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Bacteriological Quality of the Sand Beach in Sopot (Gdansk Bay, Southern Baltic)

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Abstract

This paper presents the results of two year's of research of the coastal seawater and sandy sediments along the beach in Sopot. The investigations were performed from May 1997 to April 1999. Four testing sites, perpendicular to the shore, were chosen in the area located between the mouths of two streams, Grodowy Potok and Kamienny Potok. It was revealed that the total number of mesophilic bacteria increased as distance from the waterline increased. In contrast, the number of *E.coli* was highest in the coastal water and in sand points close to the water. This indicates that there are two sources of microbiological pollution at work on sandy beaches. The first source is seawater which contains *E. coli* bacteria and the second is polluted air from the land that conveys the mesophilic bacteria. The high levels of *E. coli* bacterial pollution in the sand in the spring-summer season indicate that it is essential to monitor the sanitary conditions of this area during this period.

Keywords: sand beach, microbiological pollution, mesophilic bacteria, *E. coli*

Introduction

Sopot beach, located along the coast of Gdansk Bay, is one of the most attractive tourist destinations in Poland and it hosts thousands of Polish and foreign visitors annually. There are at least ten streams and sewage drains within four kilometers of the beach and all of them contribute to the microbiological pollution of the coastal waters [1, 2]. The evaluation of the sanitary conditions of waters used for recreational purposes is based on the number of fecal coliforms (FC). According to the standards of the Polish Sanitary Inspectorate, up to 1000 FC/100 ml of water is allowed and only the coastal waters are systematically monitored. The sanitary assessment of sand, which is an especially attractive place for children's recreation, is not addressed. Microbiological investigations of waters and sandy sediments in the region of the Sopot seaside resort were performed. The investigation area was located between the outlets of two streams, Grodowy Potok and Kamienny Potok (Fig. 1).

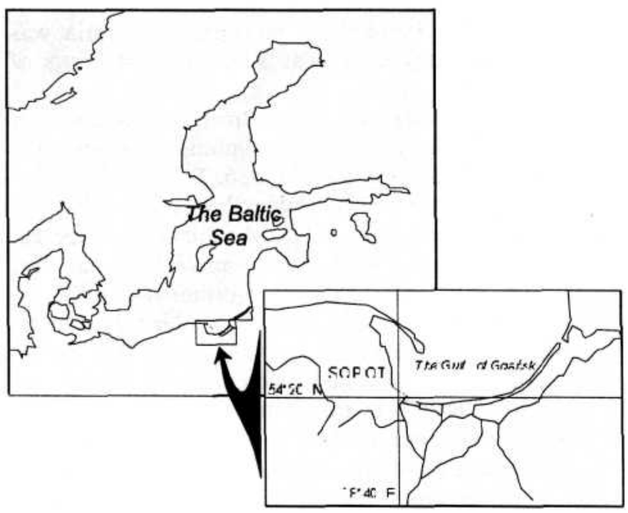

Fig. 1. Study area.

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Materials and Methods

Site Description

Sand samples were collected at four testing sites. Site I was located at a distance of 1.0 to 1.5 m from the waterline at a depth of 0.5 m, site II was on the boundary of the water and the land, site III was situated in the middle of the beach, approximately 32 m from the waterline, and site IV was in the sheltered region of the dunes, approximately 60 m from the seashore (Fig. 2). Water samples were taken at site I from 30 cm below the surface and sand samples were collected from the 0-0.5 cm layer.

At sites II, III and IV, 0-15 cm sedimentary core samples were taken. Three parallel cores were collected from these three sites at a distance of about 50 cm, and then each of them was divided into three sections - 0-5, 5-10 and 10-15 cm. An average sample was obtained by mixing corresponding layers. Additionally, sediment samples were taken at a depth of 50-70 cm at site III and at a depth of 50 cm at site IV. Water samples were placed directly into sterile 100 ml glass bottles. A sterilized stainless steel sampler 10 cm in diameter was used for collecting sediments. All samples were transported in cool containers and the laboratory tests were performed within two hours of collection. The air temperature was also recorded. A total of nineteen series of samples were collected over a two-year period from May 1997 to April 1999 at twelve points located at four sites. In total, 221 samples of sand and 19 samples of water were collected.

Bacteriological Analyses

The sample of 100 g of sand was mixed with 100 ml of Ringer solution diluted four times with 0.28% sodium pyrophosphate additive. The solution was shaken for 20 minutes with a type 358S laboratory shaker, decanted for 2 minutes, and diluted to a range of 10^{-1}-10^{-3} [3]. The number of mesophilic bacteria was denoted using nutrient agar at 37°C after 48 hours of incubation.

