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Assessment of the environmental impact of the "H. Arctowski" Polish Antarctic Station (Admiralty Bay, King George Island, South Shetland Islands)

Introduction

Polish Antarctic Station "H. Arctowski" was opened on February 26, 1977 on King George Island at the Admiralty Bay (−62°09′41″.56, 301°31′49″.99). Twelve years of its existence showed technical and organizational problems connected with its functioning. Activity of the station established for scientific purposes creates a risk of changes in ecosystem and, therefore, a need of nature protection in this region. It is necessary to evaluate its damaging influence and to undertake suitable measures consistent with actual policy of SCAR (1988). Operation of the "H. Arctowski" Station completely depends upon material transportation from outside — mainly food, equipment, building materials and fuel. From the local natural sources only fresh water was used. Energy is needed mainly for heating and lighting, radio-communication, land and water transport. Thus, operation of the station was included "par force" into natural processes of matter transportation and the energy flow within the ecosystem of the Admiralty Bay (Rakusa-Suszczewski 1987). The presence of people is also a new element introduced into this ecosystem.

The land frontier of the drainage basin of the Admiralty Bay is proposed to be taken as the limit of the Admiralty Bay region (Rakusa-Suszczewski 1980). The surface of the drainage area of the bay so measured is 365 km^2 and covers the land surface of 246 km^2, from which ice-free regions make 21.2 km^2, and surface of the Admiralty Bay itself of 119 km^2, with its water volume of about 21 km^3 (Marsz and Rakusa-Suszczewski 1987). The region of the "H. Arctowski" Station is situated near Point Thomas and forms an area not covered with ice and of the surface of 4.2 km^2. From the north and east it borders with Ezcurra Inlet waters and with the central part of the Admiralty Bay, whereas from the west and south it borders with glaciers (Fig. 1). Apartment buildings, laboratories, warehouses, fuel containers, access roads, electrical and radio installations, water-sewage system were located on the area

of 0.28 km^2 in the shore belt up to 5 m a.s.l. In this area, in its southern end, the protected zone of tundra was separated (according to own regulations of the station). This zone, richly overgrown by mosses, *Deschampsia* sp. and *Colobanthus* sp., with a surface of 0.12 km^2 adheres from the north to the penguin colony. Farther southward, there is the region of SSSI No 8 accepted after Polish proposal by the Antarctic Treaty (SCAR 1985). This decision is valid until December 31st, 1991.

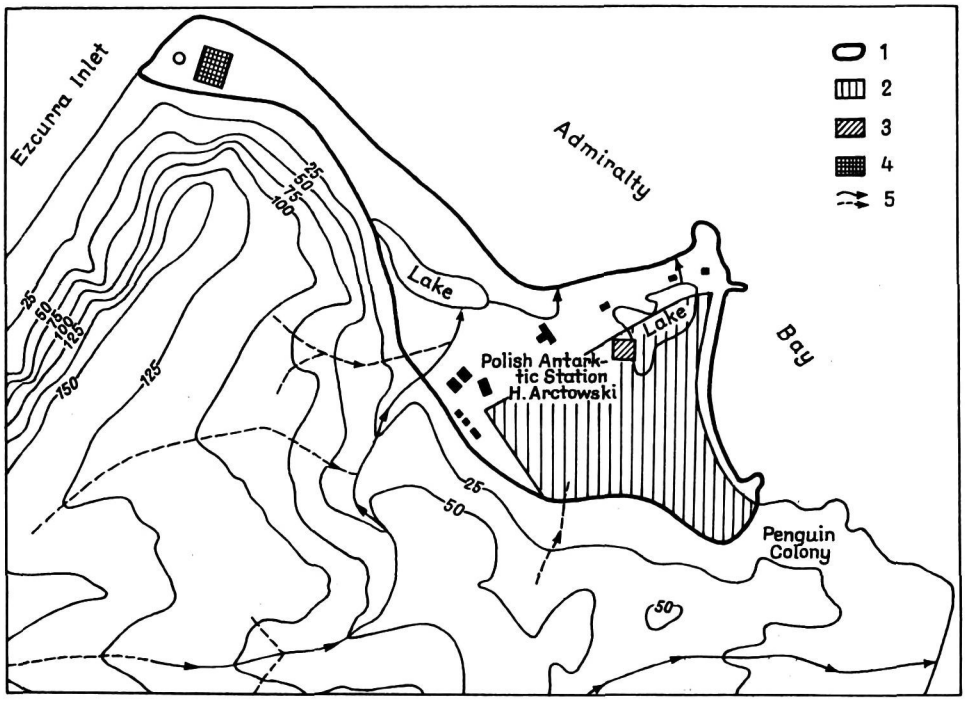

Fig. 1. Surroundings of the "H. Arctowski" Polish Antarctic Station:
1 — surroundings up to 5 m a.s.l., 2 — protected zone, 3 — meteorological garden, 4 — fuel containers, 5 — streams

Because of physiographic and climatic features of the area where "H. Arctowski" Station operates many problems connected with its influence on ecosystem are shared by other stations situated on King George Island. These problems can be solved in various ways with the use of technical and organizational means. Therefore the risk of human influence on ecosystem can vary. Especially dangerous are transport means and these energy sources which could go out of control because of technical and technological difficulties, rougheness of the nature, human negligence or ignorance.

