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Human impacts on the terrestrial ecosystem of Fildes Peninsula of King George Island, Antarctica

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Abstract: Antarctic environment has valuable baseline information for understanding the global change. The objectives of this study were to investigate the impacts of human activities on Antarctic terrestrial ecosystem. Based on the investigation results and the sampling analysis of the environment of Fildes Peninsula, King George Island, Antarctica, it was shown that there are some artificial radioactive elements——^{137}Cs in Antarctic environment: the radioactivity of ^{137}Cs in the surface-soil, the surface-moss, the fruticose lichen and the crustaceous lichen are 6.00—14.80, 25.07, 29.04 and 58.07 Bq/kg separately; i.e. the sequence of ^{137}Cs specific activity is as follows: crustaceous lichen > fruticose lichen > surface-moss > surface-soil, which demonstrates that the crustaceous lichen is one of the most sensitive monitor ways for the effect of the long-term diffusion of ^{137}Cs. The impacts of the scientific research activities on the partial ecosystem of Fildes Peninsula include: the changes of the landscape and the soil material have made a strong freezing-thawing process, which decreases the stability of the ground surface, causes the degradation of the vegetation in the some small areas; some small lakes, runoff and lichens in middle areas of Fildes Peninsula have been affected by the wastes of the stations, in the surrounding areas of the expedition stations, the concentration of Cr, Cu, Ni, Pb and Zn in the lichen and the water are higher than that of the contrasting area. Fildes Peninsula is one of the most crowded areas of expedition stations, at some extent, the environment and terrestrial ecosystem have been affected by the human activities. The conservation of the environment and ecosystem should be an important aspect of Antarctic environmental sciences.

Key words: Antarctica; Fildes Peninsula; terrestrial ecosystem; human impacts

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Since the international geophysical year (IGY, 1957—1958), Antarctica has been the object of intensive scientific investigation by teams of scientists from many countries. According to the recent data, there are more than 70 stations from 20 countries in Antarctica, with a total population of 1100—3500 (May, 1989). Over the years, vast quantities of matter in the form of foodstuffs, dress materials, fuel, building-packaging material have been transported to Antarctica, and much of this has been abandoned, which has made some localized impacts on the Antarctic environment (Campbell, 1987). And so it has been an important aspect of modern Antarctic environmental science to monitor and assess these localized impacts.

The present native terrestrial flora of the Antarctic includes 2 angiosperms, 25 hepatics, 28 macrofungi, 85 mosses, and 350—400 species of lichens, together with many species of algae, and the terrestrial animal life of the Antarctic is dominated by the invertebrates, represented by several groups form protozoans to insects and mites (Bonner, 1985; Lamb, 1970). The Antarctic terrestrial ecosystem is particularly susceptible to damage caused by the presence of humans.

In recent years, around the scientific subject of the global change, an increasing number of scientists have been paying close attention to the background value of the Antarctic environment, the impacts of human activities on the Antarctic environment (May, 1989; Bonner, 1989). This paper is based on the results of environmental survey and analysis, shows that the impacts of human activities on the soils, flora and water of Fildes Peninsula.

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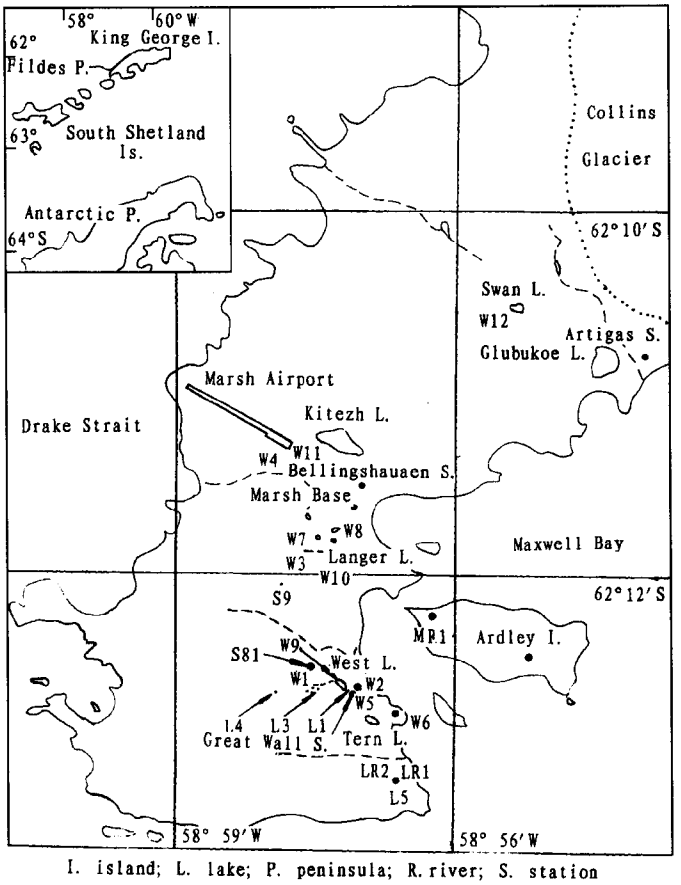
1 The background value

