

## Sanitary problems of the coastal waters

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### SPATIAL DISTRIBUTION OF FAECAL POLLUTION INDICATORS IN THE KAŠTELA BAY UNDER DIFFERENT METEOROLOGICAL CONDITIONS

PROSTORNA RASPODJELA INDIKATORA FEKALNOG ZAGADJENJA  
U KAŠTELANSKOM ZALJEVU PRI RAZLIČITIM METEOROLOŠKIM  
UVJETIMA

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Spatial distribution of faecal pollution indicators and the level of pollution in the Kaštela Bay were studied under different meteorological conditions typical for this area: during sirocco (SE), bora (NE) and maestral (SW) winds and during calm.

Spatial distribution of faecal pollution indicators in the Kaštela Bay points to the essential differences in spreading of waste waters from the main pollution source (eastern bay part) under each of studied meteorological situations. The situation with maestral was found to be most favourable from the viewpoint of microbial pollution since the waste waters do not spread from the eastern bay part, that is Vranjic basin. During bora the concentration of faecal pollution indicators is reduced in the Vranjic basin being uniformly distributed all along the northern coast of the bay. Their concentration is also considerably increased along the Čiovo Island coast. During sirocco the values of faecal pollution indicators are rather high all along the northern bay coast and very low along the Čiovo coast. During calm the level of pollution is particularly high in the wider area of the eastern bay part.

## INTRODUCTION

The Kaštela Bay is particularly strongly affected by faecal effluents. The eastern part of the Kaštela Bay (Vranjic basin) receives sewage effluents from the northern and eastern parts of the town of Split which make up approximately one third of the total municipal sewage effluents. Furthermore, there is a number of uncontrolled outfalls along the coast of Kaštela, to which also particularly high microbial pollution in the wider bay area is due.

The first systematic studies of the presence of faecal pollution indicators were carried out in the eastern part of the Kaštela Bay in 1975-1976. Measurements for detailed analysis of spatial indicator distribution were performed at a dense station grid (K r s t u l o v i ć , 1989). From 1983 on, as a part of the Adriatic monitoring programme (MED POL Phase II), a control of sanitary sea water quality of a part of this area has been regularly carried out. The results point to very high level of pollution of both the sea water (K r s t u l o v i ć , 1986; K r s t u l o v i ć and Š o l i ć , 1990) and marine organisms (Š o l i ć and K r s t u l o v i ć , 1990) in a larger part of the bay.

It should also be emphasized that all the studies showed high spatial and temporal variability of the concentrations of studied parameters. They were found to be affected by meteorological conditions that is prevailing wind.

In general, the area of Split is very windy. By an analysis of 10-year wind data series from several Adriatic stations M a k j a n i ć (1978) showed that wind force in Split exceeded 3 B in more than 75% of the cases. Wind direction in the Kaštela Bay, that is in the Split area, is highly variable like throughout the Adriatic coastal area.

Therefore and because of recorded oscillations in the faecal pollution indicator concentrations, spatial distribution of faecal pollution has been studied for the past two years and the pollution levels under different meteorological conditions, typical for this area, estimated.

## MATERIAL AND METHODS

Samples were collected from 14 stations distributed so as to be able to observe the changes in the concentration of faecal pollution indicators along the coast of Kaštela (from the east westward) and from the northern to the southern part of the bay (Fig. 1). Samplings were performed under typical meteorological situations:

- calm
- sirocco (SE)
- bora (NE)
- maestral (SW)

During each of these situations 3-4 samplings were performed. All three faecal coliform pollution indicators total coliforms, faecal coliforms and faecal streptococci

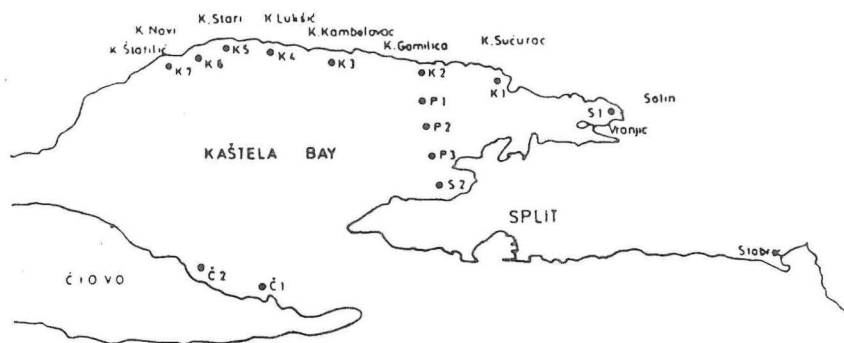


Fig. 1. Study area

were analyzed by membrane filtration method (UNEP/WHO, 1983; 1983a; 1983b).

