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Anna KRZYSZOWSKA
Department of Ecological Bioenergetics, Institute of Ecology, Polish Academy of Sciences, Dziekanów Leśny

The degree of tundra degradation in the surroundings of the Hornsund Polar Station (Spitsbergen) — reaction of the environment to human impact

ABSTRACT: Investigations were carried out in the regions of the Hornsund Station, Spitsbergen at summer 1979. The aim of the studies was to determine the effect of the Station on the natural environment around the Station. After taking an inventory of the sources of pollution and in result of the determination of the range of the pressure of anthropogenic factors the whole area under degradation was divided into three parts: an area without possibilities of recultivation, a devastated area and an area of normal natural environment.

It was found that the main source of the contamination of tundra are fuels derived from mineral oil. The distribution of fuel concentrations in the soil corresponds to the direction of the slope of the ground and the flow of the surface waters. Mechanical transformation of the surface of the tundra is also an outcome of the degradation.

Key words: Spitsbergen, tundra, human impact

1. Introduction

Polish Scientific Station is located within the range of the South Spitsbergen National Park at Isbjornhamna Bay (established by Royal Decree issued in Norway on June 1, 1973). According to the principles of natural environment conservations within the range of national parks and partial reservations any human activity that could disturb natural environment, e.g. by using motor vehicles, or littering the grounds, etc., is forbidden. These ordinances may be abrogated by the Governor of Spitsbergen as regards scientific expeditions provided that their activity will not collide with the purpose of national parks and reservations (Birkenmajer 1975).

The management of the Station is associated with the interference of man in the natural environmental system. This gives a possibility to study the reaction of the primeval environment to human impact.

The investigations conducted in 1979 during the Polish Scientific Expedition to Spitsbergen, organised by the Institute of Geophysics, Polish Academy of Sciences, were made an attempt to carry out observations and studies on the effect of the Station on the ecological changes in the environment. The scope of the studies included the inventory of the sources of pollution, determination of the range of the pressure of anthropogenic factors, determination of the effect of the waste from the Station on the changes in the soil chemism and examination of the chemism of the waters used for potable water. Chemical properties of the waters in the regions of Hornsund were analysed by Rakusa-Suszczewski (1963), and Bieroński (1975). The origin of the soil of this region, and their mechanical and chemical composition were examined by Kowaliński and Szerszeń (1962), Baranowski (1963), and Szerszeń (1965). Among the works dealing with the effect of human activities on the transformation of tundra ecosystems in the Alpine and Arctic regions there are studies treating of the means of transport effects on the transformation of tundra (Greller, Goldstein and Marcus 1974, Rickard and Brown 1974, West 1976, Webber and Ives 1978) and displacement of some species of animals (Eckstein et al. 1979); the effect of air and water pollution and the impact of tourists on the Polar environment (Webber and Ives 1978).

The aim of the studies carried out at Isbjornhamna Bay in summer 1979 was determination of the degree of tundra degradation in the surroundings of the Polar Station.

2. Description of the grounds and location of the Station

The investigations covered an about 3.5 ha area surrounding the Station and subject to direct human impact. The Station is located at Isbjornhamna Bay in Hornsund Fjord, at a height of 10 m above mean sea level, at a distance of about 200 m from the seashore, in latitude 76°59′55″ N and longitude 15°33′00″ E. It is situated on a sea terrace formed of accumulated material (Birkenmajer 1958, 1960). Four types of the subsoil were differentiated in the Station grounds (Fig. 1), depending on the degree of the growth of vegetation over the ground and the differences in the mechanical composition of the soil. The soils constituting the substratum of the Station grounds are easily permeable (the infiltration coefficient is 1.7—1.3 · 10^{-2} cm · s^{-1}). There is an escarpment rising to 9.5 m above mean sea level from which water flows down and the local runoffs arise in the time of precipitation.

