

# **SEA-WATER QUALITY AND THE LEVEL OF EUTROPHICATION IN THE MONTENEGRIN COASTAL SEA**

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## **ABSTRACT**

The recent results about investigations of the sea-water quality and the level of eutrophication are presented in our paper.

*Key words:* sea-water quality, eutrophication, waste-waters discharges

## **KVALITET MORA I STEPEN EUTROFIKACIJE U PRIOBALNOM MORU CRNOGORSKOG PRIMORJA**

### **REZIME**

U radu se donose najnoviji rezultati istraživanja kvaliteta mora u priobalnom moru Crnogorskog primorja.

*Ključne riječi:* kvalitet morske vode, eutrofikacija, kanalizacioni ispusti

### **INTRODUCTION**

Montenegrin coastal sea is among the most precious resources of Ecological Republic Montenegro and whole Yugoslavia. In the same time, it is exposed to the direct impact of all human activities from the land, being the most imperiled area of the South Adriatic. Yet, the problem of the waste-waters is not solved along the coast. Uncontrolled building decreases the sea-water quality additionally, as the waste-waters overflow directly in front of such objects. On the other hand, according to long-term scientific studies (Regner, D. 1996), open South Adriatic is the most unpolluted area of the Adriatic Sea, and among the most unpolluted area of the whole Mediterranean. From the other parts of Adriatic, it differs by the largest volume of the sea-water, the highest depth, the highest speed of the streams, the highest transparency and permanent exchange of the water-masses with Mediterranean.

Nevertheless, its coastal waters (as shallow coastal waters of the Mediterranean, and even of the the World Sea) are exposed to the microbial pollution and anthropogenic eutrophication, as a common consequence of unpurified waste-waters from the land.

For this reason, the control is necessary throughout the year, especially during summer, when increased number of inhabitants is presented along the coast. Data of Republic Statistical Office show, that, for instance, in the area of Budva, this number is higher 18-21 times during summer; in the area of Herceg Novi 5-7 times, etc. So, higher temperatures, calm weather without wind, slower circulation of the water-masses and increasing quantity of organic matter, are main characteristics of shallow coastal waters during summer (Regner D. *et al.* 2001). In this paper, some basic results about the sea-water quality and the level of eutrophication are presented for 1996-2000 period.

## MATERIAL AND METHODS

Material was collected from 28 localities in the inner (Kotor Bay), middle (Tivat Bay) and outer (Herceg Novi Bay) parts of the Boka Kotorska Bay. 26 of them were outside the bay, along the Montenegrin coast, and one in the Bojana river mouth. Standard methodology (Regner, D., *et al.*, 1995) was used for collecting of material and laboratory analyses.

## RESULTS AND DISCUSSION

Visible difference exist between the Bay of Boka Kotorska, owing to its position and natural characteristics, its exposition to the land impact and plentifulness of the fresh-water, outer part of the Montenegrin coastal sea - exposed to the open waters of the South Adriatic and the Bojana river mouth- where the river mixes with the sea-water. So, the recent investigations of the sanitary quality of the sea in the Bay of Boka Kotorska have shown, that from 28 the most known beaches, the first category frequently occurred at the localities: **Herceg Novi area:** Kamenari, Baošići, Bijela, Hotel Plaža; **Tivat area:** Seljanovo Opatovo; **Kotor area:** Stoliv, Markov rt, Prčanj, Perast, Risan.

During five-years period, at mentioned beaches up to 500 total coliforms/100ml of the sea-water were found, and up to 100 fecal coliforms/100ml of the sea. Second category (up to 10000 total coliforms and up to 2000 fecal coliforms/100ml of the sea-water) was presented often at these beaches: **Herceg Novi area:** Đenovići, Kumbor, Zelenika, Bijela vila, Blatna plaža, Njivice; **Tivat area:** Krašići, Ostrvo cvijeća, Kalimanj; **Kotor area:** Sv. Stasije, Orahovac, Morinj; while the rest beaches were predominantly second category, or sometimes exceeded the permitted values. So, beaches in

front of hotel Fjord and Maritime faculty (Kotor area) very often, Krašiči or Kalimanj (Tivat area) from time to time, and Meljine, hotel Topla and the beach in front of the Institute Igalo (Hercegnovi area) almost often, exceeded the permitted values for the second category of the sea-water quality (more than 10000 TC/100ml of the sea, or more than 2000 FC/100ml of the sea). From 26 localities **outside the Bay**, the first category of the sea was often found at these beaches: Utjeha, Veliki pjesak, Buljarica, Pržno, Lučica, Petrovac, Sv. Stefan, Kamenovo, Slovenska plaža, Hotel Avala-Budva.

Almost often, second category was found at localities: Velika plaža – Ulcinj, Mala plaža, Gradska plaža – Bar, Žukotrljica, Čanj, Sv.Stefan II, Rafailovići, Bečići, Jaz, Bigova, Plavi horizonti.

At: Port Milena, Sutomore and Bečići, from time to time (for the reason of increased number of fecal coliforms, especially), the permitted values for second category of the quality of the sea-water are overflowed. Investigations in the **Bojana river mouth** have shown that II category of the sea-water quality was found always, with the exception throughout summer 2000, when results overflowed mentioned value. On the next tables sea-water quality is presented for the whole Montenegrin coastal sea (Tab 1) and for Boka Kotorska Bay, separately (Tab 2).