At present, in the region of the Admiralty Bay several stations are functioning. Permanent ones are Polish "H. Arctowski" and Brazilian "Ferazz" stations and seasonal ones are American ornithological base situated in the

region of SSSI No. 8, Ecuador hut placed at Hennequin Point in 1988 and Peruvian station founded at Crepin Point in 1989. It would be useful in such a situation to work out common rules of operation maximally diminishing their influence upon the region of the Admiralty Bay. Well organized international cooperation should be undertaken not only within regulations and their execution but also it should concern common logistic initiatives.

The risks of sea and land transportation

In the region of the "H. Arctowski" Station the transporting operations are done once or twice a year — in austral summer or most often in spring. This is the season of highly intensive processes and biological phenomena connected with natural cycle of the polar ecosystem functioning. Therefore, the risk of negative influence is especially great in this season. The need of transportation of heavy equipment to the station — amphibians, tractors, cranes, houses, helicopters, cars or cool stores — makes it necessary to use big ships with cargo booms of 30 tons of carrying power. Thus, merchant ships as m/s "Zabrze", m/s "Zawichost", m/s "Garnuszewski" with displacement of several thousands tons are chartered. These ships have numerous crews and their normal life is connected with a production of waste and rubbish. Not all of these ships have proper burning systems or well dosed containers for rubbish.

Anchoring of these ships, lasting several weeks, create a risk of pollution of the water and the shores of the bay. In 1984 r/v "Profesor Siedlecki" when taking water from the stream in the Ezcurra Inlet was turned around by heavy wind and coiled round its shaft of the screw the hose supplying water. The ship had lost its steerability and the screw its tightness on the hose. As a result, several hundred kilograms of oil flowed into the Ezcurra Inlet.

The weight of cargo carried to the "H. Arctowski" Station varied from 36.5 to 8164.8 tons per year (Tab. 1). During an excellent weather, which occurs very rare in this region, unloading takes from several to a dozen days. From the side of Ezcurra Inlet the shore is convenient for unloading but because of small depth in this region ships have to stop about 1.5 nM from the shore nearby Dufayel Island which makes the time of transportation longer. Quick changes of wind direction and strong tidal currents complicate unloading operations at ship, on water and at the shore.

Efficient and safe water transportation depends on wind direction and its velocity, on wave amplitude and on the presence of ice. There is always a great risk for people and materials and equipment carried. Food must be transported in freezing state (down to $-20°C$) and then on land it is put into two permanently working cool stores. Scientific equipment and light cargo are transported in small portable containers. Greases, oils and petrol are transported in barrels that are sometimes not tight enough to prevent leaking. Light

Table 1

Amounts (t) of cargo delivered during successive expeditions to the "H. Arctowski" Station

Cargo characteristics	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Station equipment (laboratories, vehicles, boats)	1709	261.5	43.5	41.1	45.9	1.6	0.3	1.3	931.3	7.1	3.1	117.1	3162.8
Building materials, paints	320	7646.1	142.4	210.2	21.4	0.2	2	0.4	60.9	5.4	0.9	4	8413.9
Technical materials, fittings	170	103.5	45.4	53	6.6	4	4.5	7.3	68	10.2	5.5	12.4	490.4
Fuels, oils, greases	507	82.5	101.2	490	77.2	0.7	8.5	672	2.5	—	7.3	266	2214.9
Scientific equipment	1	25.9	30.5	31.4	3.1	0.2	2.3	0.4	1.8	2.3	0.8	3.1	102.8
Personal equipment, medicines	1.3	10.2	1.7	2.5	4.2	1.9	2.4	2	4.1	9.8	4.7	1.3	46.1
Food	30	35.1	39.4	69.8	30.3	27.9	38.2	21.8	48.1	41.6	40.1	22	444.3
Total cargo brought in (netto)	2738.3	8164.8	404.1	898.0	188.7	36.5	58.2	705.2	1116.7	76.4	62.4	425.9	14875.9
Total cargo taken away		14.0	5.0	300.0	472.0	no data	57.0	90.0	58.0	21.0	13.0	150.0	1182.0

building materials, like boards, foamed polystyrene, foil, plastic, plates are transported in bulk and under heavy winds, reaching in this region 60 m/s, can be thrown away and spread over the region.

To unload the ship and to transport the cargo to the station located some 800 m to the south one needs: floating mechanical equipment, land transport facilities, cranes and mechanical lifts. The station uses three caterpillar amphibians (PTS) of 10 tons of transport capacity. Under good weather it takes half an hour for the amphibian to cover the distance between the ship and the coast. Therefore the amphibians have to make few dozens trips to unload the ship. For unloading of heavy equipment which cannot be carried by the amphibian a pontoon-ferry was used. It was pushed by a cutter of 180 HP of engine power. In these pushboats the cooler is exposed to damages when ice comes between the screw and the bottom. It happened twice and caused leaking of few dozens liters of cooler liquid into the Bay. The presence of water transport facilities with great number of people oblige ships' captains to assure security by other floating units. Usually plastic ship's shallops are used that are not well adapted for work in polar regions. The unloading creates the risk and strong psychic tension for many people not always experienced in polar conditions.

During our first expedition, when we did not know much about weather conditions, a violent storm has broken m/s "Zabrze" adrift. In this situation the captain has ordered to cut off the ferry moored to the ship's side and loaded with cargo which made ship's handling difficult. The screw of the clearly emerged ship set in motion have scuttled the cutter moored behind the ship's stern. We have lost ferry with cargo as well.

Unloading of engine fuels creates a risk of water and coast pollution. The "H. Arctowski" Station has a fuel container of a capacity of 1000 m^3, i.e. of about 830 tons; it is located at Point Thomas. The container has the outer jacket (of the same volume as the container), which protects from oil leaking in the case when the container is broken. For the transportation of fuel from tanker to the container two barges are used, each of the capacity of 16 tons and with a double bottom which, in the case when the barge's bottom is broken, protects from oil leaking. The barges are pushed by cutters. At the coast fuel is pumped over from the barge into the container. The main container must be filled every 3—4 years.