Fildes Peninisula is located at latitude 62°10′S—62°13′S, longitude 58°53′W—59°01′W, and has an area of about 38 km^2, as Fig.1. The whole peninsula almost consists of the laminar basaltic lava, volcaniclastic rock and volcanic sedimentary rock of Tertiary system. The peninsula is a hilly area at an elevation of less than 200m, there are two wavy platforms (i.e. 40—50 m and 110—120 m above sea level), but in the east coastal area there are 4—6 stages of sea terraces which are mostly covered with gravel and sands; the climate of the study area belongs to the subantarctic oceanic type, the annual average temperature is about −2.1℃, the annual average precipitation is about 630 mm, during one year there are 4 months in which the mean monthly temperature reaches 0℃ to 5℃. The temperature of the surface soils can reach more than 10℃ during summer, and so there are some strong freeze-thaw processes, permafrost occurs at depths of 40—70 cm in most soils. The component of plant community is simple, the dominant species are cryptograms bryophyta, lichens and algae. Bryophyta occur extensively in the wet habitat on flat or gently sloping ground where the freeze-thaw disturbances are relative weak, and the cover degree of Bryophyta may reach 100% in some favorable areas. Lichens occur extensively on the surface of bedrock and gravel, and the foliose lichens occur only on the bedrock in the coastal areas. Usnea



I. island; L. lake; P. peninsula; R. river; S. station

Fig.1 Sampling sites

and Usnea antarctica are the dominant species of fruticose lichens, Usnea communities are widely and extensively developed in the study area, but Usnea antarctica communities are mainly developed in the coastal area. In the coastal area there are some breeding sites of penguins and seals (Zhao, 1994).

There are 4 expedition stations in Fildes Peninsula (i. e. Bellingshausen Station (USSR), Marsh Base (Chile), Great Wall Station (China) and Artigas Station (Uruguay)), and there are more than 100 persons who annually maintain the stations.

2 Global impacts on the Antarctic environment

The radioactive isotopic elements——^{137}Cs (cesium-137) are the fallout product from atmospheric nuclear testing and the nuclear accidents, the radioactive half-life is 30.17a. On reaching the earth's surface, ^{137}Cs are rapidly and firmly adsorbed by the fine soil grain and the biota. Therefore, ^{137}Cs are one of the most important environmental tracers for monitoring the modern impacts of global human activities on the Antarctic ecosystem.

In February 1993, the fruticose lichen Usnea (LR_1), the crustaceous lichen (LR_2), the mosses (MR_1) and the soil profiles (S_9 and S_{81}) of Fildes Peninsula were collected, the location of the samples is shown in Fig.1. All samples were oven-dried and pulverized, then were weighed and kept with polyethylene bags in the laboratory of Great Wall Station. In the summer of 1994, two crustaceous lichen samples (LR_3 and LR_4) in northern China were collected, LR_3 is in Wuling Shan National Natural Protection Region, Hebei Province (40°34′N, 117°29′E, 1900 m a. s. l.), LR_4 is in Mianchi County, Henan Province (35°10′N, 111°52′E, 200 m a. s. l.). These samples were little affected by modern industry. The samples were measured by GEM series HPGe (high-Germanium) coaxial detector system (ADCAM-100, made by EC & G Ortec USA). The measuring time for each sample was 3.5×10^5 s, and the measuring results are shown in Table 1.

Table 1 Results of ^{137}Cs specific activity* of the terrestrial ecosystem in Fildes Peninsula

Samples/Depth	^{137}Cs activity, Bq/kg	Samples/Depth	^{137}Cs activity, Bq/kg
Soil S_9 0—4 cm	14.83±1.56	MR_1 moss 0—5 cm	25.07±2.14
Soil S_9 4—12 cm	<0.93	MR_1 moss 5—8 cm	<1.10
Soil S_9 12—26 cm	<0.93	LR_1 lichen Fr.	29.04±8.29
Soil S_{81} 0—5 cm	6.14±0.62	LR_2 lichen Cr.	58.07±14.52
Soil S_{81} 5—17 cm	<0.93	LR_3 lichen Cr. China	294.69±35.81
Soil S_{81} 17—26 cm	<0.93	LR_4 lichen Cr. China	311.78±25.14