The relation on the northern shores of Hornsund consists mainly of moss — 159 species (Kuc 1968 b), lichen — 128 species (Nowak 1968) and flowering plants — 67 species (Środoń 1958, Kuc 1968 a). The soil in this region consist of material washed up by the sea (Fig. 1 — Stations 1, 3, 5—9) or alluvial soils (Fig. 2 — Stations 2 and 4), according to Szerszeń (1965) systematic's. Due to low temperatures the soils show low dynamics of biochemical circulation of natural and organic soil substances (Kowaliński

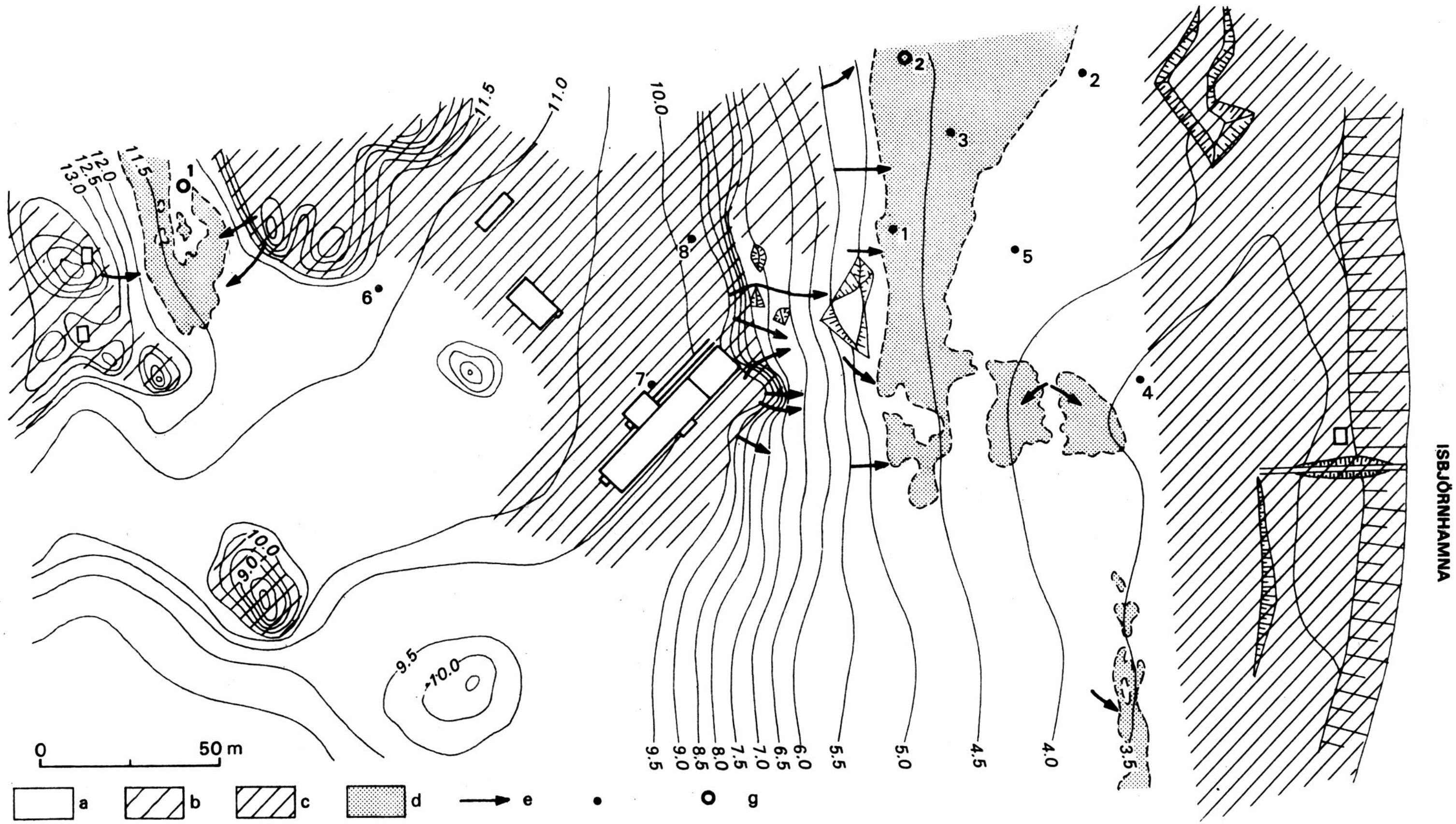

Fig. 1. Types of subsoil in the area of the Scientific Station, Polish Academy of Sciences, Hornsund, Spitsbergen

a — gravel-stone subsoil, totally overgrown with plants, b — gravel-stone subsoil, partially overgrown with plants, c — gravel-stone-rock subsoil, without vegetation, d — sediments in depressions periodically filled with water, e — fall of the ground with local run-offs, f — soil sampling station, g — water sampling station