During the year the fuel is transported from the main container to the station by 3—7 ton cistern to 7 auxiliary tanks set near electric power station. In these tanks 13.6 tons of fuel can be stored. These tanks are surrounded by a ditch and oil neutralizers are amassed at hand. Fuel transportation is an especially difficult task in winter when pumping is performed during heavy frost and wind. Then there is a risk of oil leaking and even of an explosion. Fortunately serious accident did not happen so far.

In the electric power plant of the "H. Arctowski" Station three aggregates (each of 90 KW) work by turns. Summer demand for energy is about 40 KW and in winter it raises up to 90 KW. Because we do not have filters, exhausted gases are emitted into the air. Therefore the tundra in the vicinity of station is polluted with oil combustion products and heavy metals.

The land transport in the "H. Arctowski" Station is limited to several main roads where lorries, stripper, 3 amphibians, digger, trailers and two small cross-country vehicles move along. The roads are located in the area which extends from Point Thomas to the electric power station and stores and along the apartment building and laboratories and a storm ridge up to the lighthouse situated on prominent rocks. Along with emission of combustion gases, these transport vehicles caused hardening of storm ridges. The region adjacent to the buildings is devoid of vegetation as a result of mechanical destruction by walking people and running equipment. In 1988 for recultivation of this region an attempt of fertilization with penguin guano and fencing of some less attended places was undertaken, which formed experimental "gardens". Since the station is visited by many tourists, the way to the penguin colony situated in the region of SSSI No. 8 from the lighthouse along the beach on the coastal ridge up to the Rakusa Point was opened. Visits to the penguin colony take place in small groups with a guide.

Main studies carried out at the "H. Arctowski" Station need a work at sea. The station is equipped with two boats (cutters): smaller "Dziunia" and bigger, a deck one "Słoń morski". The lauching of boats and their beaching are performed with the use of slipway on caterpillar which can be pushed down and pulled out by the track stripper. It is the most safe way, but once it has also failed. It happened that heavy slip with a boat has pulled down the tractor not heavy enough and with broken brakes into the water. The tractor sank together with a driver in the region of Point Thomas. Only by chance has he managed to swim out from the depth of 10 m.

The coasts of the Admiralty Bay of a length of 84 km are diversified. 39 km are formed by glaciers, 26 km are rocky-cliff coasts and 19 km — sand and gravel coasts. Immediate landing is possible only in restricted area and is risky for equipment and people. In one case the cutter "Dziunia" coming close to the coast was stranded by surfs together with people on the beach.

Environmental changes caused by the use of technical means

The "H. Arctowski" Station is situated on stony and sandy ground of old storm ridges; the deeper ground is rocky. The coastal line in the vicinity of station varies slightly as a result of rubble movement due to strong waves caused by southern winds.

Freshwater stream running from nearby hills fills several shallow lakes situated before the storm ridge. Water comes from melting ice and for the station needs is taken by pumps out from the ground to containers in electric power station. In the ground there were installed: the water draining system and the system of water pipes heating, using the heat coming from the alternator cooling system. It changes the thermic regime of the ground which can be seen from melting snow on the surface. It prevents the pipes from freezing and guarantees water supply all the year round. Natural flood waters and lakes are a reserve for ground water and a reservoir of fire-fighting water. Since main buildings and laboratories are made of wood a risk of fire is great. In summer, water consumption is not limited. In winter, during heavy frost, there is sometimes a shortage of water.

A sewage of the main apartment building (kitchen, laundry, toilets) runs into a septic tank. Then, once a year, it is overpumped into the bay. This sewage plays a minor role in water manuring when compared with manuring by the neighbouring penguin and sea-elephant colonies.

Package materials create greater problems. Glass and metal are drowned at the mouth of the bay in the Bransfield Strait. Production of waste material is not large but many years of the station activity increase the amount of garbage from year to year in deepest parts of the Admiralty Bay (abt. 500 m depth). Trawling across the Admiralty Bay by r/v "Profesor Siedlecki", revealed in fishing net English tins which were 30 years old. Wood and paper are burned in an area distant from the station. Plastics, so far, are minimally used.

"H. Arctowski" Station is proud having a greenhouse. Apart from vegetables and flowers cultivated there it plays a great psychological role. The people long much more for a view of fresh plant than for vitamins contained in it. However, the soil imported can be the source of introduction of viruses, bacteria and fungi despite the ban of its removing out of the greenhouse. Strongly illuminated greenhouse attracts birds especially at the end of summer when it gets dark. Food waste near kitchen exert bigger effect on birds. Despite the official ban of bird feeding at the station great skuas and sheathbills are feeding on it.

The power of radio transmitters at the "H. Arctowski" Station is high (5 KW) and they emit a wide range of the broadcast band. Radio-communication of the station is used under some restrictions. Radar or tele-communication equipment are lacking. Anyway a large antenna masts and spread wires can injure the birds during heavy winds.

The region of the "H. Arctowski" Station is very beautiful and attractive for tourists. One can find a lot of vertebrae and other bones of whales. They are a part of the landscape and testimony of history and of whalemen activity in this region at the beginning of XX century. Except for didactic and museum purposes their collection is forbidden by internal regulations.

Number of tourists visiting the "H. Arctowski" Station increases every year; they are usually old, serious and disciplined. Therefore it is rather the development of transport means that creates a threat. There are still more ships, boats and helicopters coming to the station. Once, during a fatal accident a Chilean helicopter crashed in the region of the Station in 1986.