* ^{137}Cs specific actively (Feb. 1993) was calculated with the radioactive half-life of 30.17a

It was shown there are some ^{137}Cs in the Antarctic terrestrial ecosystem, which coincides with the results of Pereira *et al.* (Pereira, 1988) and Baeza *et al.* (Baeza, 1994), and so human nuclear activities have made an effect on the ^{14}C level of the modern biota in Antarctica. From these results, the specific activity of crustaceous lichen is the strongest among these samples, i. e. the sequence of ^{137}Cs specific activity is as follows: crustaceous lichen > fruticose lichen > surface-moss > surface-soil. The best known features of crustaceous lichen are the very slow growth rate, considerable longevity and extraordinarily wide distribution, which make it has very strong absorption-enrichment of the airborne substances. Crustaceous lichen may therefore be widely used for monitoring the effect of the long-term diffusion of the nuclides.

3 Localized impacts on the Antarctic environment

3.1 Impacts on the soils

The soils nearby the stations have been affected by the localized activities, including: (1) during building the stations and the roads, the landform and the physical behavior of the soils were changed, some rock dusk was deposited on the soils (or on the ice), and then the regional soil freezing-thawing processes were disturbed, which causes the ground to become unstable. In some small areas of the middle part of Fildes Peninsula, the unstable ground makes the regional freezing and thawing mud-rock flow to occur, the fluctuating range of the lake level to be increased even the lake to be dried up in March, and some buildings to be damaged; (2) some organic pollutants, heavy metal pollutants and microbes have been put into the soils. The organic pollutant has along life in the soils due to the very slow rate of soil decomposition (Campbell, 1987). It was measured that the average contents of BHC (benzene hexachloride), DDT, PCBs and oils in the soils are 0.25×10^{-9}, 0.11×10^{-9}, 0.27×10^{-9}, 7648×10^{-9}, respectively (Pu, 1995). The heavy metal elements concentrations in the soils are very different within Fildes Peninsula, and the elemental composition of the soils is closely related to the organic matter content, the parent material and the ocean influence to the soils. Fortunately, the human impacts on the heavy metal contents of the soils are always wrapped by the high background value of the soils.

3.2 Impacts on the flora

The present native terrestrial flora in Antarctica includes 350—400 species of lichens 85 mosses, 28 macrofungi, 25 hepaticas and two angiosperms. This ecosystem is particularly susceptible to damage caused by the presence of humans (Bonner, 1989). Pu Jiabin *et al*. (Pu, 1995) showed that the contents of DDT in the lichens and mosses of King George Island are 0.24×10^{-9} and less than 0.14×10^{-9}, the contents of PCBs in the lichens and mosses are 1.33×10^{-9} and 0.34×10^{-9}. In this paper, it is shown that the impacts of the expedition stations on Usnea, which is the dominant species of fruticose lichens in Fildes Peninsula. The results are shown Table 2.

Table 2 The contents of Cr, Cu, Mn, Ni, Pb and Zn in Usnea of Fildes Peninsula (ppm)

Metal	L_1^*	L_2^*	L_3^*	L_4^*	L_5^*	L_1	L_2	L_3	L_4	L_5
Cr	5.692	3.853	3.732	2.726	2.306	2.460	2.402	2.340	1.313	2.339
Cu	35.550	36.390	23.620	11.660	11.580	9.625	17.280	8.094	7.901	6.160
Mn	14.010	4.117	11.850	14.220	21.410	11.970	4.179	11.740	9.533	24.180
Ni	3.083	1.155	1.598	0.969	1.079	1.132	0.843	1.095	0.581	1.201
Pb	31.590	12.530	4.353	2.046	1.053	8.876	3.080	1.644	0.302	0.693
Zn	51.160	48.860	54.170	26.470	33.180	29.150	36.280	26.140	20.740	26.730

Note: L_1: the lichen on the western hill of the Power Station; L_2: the lichen on the western rock of the Oil Depot; L_3: the lichen on the western hill from the Power Station 400m; L_4: the lichen on the western hill from the Power Station 750m; L_5: the lichen in the control plot. L_1^*—L_5^* are the delicate branches of the Usnea, L_1—L_5 are the old-branches of the Usnea.

The results showed that the contents of Cr, Cu, Mn, Ni, Pb and Zn in the lichens nearby the power station and the oil depot are higher than that in the control plot. For example, the contents of Pb in the lichen on the western hill of the Power House is about 30 times as much as that of the lichen in the control plot (Harlfthree Point). It was also shown that the contents of these metal

elements in the delicate branches of the Usnea higher than that in the old-branches of the Usnea. And so Usnea is one of the most sensitive pollution monitors in this region.

