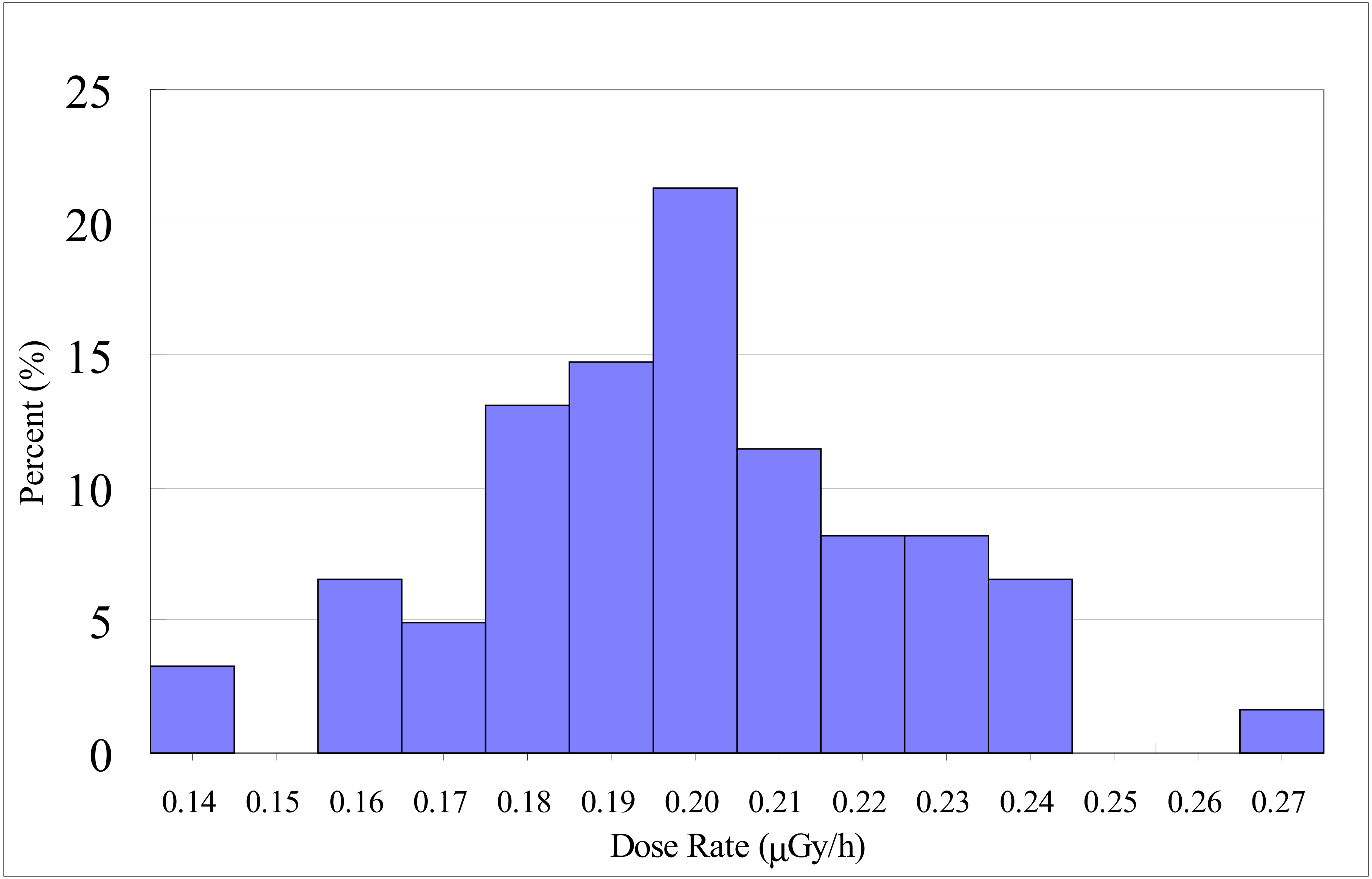

Figure 11. Frequency distribution of indoor gamma absorbed dose rate in air in Hong Kong