## RESULTS AND DISCUSSION

Spatial distribution of faecal pollution indicators points to substantial differences in sewage effluent spreading under different meteorological conditions.

### *Spatial distribution of faecal pollution indicators during calm*

The highest concentration of faecal pollution indicators was recorded from the easternmost part of the Kaštela Bay (Vranjic basin) where most of surface outfalls are located. Polluted waters tend to spread from this area along the northern bay coast, both from the east westward and from the northern part southward to the bay outlet. So, during the calm the concentration of faecal pollution indicators is reduced in proportion with the distance from the main pollution source throughout the bay (Fig.2). This pertains to all three faecal pollution indicators confirming this regular pattern of distribution.

## Faecal pollution indicators under different meteorological conditions

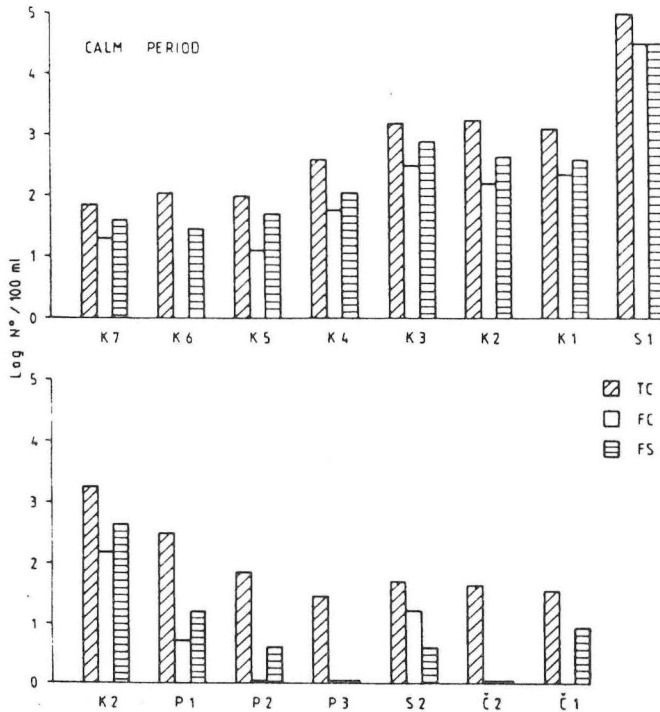


Fig. 2. Spatial distribution of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) during calm

*Spatial distribution of faecal pollution indicators during bora (NE)*

Spatial distribution of faecal pollution indicators is quite different during bora wind. Their concentration is considerably smaller in the eastern part of the bay during calm, whereas their rather high concentrations are uniformly distributed all along the northern coast of the bay. Concentrations of bacteria increase towards the bay outlet and towards the Čiovo coast which is of highest sanitary quality during calm. Thus, during bora sewage waters spread directly towards the Čiovo coast and along the northern bay coast (Fig. 3).

An analysis of data on wind force and direction for the 1949-1976 period (G r b e c, 1987) shows bora to be the wind with the highest frequency throughout the year (245%) and during summer (229%). This means that the pattern of distribution of sewage water under these meteorological conditions is best marked in the Kaštela Bay.