The medium Fluorocult LMX Broth modified ace. to Manafi and Ossmer (Merck) for simultaneous detection *E. coli* and coliforms was used [4, 5, 6, 7]. The high nutritional quality of the broth enables high growth rate of coliforms and by presence of lauryl-sulphate in large extent inhibits the growth of gram-positive bacteria. Two specific substrata chromogenic: 5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside (X-GAL) which is cleaved by coliforms to blue-green product, and the highly specific for *E. coli* (producing β-glucoronidase), fluorogenic: 4-methylumbellferyl- β -D-glucuronide (MUG) are present. Bacteria were cultured to 48 hours at 37°C. In case of a positive reaction for coliforms the broth turned a blue - green color (X-GAL reaction). *E.coli* was distinguished by the presence of β-D-glucoronidase (more specific than lactose fermentation) [8] which decomposes fluorogenic substrate - MUG. In case of presence of *E.coli* the light blue fluorescence of the methylumbelliferyl in the broth (MUG - reaction) was visible under UV light (366 nm). The MUG positive tubes were confirmed for the presence of *E. coli* by indole production into tryptone water (Merck) after incubation at 44.5° for 24 h.

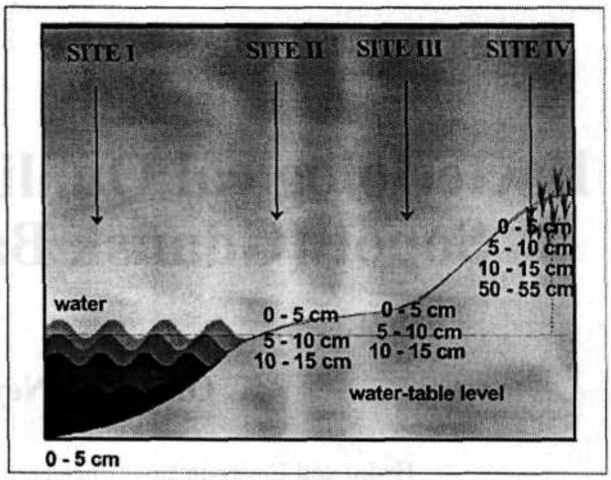


Fig. 2. Location of test sites.

Calculation of Results

The results were analysed using Statistica. The geometric mean of the number of bacteria, the median, maximal and minimal values and 50% percentiles for the total time of investigation, in subsequent months, testing sites and sand layers were determined. The results are presented in a semi-logarithmical scale denoting the colony forming units (CFU) of mesophilic bacteria per 1 g of dry sand mass or per 1 ml of water. The number of *E. coli* is indicated as MPN per 100 g of sand or 100 ml of water.

Results

Figure 3 presents changes in the geometric mean monthly concentrations of mesophilic bacteria in sand samples from May 1997 to April 1999 along with the

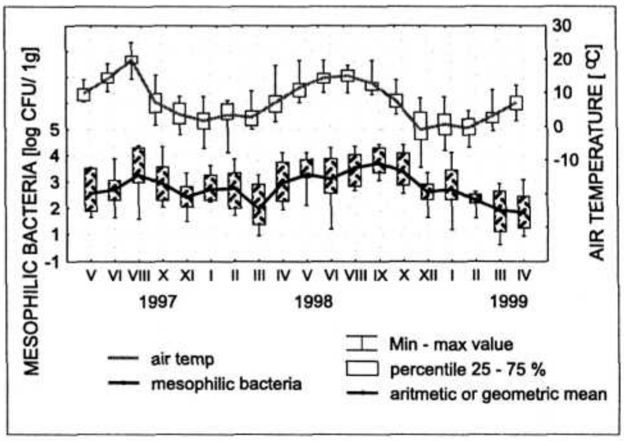


Fig. 3. Air temperature and concentration of mesophilic bacteria sand.

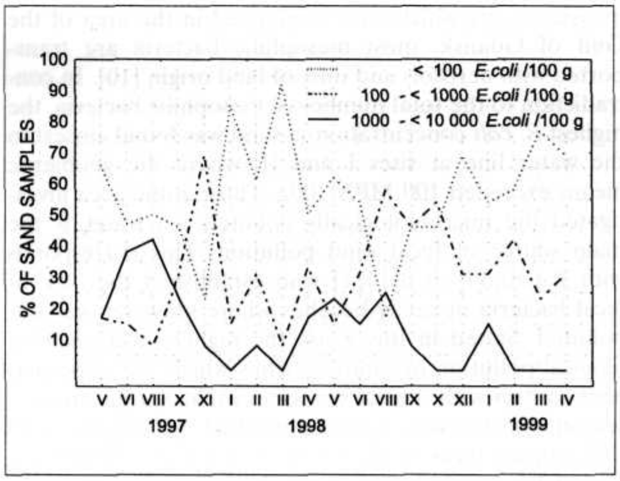


Fig. 4. Concentration of *E. coli* in sand.