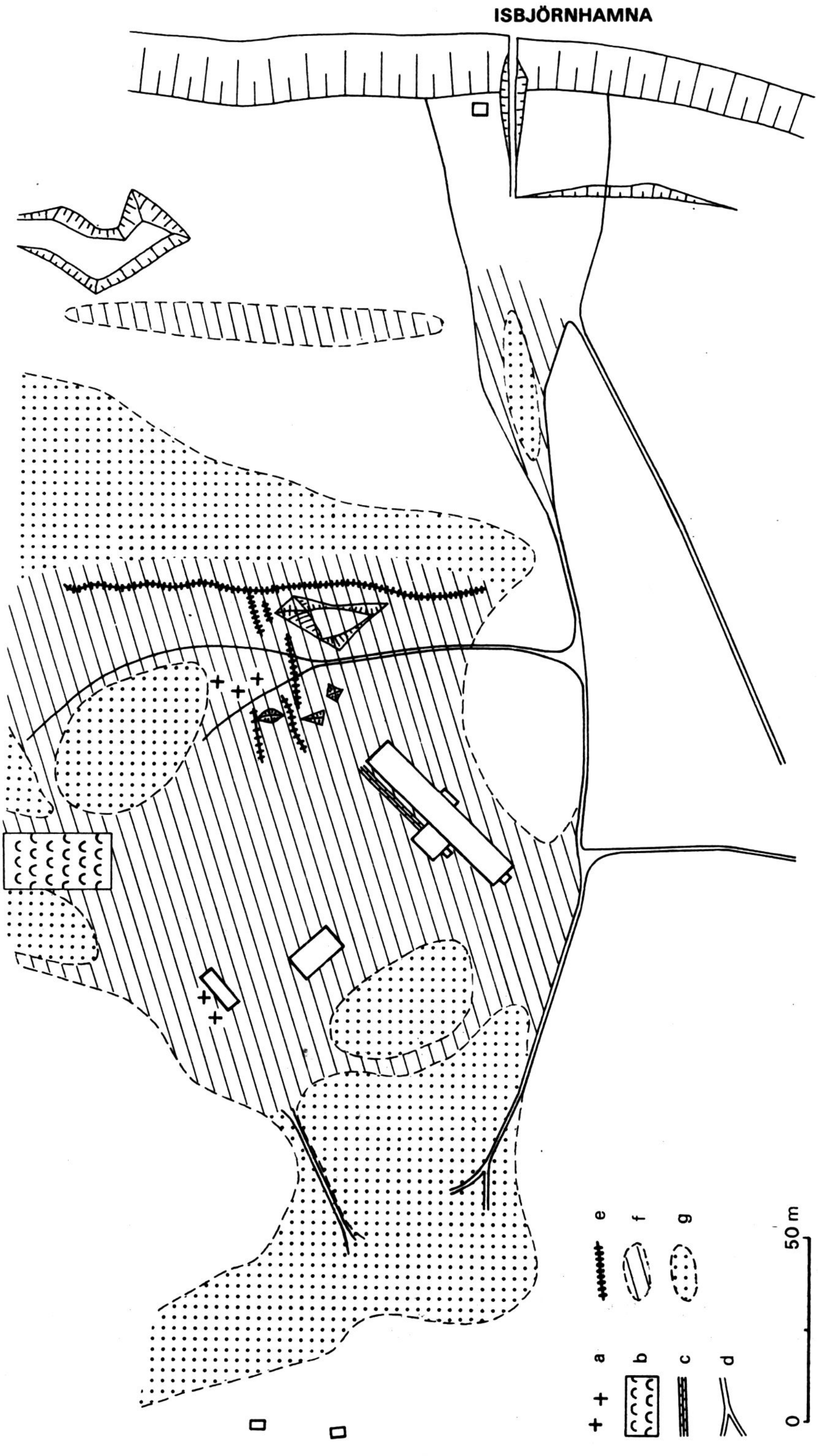

Fig. 2. Degree of degradation of the environment in the surroundings of the Scientific Station, Polish Academy of Sciences, Hornsund, Spitsbergen

a — dump of durable refuse, b — storage of fuel, c — communal sewer, d — roads, e — tracks of oil-derived fuel run-offs, f — areas without possibility of recultivation, g — devastated area (dashed line — hypothetical boundaries) and Szerszeń 1962). The ascertainment of the morphology and character of the substratum and overgrowth in the region served as basis for determination of the range of the pressure of anthropogenic factors.