Meeting with tourists creates a risk of infection for the permanent inhabitants of the station isolated under polar conditions for a long time. It would be desirable for the guests suffering from cold to introduce obligatory masks as is practiced in Japan.

The introduction of new species, alien in this region has also happened in 1988, under the metal doormat the species of *Poa* grew, that was not recorded in this area before. Cockroaches were also encountered at the station.

Number of people staying at the station

Until 1988, i.e. after twelve expeditions, 188 people have worked at the "H. Arctowski" Station in one year cycle, whereas in summer — 542 people (Tabs. 2 and 3) (Fig. 2). Altogether, including some foreign scientists, about 750 people stayed at the station. The strangers came from Argentina, Belgium, Canada, Monaco, New Zealand, Peru, Spain, USA, USSR, West Germany (Tab. 2).

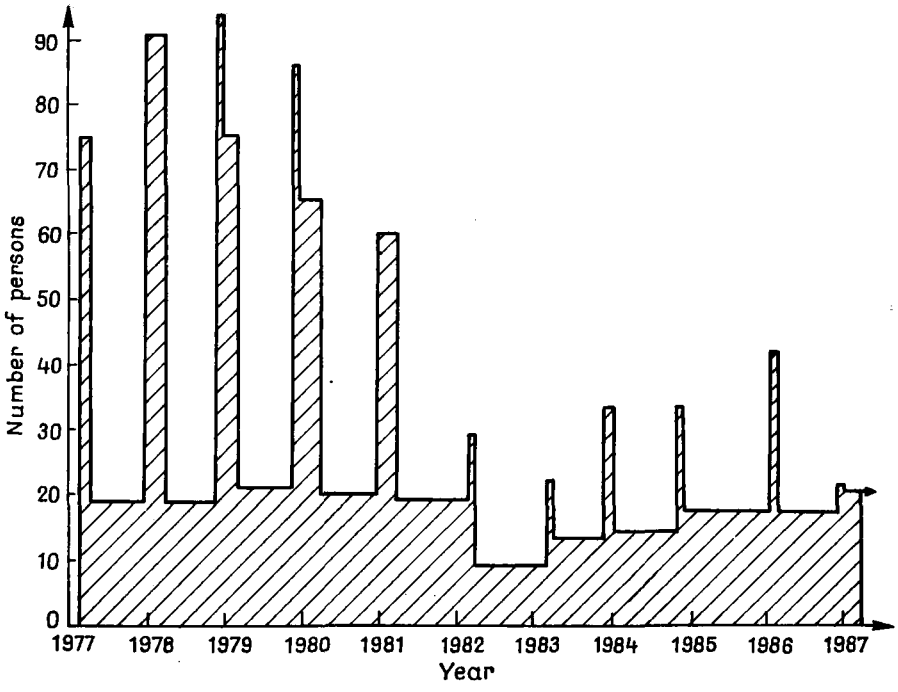

Fig. 2. The number of people staying in the "H. Arctowski" Station during successive expeditions

Table 2

Duration of periods of polar expeditions; staying days of expedition participants at the "H. Arctowski" Polish Antarctic Station

Expedition — year	Managers: — manager of expedition — technical deputy-manager — manager of wintering group — deputy-manager of wintering group	Ship — captain	Date: of departure from Poland	Date: of arriving at the station	Date: of departure from the station	Date: of arriving to Poland	Total of staying days of expedition participants of Polish Academy of Sciences	Number of foreign guests (country) x days of staying	Total of staying days of all participants
I — 1976/77	S. Rakusa-Suszczewski M. Skowron J. Jersak A. Szmat	m/t "Dalmor" — cpt. M. Lis m/s "Zabrze" — cpt. Z. Krzymiński	29.12.1976 31.12.1976	02.02.1977 27.01.1977	27.03.1977 02.03.1977	17.05.1977 04.04.1977	8950		8950
II — 1977/78	M. Zalewski L. Rościszewski J. Jucha	m/s "A. Garnuszewski" — cpt. T. Kalicki	20.11.1977	20.12.1977	24.03.1978	24.04.1978	9668	2 (USA) × 120	9908
III — 1978/79	S. Rakusa-Suszczewski J. Rembiszewski T. Górski	m/s "A. Garnuszewski" — cpt. W. Rymarz	05.11.1978	04.12.1978	15.12.1978 27.02.1979	15.01.1979 15.05.1979	12611	1 (BRD) × 76; 1 (New Zealand) × 83	12770
IV — 1979/80	A. Myrcha J. Zalewski E. Moczydłowski K. Potrzebowski	m/s "A. Garnuszewski" — cpt. T. Drączkowski m/s "A. Ledóchowski" — cpt. B. Duma	10.11.1979 02.1980	07.12.1979 09.01.1980	19.12.1979 22.03.1980	15.10.1979 04.05.1980	12825	3 (USSR) × 5; 2 (DDR) × 5	12850
V — 1980/81	K. Birkenmajer L. Rościszewski M. Zawadzki	m/s "Żuławy" — cpt. L. Skelnik "Pogoria" — cpt. K. Baranowski r/v "Prof. Siedlecki" — cpt. M. Babiak m/s "A. Garnuszewski" — cpt. T. Drączkowski	28.11.1980 07.12.1980 12.01.1981 24.02.1981	08.01.1981 04.02.1981 16.03.1981 23.03.1981	12.01.1981 04.02.1981 28.03.1981 27.03.1981	03.1981 08.04.1981 04.1981 27.04.1981	12161	4 (USA) × 159 2 (Canada, Monaco) × 54	12905
VI — 1982/83	R. Wróblewski	"Neptunia" — cpt. M. Wojciechowski	09.02.1982	21.03.1982	25.03.1982	18.05.1982	3383	4 (USA) × 150; 4 (BRD) × 134	4519
VII — 1983/84	M. Zdanowski Z. Gałązka	m/s "Zawichost" — cpt. cpt. T. Masłyk, M. Lis	08.01.1983	13.03.1983	19.03.1983	29.04.1983	3591	1 (BRD) × 132	3729
VIII — 1984/85	R. Stępnik K. Potrzebowski	r/v "Prof. Siedlecki" — cpt. R. Ludwig	22.10.1983	05.12.1983	11.01.1983	20.02.1983	5729	4 (USA) × 123; 2 (USA) × 12; 7 (Brasil) × 47 1 (Brasil) × 6; 6 (BRD) × 52	6892
IX — 1985/86	T. Wojciechowski J. Łądka	m/s "A. Garnuszewski" — cpt. R. Marcinkowski	30.10.1984	29.11.1984	09.12.1984	28.01.1985	7402	3 (Brasil) × 27; 10 (Brasil) × 22; 1 (USA) × 34; 4 (USA) × 70; 4 (USA) × 104	8433
X — 1986/87	E. Kołakowski Z. Cudek	m/s "Koral" — cpt. J. Boruta	21.12.1985	30.01.1986	26.02.1986	06.04.1986	6105 8573	14 (Chile) × 3; 3 (Spain) × 32; 4 (USA) × 78 1 (USSR) × 364; 4 (USA) × 70; 4 (Belgium) × 68;	6555 9511
XI — 1987/88	R. Wiśniewski R. Gładysz	air transport m/s "Koral" — cpt. J. Boruta	19.11.1986	17.12.1986	07.01.1987	27.02.1987	8400	1 (Argentina) × 14; 2 (BRD) × 38 lack of data	
XII — 1988/89	P. Presler K. Potrzebowski	m/s "A. Garnuszewski" — cpt. A. Drapella	04.12.1987	05.01.1988	02.02.1988	03.03.1988			