3.3 Impacts on fresh water

12 fresh water samples of Fildes Peninsula were analyzed. W_1 is the water of the run-off into West Lake, W_2 is the water of the run-off in the area of the Great Wall Station, there are some suspended organic materials in the water, W_1 and W_2 are the same water-system; W_3 is the water of the run-off into Langer Lake; W_4 is the water Biology Valley River, there are some solid waste and oils in the river water, and some mosses in the river bottom have been damaged by these waste; W_5 is the water of Tern Lake (west), W_6 is the water of Tern Lake (east); W_7 is the water of the lake in the southwest of Marsh Base, this lake is the drinking-water source. W_8 is the water of the lake in the southwest of Marsh Base, there are some solid waste in this lakeside; W_9 is the water of West Lake; W_{10} is the water of Languor Lake; W_{11} is the water of Kitezh Lake; W_{12} is the water of Swan Lake.

The results of the 12 samples showed (Table 3) the contents of Ca, P, S and Mg in the W_2 are higher than that in W_1; the contents of Ca, P, S, Mg, Fe and Pb in W_4 is unusually high, which indicates that the water and the mosses in Biology Valley have been affected by the human activities; the contents of Ca, Cu, Fe, Mn, P, Pb, Zn in W_6 and W_8 are very higher than that in their each neighboring water bodies W_5 and W_7, and there have been some ochreous deposit in the lakes (W_6 and W_8), which indicates that these solid waste have polluted the water quality of the lakes and the rivers. But the localized impacts on the waters of W_1, W_3, W_5, W_7, W_9, W_{10} and W_{12} are not clear.

Table 3 The element contents of the water in Fildes Peninsula, Antarctica, mg/L

No.	pH*	Ca	Cu	Fe	K	Mg	Mn	P	Pb	S	Zn
W_1	6.32	1.290	0.021	0.000	0.114	0.480	<0.000	<0.001	<0.001	0.152	0.002
W_2	6.56	2.407	0.011	0.000	0.283	1.073	0.002	0.102	0.003	0.478	<0.001
W_3	7.82	2.145	0.176	0.208	0.266	0.903	0.007	<0.001	<0.001	0.373	<0.001
W_4	7.14	5.163	0.005	0.310	0.598	1.820	0.039	0.082	0.020	1.028	0.050
W_5	6.87	2.207	0.004	0.006	0.269	1.185	<0.001	0.020	<0.001	0.391	0.004
W_6	7.01	5.546	0.051	0.882	0.553	2.053	0.024	0.121	0.002	0.585	0.038
W_7	7.34	3.262	0.019	0.376	0.853	3.073	0.007	0.040	0.008	1.344	0.007
W_8	7.36	5.413	0.068	0.781	0.488	1.772	0.026	0.060	0.025	0.847	0.040
W_9	6.20	2.252	0.100	0.000	0.232	1.423	0.002	<0.001	<0.001	1.513	1.070
W_{10}	7.56	5.819	0.081	0.011	0.414	1.258	0.007	<0.001	0.019	2.154	0.059
W_{11}	—	3.265	0.003	0.258	0.413	1.656	0.006	0.102	0.009	0.792	0.015
W_{12}	—	1.824	0.001	0.331	0.702	1.821	0.002	0.015	<0.001	1.706	<0.001

* These results were measured at the field sites in January 1993

4 Conclusion

There are some ^{137}Cs in the terrestrial ecosystem of Fildes Peninsula, the sequence of ^{137}Cs specific activity is as follows: crustaceous lichen > fruticose lichen > surface-moss > surface-soil, which demonstrates that the Antarctic environment has been affected by human activities undertaken elsewhere in the world. Human nuclear activities have made an effect on the ^{14}C level of the modern biota in Antarctica, and Crustaceous lichen may therefore be widely used for

monitoring the long-term diffusion of the nuclides.

The anthropogenic disturbances are clear in the study area, the lichens and mosses around the scientific expedition stations have been disturbed with the gases and dust of the power stations, and some small lakes have been polluted with the solid wastes, but the disturbance of the soils is not clear.

Antarctic terrestrial ecosystem is very fragile, and the environmental capacity is very small. Therefore, domestic and human wastes and the kitchen refuse of the stations can be disposed in the sea with minimum treatment, the gases, waste heat and dust from the power stations should been minimized with some treatment equipment, and the solid wastes should be packed into trunks or containers and removed from Antarctica, which is one of the most effective measures for the conservation of Antarctic ecosystem.

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