Since the establishment of the Station in 1957 about 2500 tons of cargo was brought in and about 280 persons (visitors not included) stayed over there for some time. Power is supplied by generators using fuel kept in 200 l barrels stored away at a distance of 60 m from the powerstation. At present two metal containers (5 m in length, 2.45 in diameter, 25 m^3 volume) have been installed.

Sewage and waste from the bathroom and kitchen are drained off to a ditch running parallel to the Station house and ending at the escarpment (Fig. 2).

3. Methods

Water samples were collected every 10 days from the water pools used a source of potable water for the habitants of Polar Station and the Camp of a summer group of scientists. Samples of the soil were collected only once directly in the the neighbourhood of the Station. On the day of sampling, temperature, electrolytic conductivity, the pH value, hardness, alkalinity, content of chlorides, calcium, iron, sulphates, nitrate nitrogen, and phosphates were determined in the water samples. Water temperature was determined using an Asman thermometer (exact to 0.2° C). Conductivity was determined by means of a Mera Elvro, type N 571, battery conductometer and converted into units of total mineralization of water. The pH, alkalinity, hardness, content of calcium, chlorides, nitrate nitrogen and phosphates were determined using standard methods (Hermanowicz et al. 1976). For determination of nitrate nitrogen and phosphates content a Zeiss 10 spectrocolorimeter was used. In 10 water samples the composition of cations was determined a Q24 spectrograph. In 9 samples of the soil collected at the depth of 5—10 cm downwards from the surface of the ground actual humidity, pH value and from the aqueous extraction electrolytic conductivity and chlorides content were determined.

The content of oil-fuels in the soil was determined in a Soxlet apparatus using the method of petroleum ether extraction. The analyses of the chemical composition of water and soil were carried out in the Chemical Laboratory of the Polar Station between 23 July and 12 September 1979 (except spectral analysis of water and determination of the content of petroleum products in the soil).

4. Results

Having in view potential contamination of the environment all the cargoes supplies to the Station were divided into different groups of materials, such as: fuel, oils and lubricants, technical chemicals, cleansing agents, and food containers (Table I).

Table I

Sources of potential contamination of the environment
Groups of materials brought into Polar Station in 1979

Total cargo (ton)	Fuels (m^3)	Lubricants (m^3)	Technical chemicals (kg)	Household chemicals (kg)	Food containers	
					metal (number)	glass (number)
320	420	40	120	364	10.610	8989

The main source of solid waste are empty food containers, i.e. cans, glass jars, plastic boxes and bags, etc., accumulated on the dumping ground below the escarpment at Wilczekodden (Table I). The main source of liquid pollutants are fuel for generators leaking out from damaged barrels or spilled when poured out of the barrel and water-supplyandsewage system at the Station.

Compounds derived from mineral oil cause changes in chemical composition of soil and water. Traces of fuel run-offs are visible on the escarpment in the form of a scorched, stinking spots on the ground. A strip of land polluted with fuel extends over a distance of 100 m from the base across the escarpment to the local depressions in the ground. There is a marked increase of contamination in accordance with the direction of the downward slope of the ground and the flow of waters (cf. Figs. 2 and 3). The highest contamination with oil-derived fuel — 2660 mg $\cdot$ 100^{-1} g dry weight was recorded directly at the Station building and below the escarpment in the local depression (1360 mg $\cdot$ 100^{-1} g dry weight). The highest water level in that depression was marked by a dark line at its edge formed by the residuum of the oil-derived compounds (Table II).

Sewage infiltrates deep into the ground in the summer time due to good permeability of the soil, so, that waste water is rarely seen in the ditch.

In determination of the degradation of the surface of tundra surrounding the Station particular attention was given to mechanical transformations, e.g. tracks of destroyed overgrowth (Fig. 2). How persistent these changes are is well-evidenced by the trail of a single passage of a motor-car from Vaerenhusa to Sornhajmfjelet in 1958. The transformation of the natural environment around the Station shows different degrees of degradation. The most degraded are: the area on the escarpment directly around the buildings of the Station, the area below the escarpment and public roads. These are tracts devoid of overgrowth, strongly transformed mechanically or chemically, with no possible of recultivation, covering an area of about 1.2 ha. The devastated areas include the grounds of "Meteorological Garden" and "Magnetic Houses" (about 1.0 ha). The overgrowth in this area is partly destroyed and the main source of pollution is solid waste (Fig. 2).