Most numerous teams worked at "H. Arctowski" in summer seasons from 1978/79 to 1981/82. Least numerous expeditions took place in 1982/83 and 1983/84 when only 9 and 13 people, respectively, wintered at the Station and summer groups were cancelled. The Station is also visited by many tourists, scientists and ships' crews. Polish trawlers arrived here in 1977/78 and 1978/79 taking, among others, drinking water. Medical help was also given to fishermen. Five appendix operations were performed at the Station. Aid was given to the foreign ships as well.

Touristic ships, like "Lindblad Explorer" (95 passenger places) or "World Discoverer" (120 passenger places) often visit the Station. They use to arrive several times in the summer. On the average that means some 100 visitors during each anchorage. The crowdiest season was 1987/88 — 1800 visitors; average number of these guests in summer (from January to March) was 770 people. Altogether 9000 people visited the Station (Tab. 3).

Table 3

Number of people staying at the Station during following expeditions

Expedition	Number of expedition participants		Number of days at the Station		Visits *
	wintering group	summer group	wintering group	summer group	
I 1976/77	19	56	250	75	200
II 1977/78	19	91	255	53	490
III 1978/79	21	75	287	74	400
IV 1979/80	20	64	268	110	700
V 1980/81	19	60	358	89	600
VI 1982/83	9	29	363	4	850
VII 1983/84	13	22	261	9	840
VIII 1984/85	14	33	322	37	1200
IX 1985/86	17	33	416	10	1700
X 1986/87	17	41	294	27	440
XI 1987/88	20	38	364	21	1800
XII 1988/89	20	20	391	29	no data
Total	208	562	3889	538	9220

* — short visits of tourists, scientists and members of other expeditions.

Area surrounding "H. Arctowski" Station being under direct influence of human activity amounts to 0.28 km^2, area of the immediate vicinity of Station buildings — 0.16 km^2, and the area protected by internal regulations is 0.12 km^2 (Fig. 1). It can be estimated that in summer an average population density is 175 person/km^2, and in winter — 60 person/km^2. For comparison one can note that the area around similar Norwegian polar Arctic station in Ny-Alesund (Svalbard) is 0.4 km^2 (Krzyszowska 1988) and around Polish polar station in Hornsund (Svalbard) is 0.06 km^2 (Krzyszowska 1985).

Technical work and the amount of cargo delivered

The station was built by a team of 75 people together with the crews of m/t "Dalmor" and m/s "Zabrze" within 57 days. Heavy equipment made 62% of the cargo brought in. It consisted of 31 container-houses with all facilities, steel halls, transport means as: cross-country vehicles, trucks, caterpillar carrier (ATS), 3 amphibian carriers (PTS), 2 cranes, a stripper. For water transport there were used 3 motor cutters, 6 boats, 16 steel pontoons, 2 rubber pontoons. During the first expedition there were built: apartment building (340 m^2), hydrophores (15 m^2), hydrobiological laboratory (60 m^2), aquarium laboratory (15 m^2), radio-meteorology center (60 m^2), steel hall (432 m^2), wooden hall (378 m^2), cold store (34 m^2). Also, electrical supply line and radio-telephone line were installed.