## Faecal pollution indicators under different meteorological conditions

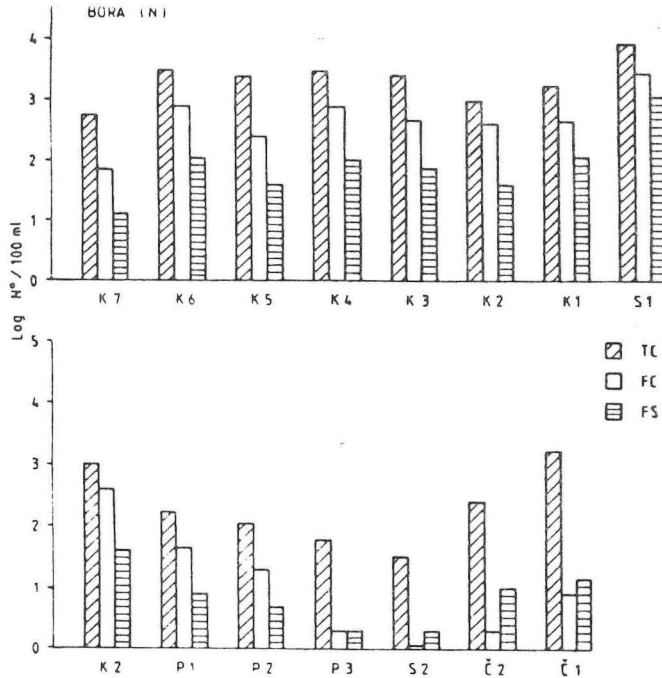


Fig. 3. Spatial distribution of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) during bora (NE 5m/s)

*Spatial distribution of faecal pollution indicators during sirocco (SE)*

During sirocco surface currents from both eastern and southern part have a direction towards the northern bay coast. The same way, sewage effluents from the eastern part spread over a part of the profile to the south and the entire northern bay part. The concentration of faecal pollution indicators is high all along the Kaštela coastal belt and, as distinct from the results for the bora situation, very low along the Čiovo coast (Fig. 4).

Sirocco frequency is considerably lower than that of bora, so it may be assumed that such a spatial distribution of faecal pollution indicators will be more rare in the Kaštela Bay. This particularly applies to summer which is very interesting from the standpoint of the use of these waters for recreative purposes since sirocco frequency is 98% in summer whereas it is 135% for the year as a whole (G r b e c , 1987).

*Spatial distribution of faecal pollution indicators during maestral (SW)*

Maestral is typical summer wind, very characteristic and frequent in this area. Its frequency is 172% in summer which is greatly in excess of the average value for the year as a whole (109%). It blows towards the eastern part of the bay forcing surface

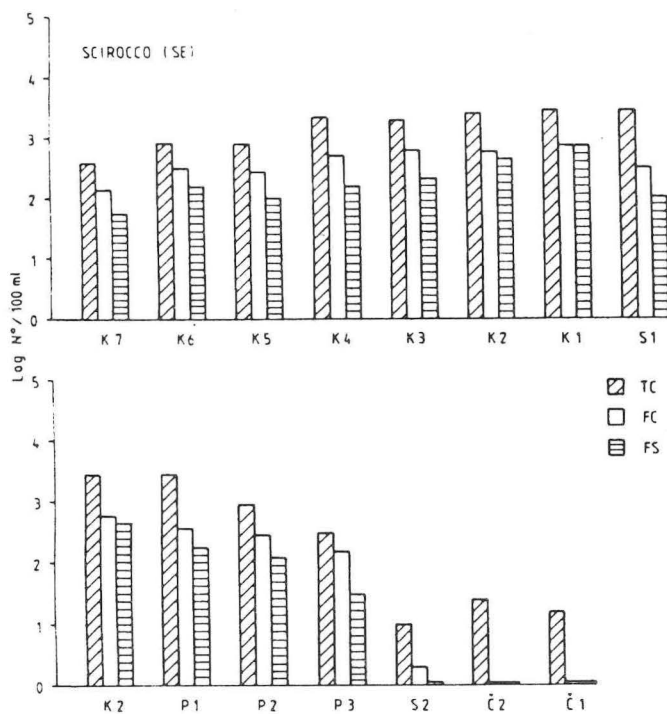


Fig. 4. Spatial distribution of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) during sirocco (SE 5m/s).

currents which do not permit spreading of sewage effluents from the eastern bay part, the heaviest pollution source. This means that the most favourable situation is established during maestral, since spreading of sewage effluents from the eastern part of the bay is poorest and concentrations of faecal pollution indicators in the rest of the bay lowest (Fig. 5).