Moreover, the investigations included analyses of the waters used as potable water for members of scientific expeditions staying at the Station. In summer water is drawn by means of a rubber tube from local small pools deriving water from melting snow cover and glaciers, inflow of small

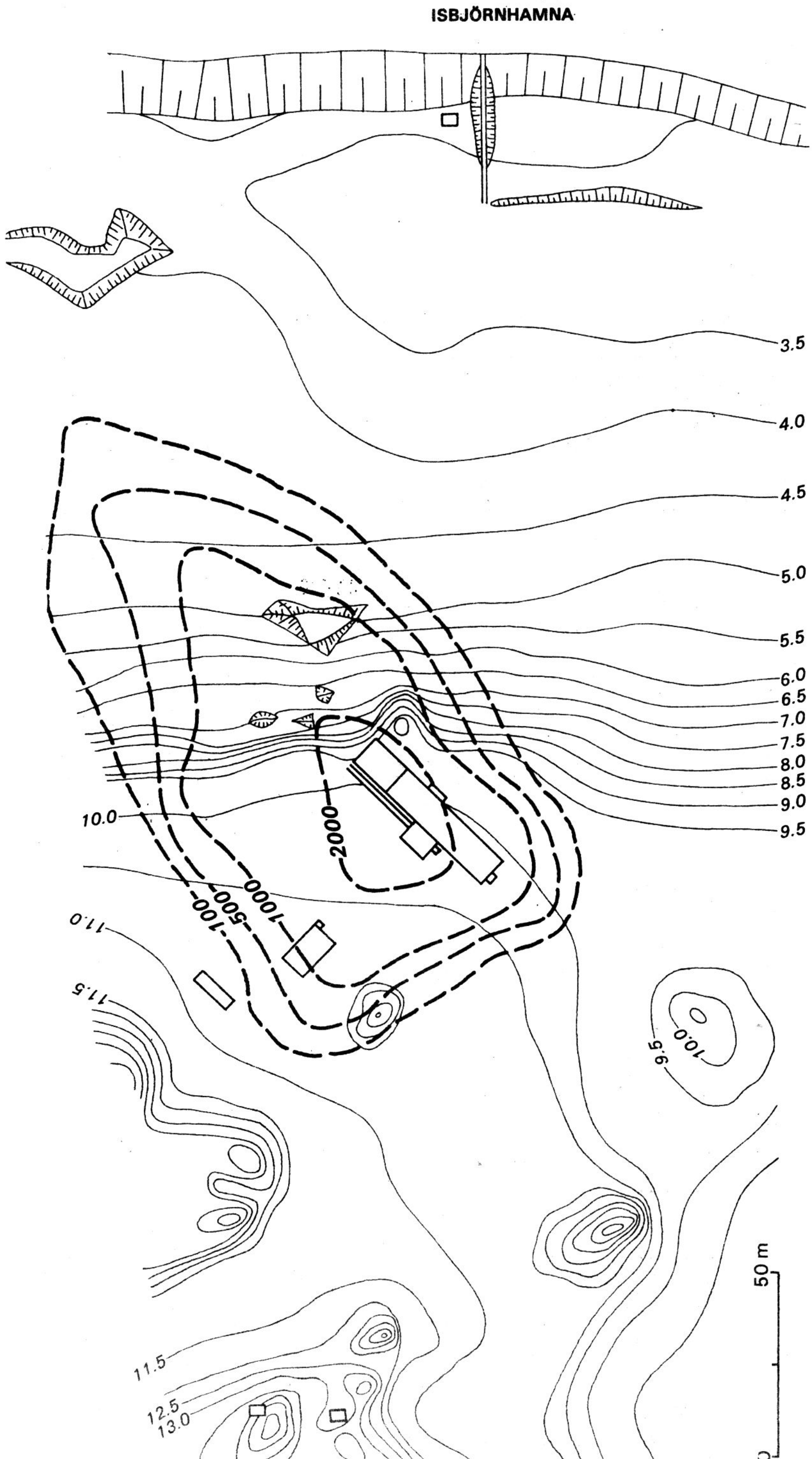

Fig. 3. Distribution of fuel content in the soil in the area of the Scientific Station, Polish Academy of Sciences, Hornsund, Spitsbergen (mg · 100 g^{-1} dry weight soil)