The biggest amount of building materials (7646 tons) (Fig. 3) was delivered to the station during the second expedition. Then there were built: new warehouse (387 m^2), fuel tank (1000 m^3), fuel pumping station, summer groups' laboratory (100 m^2), two apartment houses for summer groups (2×30 m^2), geophysical laboratory (68 m^2), two magnetic laboratories (2×15 m^2), new drinking water intake with pumping station and underground water-pipe network of total length of 240 m. The main station building was restored and developed, uderground sewage setting tank (12 m^3) and external lighting system (of the length of 380 m) were installed. In station buildings a telephone net was fitted. The lighthouse was built. Its geographic coordinates were revised in 1987/88 and now they are −62°09′41″.56, and 301°31′49″.99.

The goals of the third expedition were the construction of a water intake for biological laboratory, conservation of buildings and equipment, development of meteorological station and greenhouse construction. The expedition cargo consisted of building materials making 35% of a total cargo and of technical materials (11%). Ten tons of fuel for helicopters were delivered.

In the fourth expedition 490 tons of fuel from m/s "Gryf Pomorski" were delivered (Fig. 3). The station of oil distribution was built. During the fifth expedition automatic system of aggregate supplying with fuel was installed. The crews operating at the station repaired and conserved the buildings, and made routine works connected with station servicing.

The aim of technical activities after 1980 was to help scientific work being also necessary for the continuing operation of the station. In 1985 new heavy equipment: bulldozer, transporter, crane and two container-houses were delivered to the station (Fig. 3).

Electric energy was originally supplied by six generators PAD-36, which were exchanged during the eighth expedition for 3 Diesel engines of 90 KW

each. They are working in shifts using a diesel oil DZ-50 (IZ-40). A considerable amount of diesel oil was delivered in 1984 (672 tons) and in 1988 (250 tons) (Fig. 3). Fuel consumption is 600—700 l/24 h and during a year it varies from 146 to 255 tons (Tab. 4).

Along with fuel, food was a great part of cargo delivered (Tab. 1). The biggest amount of food came with the VIIth expedition: up to 10.3 kg/person/24 h, which was also a reserve for the next eighth expedition. Average amount of food delivered was 4.9 kg/person/24 h (Tab. 5).

Since the beginning of Station functioning 13700 tons of materials were delivered to the area of 0.28 km^2 (Tab. 1) which makes the total load of 48.9 kg/m^2. This value diminished by the amount of food and fuel used is 43.4 kg/m^2. For comparison, the amount of materials existing in the vicinity of Polish polar station in Hornsund was 31 kg/m^2 (Krzyszowska 1986) and that of the materials brought to the Antarctic Soviet scientific stations during 25 expeditions was 160783 tons (Širšov and Gindin 1985). An average amount of water used at the "H. Arctowski" Station was 123 l/person/24 h.

Waste production and treatment

Every few years the scrap storage is removed from the "H. Arctowski" Station by ship. During IV-th expedition 250 tons of scrap and waste were taken out and during V-th expedition 427 tons (Tab. 1).

Until 1988 unburned waste, i.e. glass, tins, metal, were stored in fuel barrels (200 l) and drowned in the sea at the mouth of the Admiralty Bay in the Bransfield Strait. An average number of barrels drowned was 60—80 pieces a year. The major amount of waste is connected with foodstuffs. After one year operation the station leaves 14 thousands of glass package and 8.5 thousands of metal package which are drowned afterwards. In the nearest future the waste is expected to be taken out of the Antarctic region.

Local and global pollution with chlorinated hydrocarbons

The pollution of the Antarctic region reflects a global pollution and can show the tendencies of many years changes. As it is known, during last 15 years, the global use of DDT decreased whereas using of HCH in agriculture increased. Moreover the amount of PCB in the atmosphere is now higher as a result of industrialization. It was proved by the presence of these compounds and by changes of their content in living organisms studied by Polish scientists in the region of the South Shetlands and the "H. Arctowski" Station (Łukowski 1978a, b, 1983a, b, Karolewski and Halba 1987, Łukowski and Ligowski 1987,