## Faecal pollution indicators under different meteorological conditions

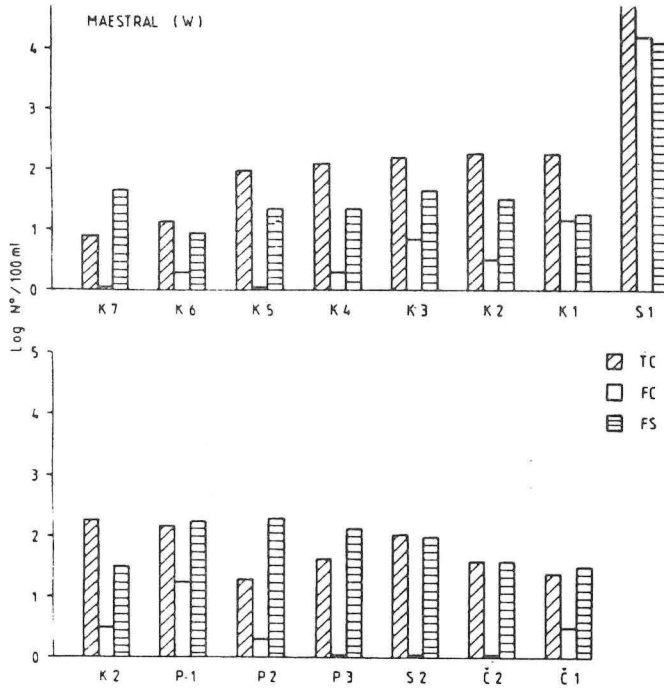


Fig. 5. Spatial distribution of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) during maestral (SW 3m/s)

## CONCLUSIONS

Spatial distribution of faecal pollution indicators in the Kaštela Bay showed significant differences under different meteorological conditions:

- the situation with maestral was found to be most favourable from the viewpoint of microbial pollution since sewage waters are retained in the eastern part of the bay that is in the Vranjic basin.

- during bora the concentrations of faecal pollution indicators are reduced in the Vranjic basin being uniformly distributed all along the northern coast of the bay. Their concentration is also considerably increased along the Čiovo Island coast.

- during sirocco the values of faecal pollution indicators are rather high all along the northern bay coast and very low along the Čiovo coast.

- during calm the level of pollution is particularly high in the wider area of the eastern bay part.

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## PROSTORNA RASPODJELA INDIKATORA FEKALNOG ZAGAĐENJA U KAŠTELANSKOM ZALJEVU PRI RAZLIČITIM METEOROLOŠKIM UVJETIMA

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### KRATKI SADRŽAJ

Istraživanja prostorne raspodjele indikatora fekalnog zagađenja kao i procjena stupnja zagađenja Kaštelanskog zaljeva vršena su pri različitim meteorološkim uvjetima tipičnim za ovo područje: za vrijeme juga (SE), bure (NE), maestrala (SW) i u mirnim uvjetima bez vjetra.

Prostorna raspodjela indikatora fekalnog zagađenja u Kaštelanskom zaljevu ukazuje na bitne razlike u širenju otpadnih voda od glavnog izvora zagađenja (istočni dio zaljeva) kod svake od ispitivanih meteoroloških situacija. Najpovoljnije stanje u cijelom Kaštelanskom zaljevu s aspekta bakterijskog zagađenja je utvrđeno za vrijeme puhanja maestrala kod kojeg se otpadne vode zadržavaju u istočnom dijelu zaljeva, odnosno Vranjičkom bazenu. Za vrijeme puhanja bure koncentracija indikatora fekalnog zagađenja smanjuje se u Vranjičkom bazenu i uglavnom je izjednačena u dosta visokim koncentracijama duž cijele sjeverne obale zaljeva. Znatno povećan stupanj zagađenja u ovim meteorološkim uvjetima utvrđen je i uz obalu Čiova. Koncentracija indikatora fekalnog zagađenja za vrijeme puhanja juga je visoka duž cijele obale uz kaštelanska naselja i, za razliku od rezultata dobijenih za vrijeme bure, vrlo niska uz obalu Čiova. U mirnim meteorološkim uvjetima bez vjetra visok stupanj zagađenja utvrđen je na širem području istočnog dijela zaljeva.