Table II

Topography of the sampling stations and some chemical properties of the soil samples

Humidity (%)	pH		Conductivity (µS)	Oil and grease content (mg · 100^{-1} g d. w.)	Station No.	Locality	Height a.s.l. (m)	Dominant plant	Extent of overgrown areas (%)
	H_2O	1 n KCl							
18.32	6.4	6.0	46	n. f.	1	200 m N of Station. Sea terrace (zero test)	11.5	lichen saxifraga	80
2.00	7.0	6.5	40.5	1360	2	50 m E, below escarpment, depression filled with water periodically. The lowest terrace	4.7	no vegetation	—
10.91	6.8	6.0	31.5	n. f.	3	100 m W of Isbjornhamna Bay	4.2	saxifraga moss	30
3.80	7.0	6.3	30.5	690	4	70 m E, below escarpment, depression filled with water periodically	4.4	no vegetation	—
12.69	6.8	5.9	32.2	n. f.	5	100 m S of No. 3, 80 m W of Isbjornhamna Bay	3.5	moss saxifraga	30
45.85	6.6	6.0	30.0	n. f.	6	50 m S of No. 3, 120 m W of Isbjornhamna Bay	4.2	moss lichen saxifraga	70
2.51	6.6	5.8	18.5	n. f.	7	Meteorological Garden at the Station	11.2	saxifraga moss lichen	90
25.33	7.0	6.0	44.5	2660	8	Close to the Station building	10.0	no vegetation	—
1.39	6.6	6.3	42.3	1100	9	300 m N of Station building	9.7	no vegetation	—

streams and precipitations. In winter water is derived from melting icebergs. On the average 150 litres of water are used daily. Spectral analysis of potable water showed in summer season the presence of cations, such as: Fe, Ca, Si, B, Ag, Mg, Mn, Na and Cu. In winter, the water from melting ice from the glaciers contained only traces of those ions and Ag ions were absent. Potable water is soft or very soft; the value of mineralization is very low (fresh water). The values of the elements determined in water were higher in the samples collected in August and September than in July, which was due to evaporation and more intense biogenic processes.

5. Discussion

Out of 3.5 ha tract of land under the management of the Station at Hornsund up to 30% of the area is degraded and partly devastated (Fig. 2). Oil-derived fuels used at the Station constitute the greatest threat to the natural environment (Fig. 3). The content of oil and its derivatives in the soil is an indicator of chemical contamination of the environment. The remaining indicators, such as: pH value, electrolytic conductivity and chlorides content do not show any changes, as compared with zero test results. The pH values in the collected soil samples (Table II) do not differ significantly from the values in the samples of lithologically and genetically similar soils, described by Szerszeń (1965). Concentration of grease and mineral oil pollutants in the surroundings of the Station ranges from 690 to 2660 mg $\cdot$ 100^{-1} g dry weight. By way of comparison, concentration of oil and grease in the environment of petrol filling stations in the area of Warsaw ranged from 3280 to 6070 mg $\cdot$ 100^{-1} g dry weight (Daukszo, Kucharska-Wis and Piechucki, unpublished data).

Oil products infiltrating into the soil destroy its filtering and absorbing capacity, natural composition of microflors is subject to changes and consequently biological equilibrium is disturbed. Self-purification is possible only at the surface layer of the soil where aerobic microorganisms can live and grow (Miłkowska-Jankowska, Maleszewska and Łuczak 1976). In the soil contaminated with oil the quantity of aerobic and anaerobic bacteria and oil decomposing fungi increases even at the depth of 40 m downwards (Pinholt, Struwe and Hjoller 1979). However, under the conditions prevailing at Spitsbergen, at the mean air temperature of about 3—5° C in summer, biochemical decomposition may be slower and contamination of soil with oil-derived fuel is more persistent, so that the effects of degradation may last for many years. In the chemical analysis of the composition of crude oil 50 different elements were found, 40 of them were metals or metal-derived salts (Clark and Brown 1977). It is why one of the principal stages of the investigations for the prospective building of petroleum pipelines in the Arctic regions of Canada were studies on their effect upon the environment (The Canada Year Book 1976—1977).