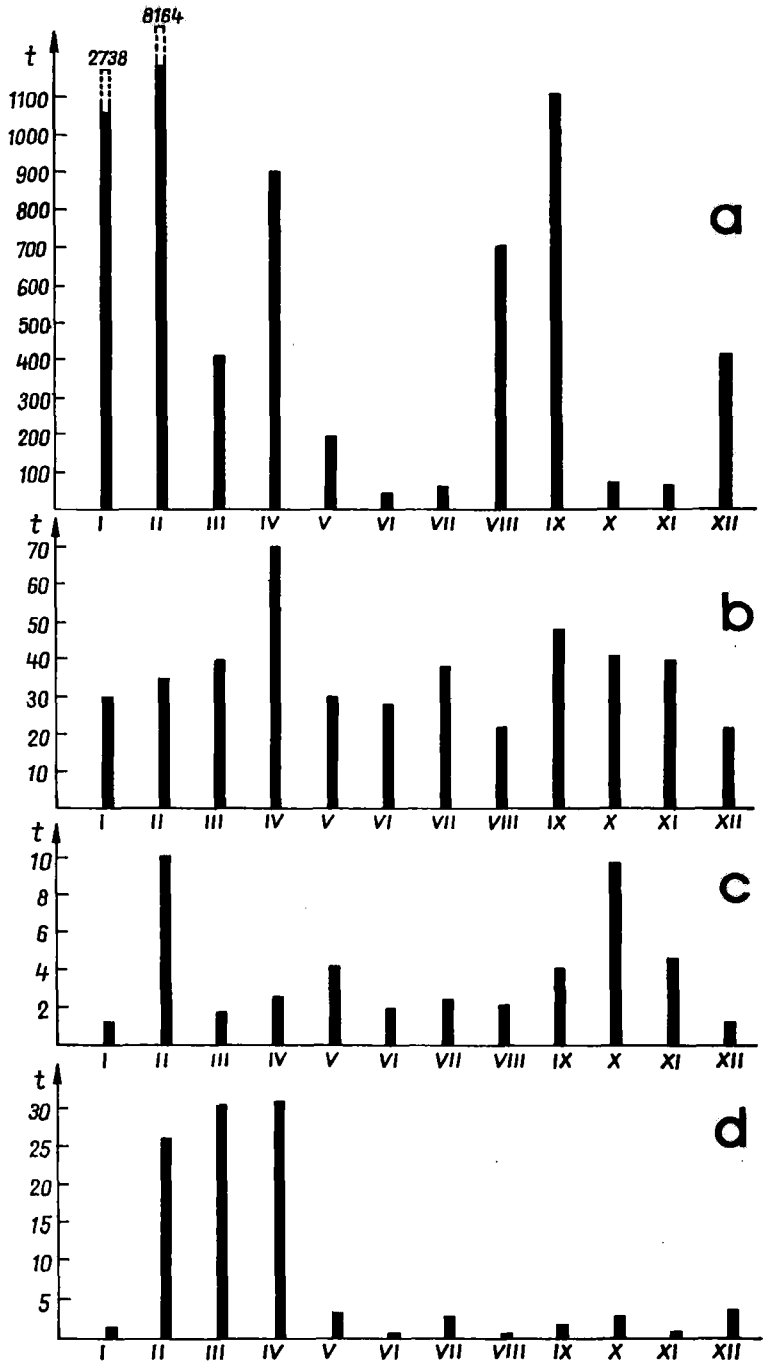

Fig. 3A. Amount of cargo (t) delivered to the "H. Arctowski" Station during successive expeditions: a — total cargo, b — food, c — personal equipment, d — scientific equipment

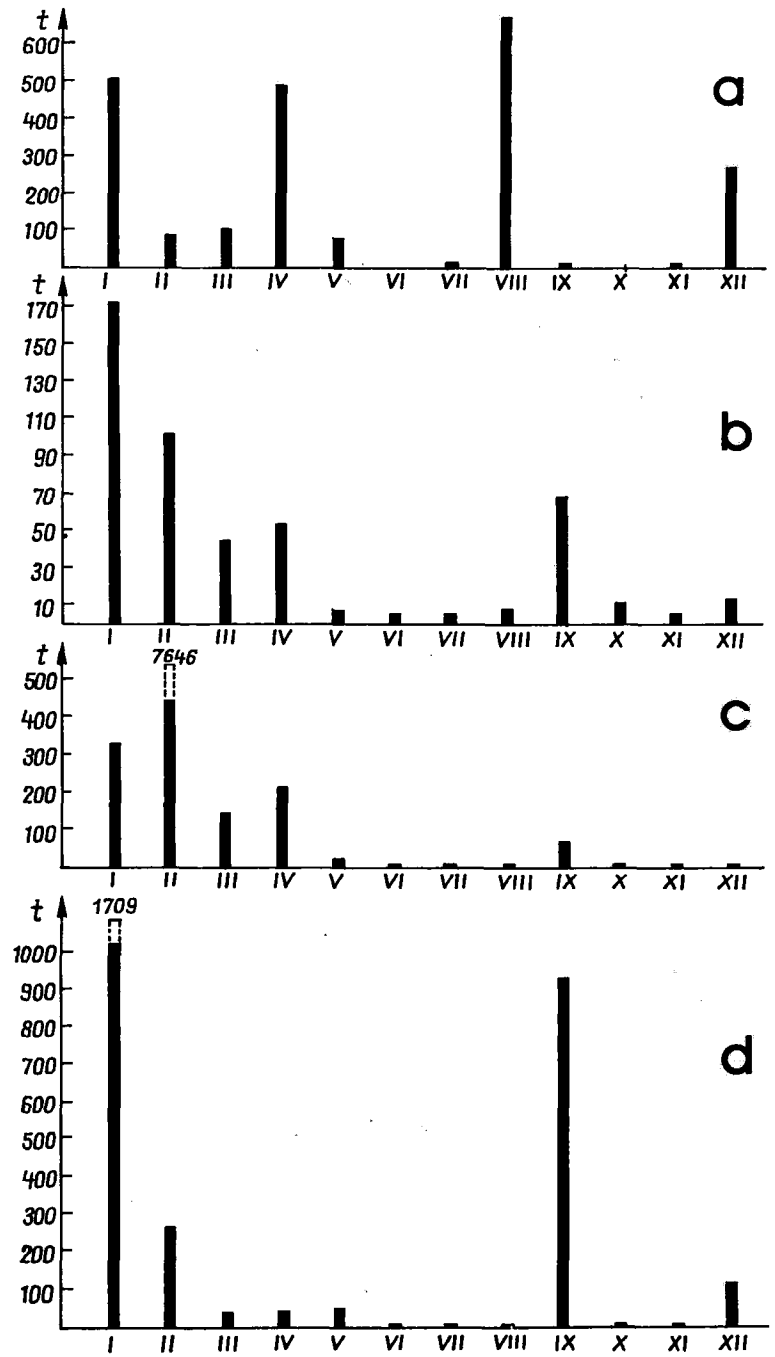

Fig. 3B. Amount of cargo (t) delivered to the "H. Arctowski" Station during successive expeditions: a — fuels, oils, greases, b — technical materials, fittings, c — building materials, paints, d — station equipment (laboratories, vehicles, boats, etc.)