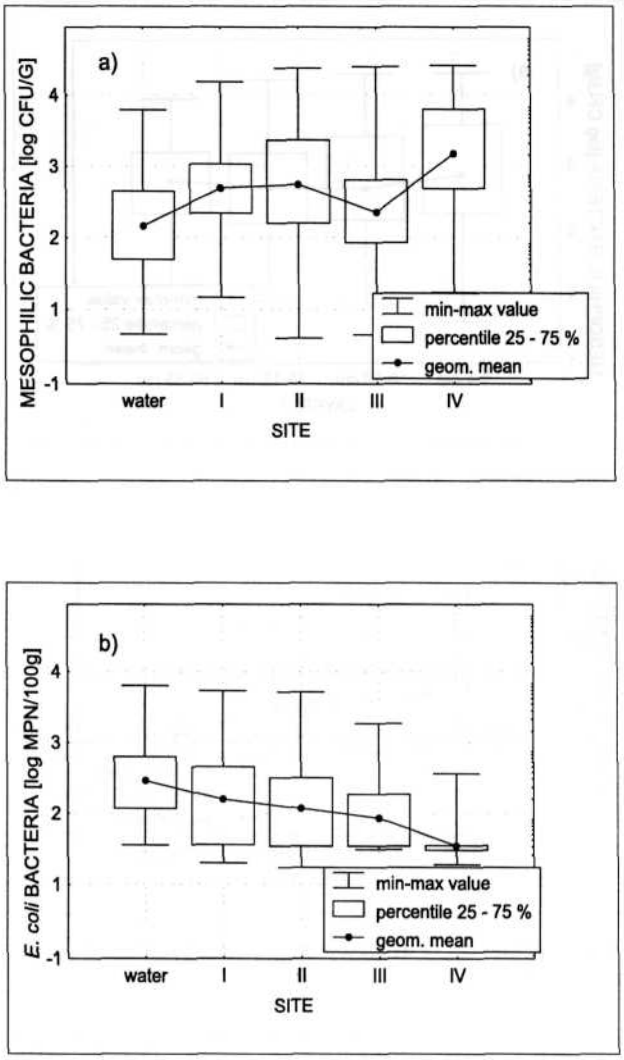


Fig. 5. The number of a) mesophilic bacteria b) *E.coli* in waters and at sand testing sites

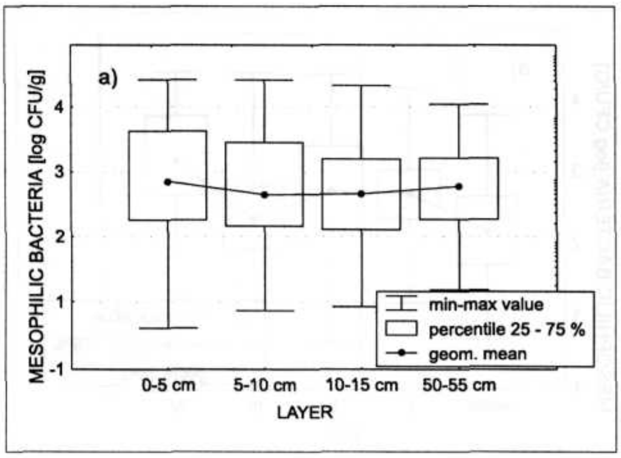
arithmetic mean monthly air temperatures. In 1997, the highest temperature, 20°C, was noted in August, which corresponded with maximal numbers of bacteria, which approached 2000 CFU/g. In 1998, the temperature in August was approximately 10°C lower than it had been in the previous year and the highest concentration of bacteria, amounting to 5400 CFU/g, occurred at the end of September. The lowest concentration of mesophilic bacteria in the sand was noted during the time of the lowest temperatures. The geometric mean monthly concentrations of mesophilic bacteria ranged from 100 - 600 CFU/g from October 1997 to March 1998 when the temperature varied from +2°C to +4°C and from 90 - 580 CFU/g in the period from December 1998 to March 1999 when the temperature ranged from -1°C to + 3°C. A relatively small number of mesophilic bacteria was observed in April 1999, as well, something which can be connected with the lower minimal air temperatures during the 1999 winter months.

The highest level of *E. coli* sand pollution (Fig. 4) occurred in the period from May to October 1997 and from April to August 1998. The MPN of *E. coli/100* g in these two periods ranged from 1000 to 10,000 in 17%-42% and 15%-25% of the samples, respectively. The beach was in the best sanitary state in the cold period from December to April. In the first year of investigations (V 97 - IV 98), the lowest values of *E. coli* did not exceed 100 MPN/100g of sand and they occurred in 60-92% of the samples. In the second year of investigations (V 98 - IV 99), such a low *E. coli* concentration was confirmed only in 54-77% of the samples.

