

The Bacteria *Azotobacter*, *Beggiatoa*, and *Desulfovibrio* in the Surtsey soil

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INTRODUCTION

The soil of Surtsey contains only extremely low amounts of organic matter and very low quantities of available nitrogen. Therefore, it was not surprising to find that the first colonizers of importance were certain blue-green algae and mosses, since both of them are photoautotrophic with low nitrogen requirements. Chemoautotrophic bacteria may also act as pioneers in this type of soil and can be of importance for further development of plant associations. For instance, bacteria of nitrification together with denitrifiers were commonly occurring in the first stage of colonization. It is also of interest to study other groups of bacteria linked to the nitrogen cycle of Surtsey and characterized by ability to live under severe conditions.

The occurrence of the following bacteria are studied in this paper: *Azotobacter*, *Beggiatoa*, and *Desulfovibrio*, which all have the power to fix nitrogen. Schwartz & Schwartz (1972a, 1972b) have made similar investigations in the same area.

This investigation is a continuation of our Surtsey studies which started in 1970 (Henriksson *et al.*, 1972, Henriksson & Henriksson 1974a, 1974b, Henriksson & Rodgers, 1978).

SOIL SAMPLING AND ENRICHMENT CULTURES

The soil sampling was performed in the same way as earlier described (Henriksson & Henriksson 1974a). The soil samples were collected from the soil surface only, which means the upper 1 cm layer. The localities studied are described and plotted on maps by Henriksson & Rodgers (1978, Tables 1—2, Figures 1—2), and the samples from 1976 have also been studied by Hedin (1978) investigating the terrestrial microfauna. They correspond to those of 1974. The sites were chosen on the basis of being an interesting object of study,

and therefore are not quite typical for the islands as a whole. The days of sampling were July 29—31 and Aug. 1—3 1974 and Aug. 7—10 1976.

About 1 g of soil from each locality, divided into two parallels, was used for the enrichment cultures of each of the three types of microorganisms studied.

The medium for the enrichment of *Azotobacter* was the same as earlier used (Henriksson & Henriksson 1974a). The *Azotobacter* growth was determined by studies of the film developed on the medium surface.

For the enrichment cultures of *Beggiatoa* the medium recommended by Aaronson (1970) was used and was prepared as follows: Dried hay was extracted 3 times at 100°C in large volumes of water. The extracted hay was then drained and dried at 37°C. A suspension of 0.8 g hay/ 100 ml of water was used as medium after autoclaving. The growth of *Beggiatoa* was determined by studies of the surface of the medium. For that purpose a microscope with phase contrast equipment was used.

The enrichment medium used for *Desulfovibrio* was as follows (Parkinson *et al.* 1971): K_2HPO_4 0.5 g, NH_4Cl 1.0 g, Na_2SO_4 1.0 g, $CaCl_2 \cdot 6H_2O$ 0.1 g, $MgSO_4 \cdot 7H_2O$ 2.0 g, sodium lactate (70% solution) 3.5 g, yeast extract 1 g, $FeSO_4 \cdot 7H_2O$ 0.002 g, water 900 ml (pH 7.5), and sodium thioglycollate 0.1 g, ferrous ammonium sulphate 0.1 g, water 100 ml (pH 7.4 ± 0.3). The two solutions were separately autoclaved. The bottles were completely filled. The blackening of this medium indicates presence of sulfate reducing bacteria.

All cultures were incubated at 20°C for 12 weeks.

In the cases where the bacteria studied were found in at least one-third of the enrichment cultures, the bacteria have been recorded as present

in the Surtsey soil; and if never found as not being present.

RESULTS AND DISCUSSION

The presence of the bacteria *Azotobacter*, *Beggiatoa*, and *Desulfovibrio* in soil samples from Surtsey is presented in Table 1.

Table 1

Nitrogen fixing organisms studied in enrichment cultures originating from about 1 g of soil. The table includes about 15 localities each year, "+" signifies that the bacterium is found in at least one-third of the enrichment cultures, "-" signifies that the bacterium is never found.

	1974	1976
<i>Azotobacter</i>	-	+
<i>Beggiatoa</i>	+	+
<i>Desulfovibrio</i>	-	-

It is of interest to find that in 1976 *Azotobacter* is a part of the microbial life on Surtsey. Since *Azotobacter* grows heterotrophically, the bacterium is of very little importance as a nitrogen fixer in the upper soil layer of Surtsey in comparison to the blue-green algae. However, when growing in the rhizosphere of the emigrated phanerogams, *Azotobacter* may play an important role as supplier of nitrogen to the associated plants, since the roots are able to give off organic matter to the surroundings in more or less degrees.

Beggiatoa is facultative chemoautotrophic and is able to use hydrogen sulfide as an energy source. This bacterium occurs in fresh water and marine environments containing hydrogen sulfide and is common in mud. It therefore seems surprising to find *Beggiatoa* species around the crater borders of Surtsey belonging to the first emigrants. The soil analyses of the Surtsey soil show very low content of sulfur (Henriksson & Henriksson 1974a). However, hydrogen sulfide in soil disappears easily at sampling, and therefore is not included in these actual analyses, but the smell of hydrogen sulfide on the island indicates its presence.

From an ecological point of view *Beggiatoa* is

probably not an important link in the nitrogen cycle nor in the sulfur cycle of Surtsey.

Sulfate-reducing bacteria (such as *Desulfovibrio*) have not yet been found on Surtsey. Enrichment cultures from soil sampled in 1974 near the airport of Heimaey, showed, however, that they did occur there. Our analyses indicates that the microbial sulfur cycle of Surtsey is still not quite complete.

ACKNOWLEDGEMENTS

Support for travel to Surtsey was provided by the *Swedish Natural Research Council* and accommodation on Surtsey by the *Surtsey Research Society*.

ABSTRACT

Enrichment cultures from soil samples collected from different localities in 1974 and 1976 showed that *Azotobacter* was not found in the 1974 samples but was common two years later. On the contrary, *Beggiatoa* species were found both years but *Desulfovibrio* has not yet been recorded. The ecological importance of these bacteria for the microbial development of the Surtsey soil is mentioned.

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