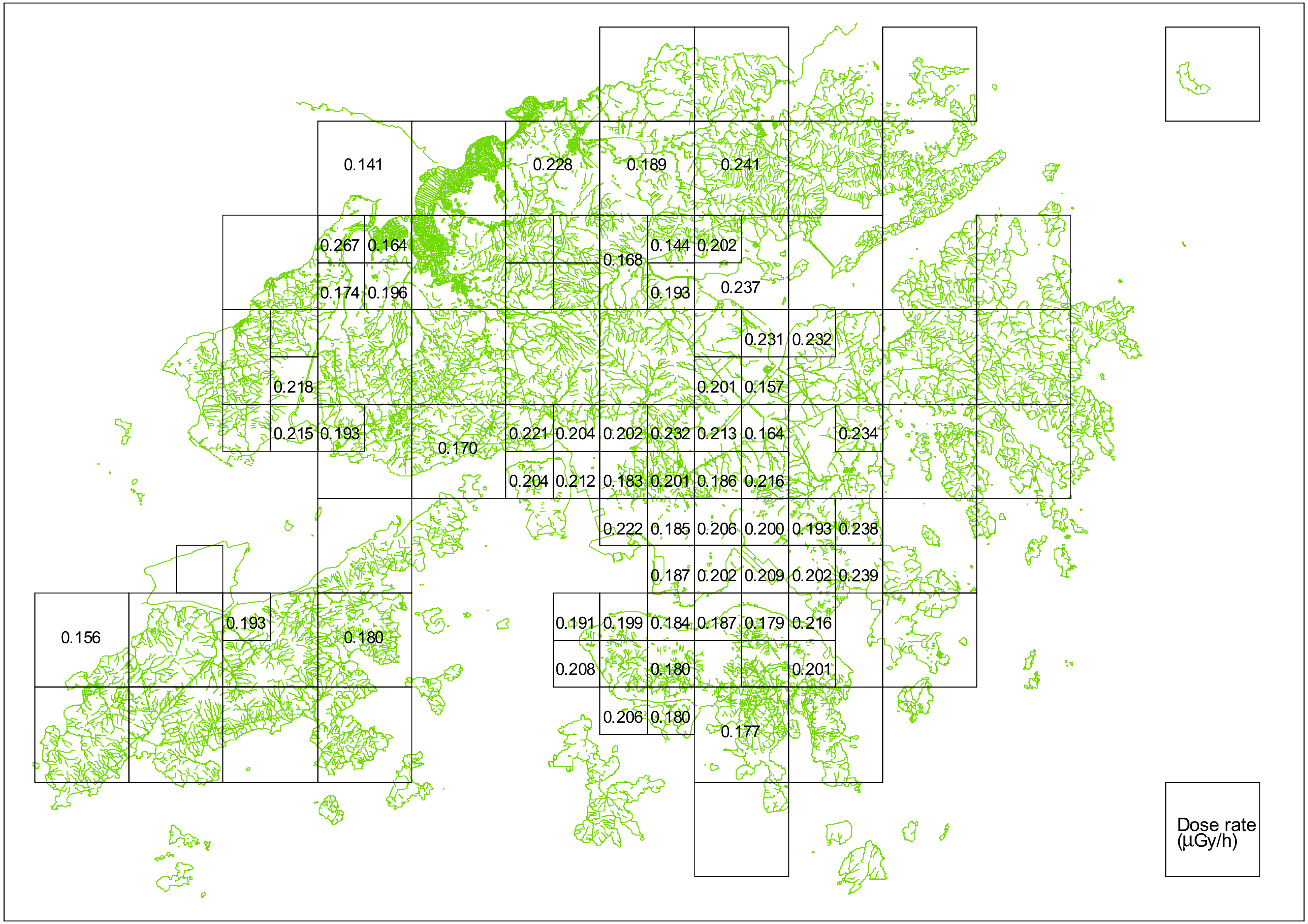

Figure 12. Spatial distribution of indoor gamma absorbed dose rate in air in Hong Kong