Table 4

Amount of fuel (tons) used during V—XI expeditions

Expeditions	V	VI	VII	VIII	IX	X	XI
Diesel oil DZ-50 (IZ-40)	215	150	146	167	200	170	255
Engine oil superol (CC, DC)	lack	2.5	3.0	1.4	3.0	2.4	3.2
Other oils and greases	of	0.5	1.1	3.0	0.9	1.2	0.6
Ethyl gasoline	data	3.0	1.2	3.5	3.2	1.2	1.8
Aircraft fuel		1.9	—	20	—	—	—

Table 5

Amount of food (netto), number of waste food package during following expeditions

Expedition	Food		Number of glass package		Number of metal package	
	tons	kg/person/24 h	pieces	piece/person/24 h	pieces	piece/person/24 h
I	30	3.3		lack of data		
II	35.1	3.6	1550	1.6	9540	1.0
III	39.4	3.0	2550	2.0	13200	1.0
IV	69.8	5.4	26270	2.0	18490	1.4
V	30.3	2.3	18600	1.4	9900	0.7
VI	27.9	4.9	12400	2.2	6600	1.2
VII	38.2	10.9	19000	5.1	9670	2.6
VIII	21.8	2.2	11750	1.2	5740	0.6
IX	48.1	5.7	21280	2.5	6940	0.8
X	41.6	6.8	28120	4.6	6850	1.1
XI	40.1	4.7	13260	1.5	6760	0.8
Total	422.3		154780		93690	
Mean	38.4	4.7	14068	2.4	8517	1.1

Łukowski, Karolewski and Górski 1987). Transportation of DDT, HCH and PCB to the Antarctic and absorbing of these compounds into the organisms of higher level of the trophic chain with omission of the Antarctic primary production can also be performed by some wandering species of birds flying from the North and even from the northern hemisphere as well as by some fish species and whales crossing through the Antarctic Convergence. Seasonal migrations of animals and transportation of plankton (e.g. krill) by currents from the area of greater pollution (Drake Passage) to that of lesser pollution (the South Sandwich Islands) facilitate the distribution of DDT, HCH and PCB in the Antarctic ecosystem (Łukowski and Ligowski 1987).

In the region of the "H. Arctowski" Station surrounded by glaciers and in the basin of the Admiralty Bay the amount of chlorinated hydrocarbons in phytoplankton is higher than oustide of the bay (Łukowski and Ligowski

1987). It seems to be the result of former accumulation and present washing out of these compounds from glaciers which have been intensively melted during last few years in the process of recent deglaciation of the King George Island.

The CH_3 remnants not absorbed by penguins and washed out of guano and ornithogenic soils in the region of many colonies of penguins feeding mainly on krill can also be the source of local pollution increase in the basin of Admiralty Bay (Łukowski, pers. comm.).

Seasonal fluctuations of ice cover on sea without doubt can influence seasonal accumulation of chlorinated hydrocarbons and their transmission into the water while melting of the ice and snow cover. This problem is not yet worked out. The region of the "H. Arctowski" Station traces of DDT, DDD, DDE, HCH and PCB. They were found in phytoplankton, in birds and their eggs and in all pinniped species. The station is not a source of DDT or HCH, however in its region small amounts of plastic package were burnt. Also, oil paints are used. Strong winds carrying snow and sand take off paint particles that pass into environment; the same concerns old paint remnants scraped before new painting. Possible influence of these local PCB sources is minimal but it must be ruled out by the ban of plastic burning and the change of the quality of paints used.

Heavy metals

Studies carried out in the region of the Admiralty Bay proved that the contents of Cu, Cd and Pb in rain water was slightly higher than their contents in sea water, whereas contents of Co, Ni and Zn was higher in sea water (Pęcherzewski 1987). The amount of Cu, Pb and Zn in rain water over North Sea is several dozen times higher than in the region of the "H. Arctowski" Station. The contents of heavy metals in lichens growing near the waste dump is much greater than in more distant regions (Olech 1991).

Conclusions

To minimalize the negative influence of the "H. Arctowski" Station upon the ecosystem of the Admiralty Bay its functioning should be reorganized by:

1. Reduction of unloading time; because the risk of accident increases with prolongation of loading, unloading, navigation between ship and land, presence of people on transporting carriers and using of heavy equipment on land. A barge of great load capacity should be used and transport of cargo to the station and out of it should be performed with the use of containers.
2. Reduction of fuel variety and elimination of these transport means which use fuel different from crude oil. It will limit the number of barrels with petrol,

diesel oil, grease and will lower a risk of pollution. Lead-free petrol should be introduced.

3. Activity of the station should be limited to the area already managed. Internal roads and tracks should not be changed or extended. The storage of materials and waste as well as building of new houses should be located within the already used area.

4. Concentration of apartment buildings and laboratories will allow to shorten electrical, heating and water-sewage systems and will enable to save energy. Installations not used should be removed.

5. Rubbish, used grease, accumulator batteries and especially oils, plastic package which are not allowed to burn in the Antarctic should be removed from the area. It is necessary to install filters of combustion gas emitted by the electric power station and the incinerating plant for wood and paper. In the greenhouse hydroponics should be applied to decrease the risk of possible introduction of alien species into the ecosystem.

6. Closer, international cooperation, especially with countries having stations at the Admiralty Bay and on the whole King George Island in sharing transportation of people, equipment, materials, waste to and out of all stations. It will reduce the number of ships operating in this region and will diminish overload costs.

7. Strict obeying to the rules of Antarctic nature protection approved by Antarctic Treaty. Applying the recommendations of SCAR and CCAMLR.

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