The lowest number of mesophilic bacteria was observed in the water (Fig. 5a). The geometric mean of bacteria concentrations reached 160 CFU/g and in 25-75% samples it oscillated between 50-500 CFU/g. The concentration of mesophilic bacteria in the sand was higher and increased with the distance of the investigated site to the waterline. On average, 500 CFU/g was observed at site I, while at site **II** this figure was 600 CFU/g. The highest number of mesophilic bacteria was noted at dune sample site IV where the geometric mean was 1600 CFU/g and in 25-75% of samples there was 500-7000 CFU/g. Only site **III,** situated midway between the water and the dunes, was the exception. The average value of bacteria noted there did not exceed 250 CFU/g and in 25-75% of samples there was 100-700 CFU/g.

An inverse relationship was observed for *E. coli* bacteria (Fig. 5b). The highest geometric mean of the number of *E.coli*, approximately 320 MPN/100 g, was noted in **the water (in** 25-75% of samples there was 130-700 MPN/100g) and in sand covered with water (site I) there was approximately 170 MPN/100g (in 25-75% of samples there was 40-500 MPN/100g). The lowest geometric mean of *E. coli* concentrations were found at the sites farthest from the waterline, namely site **III** and site IV, where levels approached 90 MPN/100g and 40 MPN/100g, respectively.

With regard to the entire research period, the number of mesophilic bacteria in the sand layers of the investigated sites declined uniformly to a depth of 10 cm



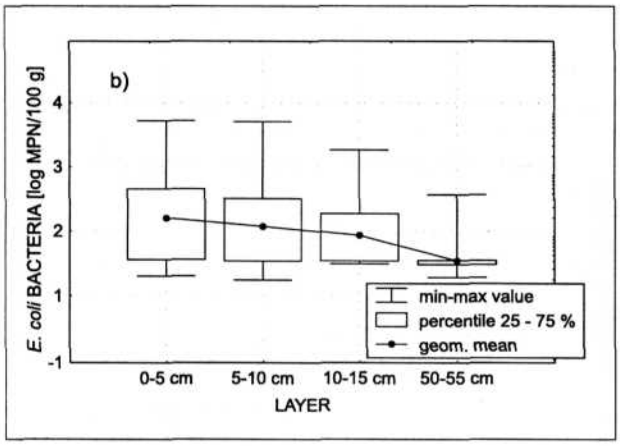


Fig. 6. The number of a) mesophilic bacteria b) *E.coli* in following sand layers.

(Fig. 6a). There was approximately 780 CFU/lg in the 0 to 5 cm layer. The values of the geometric mean of the bacteria number in layers below 5 cm of sand did not exceed 500 CFU/g. Together with depth, *E. coli* bacteria pollution decreased from an average value of 170 MPN/100g in the 0-5 cm surface layer to 40 MPN/100 g in the 50-55 cm layer (Fig. 6b).

Discussion

The analysis of the results indicates that air temperature can influence the growth rate of the total number of mesophilic bacteria. The highest concentrations of these bacteria were observed in the warmest periods of the year. It was revealed that the number of mesophilic bacteria increases at sites which are farther away from the waterline.

An inverse relationship was noted with regard to *E. coli,* the only biotype of the family Enterobacteriaceae that is almost always fecal in origin [9], the concentration of which decreased with distance from the waterline. The results prove that there are two sources of microbiological pollution influencing the quality of sandy beaches. The first is wastewater or polluted stream waters which contaminate seawater and the second source is polluted air coming from the land. Waves that break onto the sand and hit its surface carry fecal bacteria. According to measurements which were conducted in the area of the Gulf of Gdansk, most mesophilic bacteria are transported with aerosols and dust of land origin [10]. In contradiction to the total number of mesophilic bacteria, the highest *E. coli* concentration in sand was found closest to the water line at sites I and II, where the geometric means exceeded 100 MPN/100g. Thus, in the area investigated the microbiologically polluted sea water is the main source of fecal sand pollution. This corresponds with Papadakis et al. [11] who established the lack of fecal bacteria in sandy beaches where seawater was unpolluted. Stated in this work, the higher fecal microbiological pollution of sandy beaches which are in permanent contact with coastal sea water in the spring-summer season, concurs with results published by Mendes et al. [12]. On the basis of the results which were obtained, it should be concluded that the bacteriological state of sandy beaches which are used for recreational purposes, especially during the spring-summer season, should be monitored along with the shore seawater.

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