The degree of degradation of the environment in the surroundings of the Station depends not only on the content of oil-derived fuel in the soil but also on mechanical transformation of the tundra surface. The results of the observations corroborate the findings from the studies on the degree of the devastation of tundra, showing that regeneration of lichen destroyed under the effect of air pollution or mechanically often takes a very long time, 50 years or more (West 1976). It is advisable that movement of means of transport should be restricted to the areas overgrown with small plants (Greller, Goldstein and Marcus 1974).

It was found (Medwecka-Kornaś 1973) that the richer the ecosystem the less frequent the development of a given production. Therefore, diversity is a certain quarantee for the maintenance of biological equilibrium — stability of ecosystems and balancing the constituents and processes within their range. Since this is a simple ecosystem whatever interference from outside not connected with natural conditions may upset the existing balance in spite of the fact that vegetation in Arctic environment shows the characteristic features of stability despite sometimes varying environmental conditions (Dahl 1975). Being aware of the importance of this problem Project No. 6: "Human impact on the productivity and crops in the mountains and Arctic ecosystems" was included within the UNESCO Program "Man and the Environment". The Project includes, among others, studies on the sensitivity of these environments to human impact and activities, such as: the use of the land surface for transportation, technical installations, contamination, etc. (UNESCO 1974).

For comparative motives the analyses of potable water for the hut built near the Werenskiëlda Glacier and for a trapper's "hus" at Hytteviki were carried out. This water belongs to class HCO_3, Group Ca^{+2}, Type III, after Alekin classification (Rakusa-Suszczewski 1963) or to Type HCO_3 — Ca^{+2} — Cl^-, after Ščukareva-Priklonskij classification (Bieroński 1975), which corresponds to chemical properties of the analysed waters (Table III).

The values of the elements determined in potable water are within the range permitted by Polish standard for the class I surface waters, except the waters from Hytteviki having a much higher content of nitrate nitrogen and phosphates. This is connected with the presence of a bird colony which corroborates the findings from the studies by Bieroński (1975). The occurrence of Ag, Si and Fe in higher quantities than traces is connected with the character of the bed-rock.

6. Conclusions

The main sources of pollution are: durable refuse — not subject to decomposition, oil-derived fuel and household sewage and waste matter. Oil-derived fuel is the most imminent threat due to the localization of the source of contamination at the escarpment, good permeability of the soil and thermic conditions.

The distribution of oil-derived fuel concentrations is concordant with the direction of the slope of the ground and the flow of surface waters. In consequence of the degradation of tundra an increase in the concentration of oil-derived fuel in the soil is observed as well as a permanent mechanical transformation of the surface of tundra. A time and space inspection

Table III

Chemical composition of potable water (at the northern shores of Hornsund Fjord)

	Potable water in summer				Potable water in winter	Polish standard of purity (Class I)
	Water for the Station	Water for camp of summer group	Water for Varenhusa	Water for Hytteviki		
pH	6.4—7.8	7.4—7.6	7.2—7.4	5.2—7.6	6.2	6.5—8.0
Hardness ($mval \cdot l^{-1}$)	0.40—1.94	1.60—2.72	4.14—5.34	0.62—0.80	0.60	7.0 and below
Total mineralization ($mg \cdot l^{-1}$)	32.83—347.0	99.22—519.69	234.49—284.85	56.24—130.23	30—60	—
Iron ($mg\ Fe \cdot l^{-1}$)	n.f.	n.f.	n.f.-trace	n.f. —0.01	n.f.	1.0 and below
Chlorides ($mg\ Cl \cdot l^{-1}$)	2.06—13.13	4.18—14.49	2.34—4.89	3.90—9.66	10.7—63.9	250 and below
Sulphates ($mg\ SO_4 \cdot l^{-1}$)	0.96—21.12	0.96—4.80	—	—	—	150 and below
Nitrite nitrogen ($mg\ N\text{-}NO_3 \cdot l^{-1}$)	0.10—2.50	0.08—0.98	n.f.	7.20—6.40	n.f.	1.5 and below
Phosphates ($mg\ P\text{-}PO_4 \cdot l^{-1}$)	—0.10	—0.025	n.f.	1.40—0.73	n.f.	0.2 and below

of the existing degree of degradation of the environment in the surroundings of the Arctic Station is of great importance.

The chemical analyses of potable water indicate the necessity of water treatment, especially in winter season.

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7. Summary

The investigations were carried out in summer 1979 in the region of the Hornsund Station at Spitsbergen. The aim of the studies was determination of the effect of the Arctic Station upon the changes in the natural environment in the close surroundings of the Station. The area of the grounds around the Station, under direct human impact, averages 3.5 ha. Since the establishment of the Station about 2500 ton of cargo were brought in and about 280 persons stayed over there. The main sources of pollution are: solid waste, not liable to decomposition, oil-derived fuel and household sewage and waste matter (Fig. 2).

Oil-derived fuel is the most imminent threat due to thermic conditions, localization of the source of contamination at the escarpment and good permeability of gravely and rocky ground covering a large area of the Station grounds (Fig. 1). Concentration of grease and mineral oil in the surroundings of the Station ranges from 690 to 2660 mg · 100^{-1} g dry weight (Table II). An increase in the content of oil-derived fuel is concordant with the direction of the slope of the ground and the flow of the surface waters (Figs. 1 and 3). Mechanical transformations of the surface of tundra have an likewise an effect on the degree of the degradation of the environment of the Station (Fig. 2).

The analyses of potable water for the Arctic Station showed that due to low mineralization and low content of calcium and magnesium salts in water it requires a special treatment (Table III).

8. Резюме

Работы проведено летом 1979 года в районе Станции Хорнсунд на Шпицбергене. Целью исследований было определение влияния полярной Станции на изменения натуральной среды в непосредственном её окружении. Площадь вокруг Станции находящаяся в непосредственном влиянии человека достигает 3,5 гектара. От начала деятельности Станции на эту площадь доставлено 2500 тонн груза, в этот период здесь пробывало около 280 человек. Источником загразнения являются постоянные, неразлагающиая отходу, нефтепоходное горючее и бытовые хозяйственные нечистоты (рис. 2).

Самой большой угрозой является нефтепоходное горючее в связи с термическими условиями а также расположением источника загрязнения находящегося на склоне и на хорошую пропускаемость гравийной и крупнообломочной почвы, занижающей самое большое пространство на площади Станции (рис. 1). Сгущение загразнения минеральными маслами в окружении Станции выступает от 690 до 2660 мг·100^{-1} г сухого веса (таблица II). Рост содержания нефтепоходного горючего сответствует направлению склона местности и направлению течения проверхностных вод (рис. 1 и 3). На степень деградации среды окружающей Станцию влияют тоже механические деформации поверхности туньры (рис. 2). Исследованная питьевая вода для нужд полярной Станции в связи с небольшой минерализацей ис недостаточным содержанием известковых и магниевых солей требует кондиционирования (таблица III).

9. Streszczenie

Prace prowadzono latem 1979 r. w rejonie Stacji Hornsund na Spitsbergenie. Celem badań było określenie wpływu Stacji polarnej na zmiany środowiska naturalnego w bezpośrednim jej otoczeniu. Powierzchnia terenu wokół Stacji, znajdująca się pod bezpośrednim wpływem człowieka wynosi 3,5 ha. Od początku działalności Stacji na teren ten przywieziono około 2500 ton ładunku, przebywało tu w tym czasie około 280 osób. Źródłem zanieczyszczeń są odpady stałe nie ulegające rozkładowi, paliwo ropopochodne i ścieki bytowo-gospodarcze (rys. 2).

Największe zagrożenie stanowi paliwo ropopochodne, ze względu na warunki termiczne oraz usytuowanie źródła zanieczyszczenia na skarpie i na dobrą przepuszczalność gruntów żwirowo-kamienistych, zajmujących największy obszar na terenie Stacji (rys. 1). Stężenie zanieczyszczenia tłuszczami i olejami mineralnymi w otoczeniu Stacji waha się od 690 do 2660 mg · 100^{-1} g suchej masy (tabela II). Wzrost zawartości paliwa ropopochodnego jest zgodny z kierunkiem spadku terenu i kierunkiem spływu wód powierzchniowych (rys. 1 i 3). Na stopień zdegradowania środowiska otoczenia Stacji wpływają również mechaniczne przekształcenia powierzchni tundry (rys. 2).

Badane wody pitnej dla Stacji polarnej, ze względu na małą mineralizację i małą zawartość soli wapiennych i magnezowych wymagają uzdatniania (tabela III).

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AUTHOR'S ADDRESS:
Mgr Anna Krzyszowska
Zakład Bioenergetyki Ekologicznej
Instytutu Ekologii PAN
Dziekanów Leśny,
05-150 Łomianki, Poland