Tab 1. Sea-water quality throughout summer in 1996-2000 period in the Montenegrin coastal sea

Area	Bojana river mouth	Coastal sea outside the Bay of Boka Kotorska	Herceg Novi Area	Tivat Area	Kotor Area
1996	II	20 I; 6 II	10 I; 3II	5 I	6 I;3 II;1>II
1997	II	18 I; 7 II; 1> II	3 I; 7II;3>II	1 I; 4 II	6 I; 4 II
1998	II	17 I; 7 II; 2>II	1 I; 7II;5>II	3 I; 2 II	1 I;7 II;2>II
1999	II	16 I; 10 II	1 I; 12 II	1 I; 4 II	4 I; 6 II
2000	> II	15 I; 10 II; 1>II	12 II; 1> II	1 I; 4 II	1 I; 9 II

Tab 2. Sea-water quality throughout summer in 1996-2000 period in the Boka Kotorska Bay

Year	I category (to 500 TC/100 ml)	II category (to 10000 TC/100 ml)	>II category (more than 10000 TC/100 ml)
1996	21	6	1
1997	10	15	3
1998	5	16	7

1999	6	21	5
2000	2	25	1

So, it can be seen from above tables that the decreasing of the sea-water quality is visible in the Bay of Boka Kotorska, especially. Outside the Bay, where the influence of the open South Adriatic is stronger, this process is slower. The decreasing of the sea-water quality is more important, because the number of tourists is relatively low in recent years. It was interesting to compare our new results about the quantity of total coliforms with these of Ristanovic and Dutina from 1979. The same methodology was used, but previous results showed higher number of TC bacteria in front of hotel Fjord and Markov rt, as in Bar, Sutomore and Budva. In the meantime, industrial zone was dislocated and the production of detergents, soaps, etc. among the rest, stopped in the Kotor Bay.

Simultaneously, waste-water discharge (about 2km long) was built in Budva, and the existing one was repaired in Bar. On the other hand, quantity of the fecal coliforms, compared with results of Stjepčević (1994), showed the decreasing of the sanitary quality, including even some beaches outside the Bay (Ulcinj, Bar, Budva, for instance), where overflowed values of FC were found from time to time.

So, the solution of the waste-waters is among main problems in the Montenegrin coastal sea, as we can not prognosticate the level of bacterial pollution (with harmful effects to human health), in advance.

Besides, from the attainable data, the recent results about the level of eutrophication at the Montenegrin coastal sea are introduced in our paper.

Having in mind the international classification of the eutrophication (Chiaudani et al.,1982; Yamada et al.,1980), at the same localities: transparency, sea-water colour, oxygen saturation and composition and biomass of the microphytoplankton, biomass of zooplankton and biomass of heterotrophic bacteria were measured. So, in the Boka Kotorska Bay, already oxygen saturation (up to 162.63% O<sub>2</sub>) showed the existence of high level of eutrophication. Such values (exceeding 100% O<sub>2</sub>) were characteristic for eutrophic and extremely eutrophic areas. Sea -water colour was between blue (II) and greenish (V-VI) in the Bay of Kotor. During the period of strong rainfalls, it was yellowish and brownish (XIX-XX according Forell-Uhle scale). In the Tivat area it was usually blue-greenish (VII-VIII), or dark green (XI-XII), while in the area of Herceg Novi, it was blue-greenish (VII-VIII) to brownish (XIX-XX). So, the changes were the most frequent in the Kotor and Tivat areas, what is the characteristic of eutrophic areas. In 1996-2000 period, transparency was usually lower in the Kotor Bay (between 3 and 6m, with maximal value of 16.5m - in the middle of the bay). Similar values were found in the Tivat Bay,

while in the outer part - Hercegnovi area, it was the highest - up to 19m in the middle of the bay. Along the coast, it was lower from time to time, at some localities in the Kotor (hotel Fjord, Maritime faculty, etc.) and Tivat area (Krašiči, Kalimanj). Occasionally, the sea-water color was changed in the Hercegnovi area, too (Blatna plaža, Igalo, etc.).

Eutrophication was even more visible keeping in mind the composition and biomass of phytoplankton, biomass of zooplankton and biomass of heterotrophic bacteria and their oscillations throughout the year. In the Bay of Boka Kotorska (as at the whole Montenegrin coastal sea), four phytoplankton groups were the most frequent: *Baccilariophyceae*, *Dinophyceae*, *Haptophyceae* and *Dictyophyceae*. The first one occurred with the highest density, especially in spring, when its number overflowed  $10^6$  cells/dm<sup>3</sup>. However, during summer, instead of stagnation, the increasing of microphytoplankton biomass was found. This increasing was the consequence of increased number of inhabitants (3-5 times at an average) along the coast, and increasing quantity of the organic matter that came from the outlets. Dominant species were: *Skeletonema costatum*, *Leptocylindrus danicus*, *L.minimus*, *Nitzschia seriata* and 10 other species characterised as opportunistic species. All of them are indicators of eutrophicated sea. Their percentage between other species increased during recent investigations. So, *Skeletonema costatum* appeared, from time to time, with more than  $10^6$  cells/dm<sup>3</sup> throughout the whole year. Instead of this species, some of above-mentioned species could appear, causing visible unsuspected phytoplankton blooms, during summer, especially (Vuksanović et al 1999, 2000). Such changes of composition, changed ratio between dominant and other species, and high biomass of phytoplankton ( $10^6$  to even  $10^7$  cells/dm<sup>3</sup>, or more.), classified Kotor Bay among the most eutrophic ecosystems of the eastern Adriatic coast. Similar consequences of eutrophication were found in copepods (zooplankton), the first consumers of organic matter produced by phytoplankton. The increasing of their biomass and changed rhythm of density - with the unusual highest values during summer were caused by higher level of eutrophication. Summer maximum of copepod density is especially unsuspected phenomenon in the temperate climatic belt to which Adriatic belongs. Such high values are visible from the next table:

Table 3. Annual oscillations of copepod density in the Kotor Bay

Month	I	II	III	IV	V	VI	VII	VIII	IX	X
Number	4686	6123	2072	3074	2957	2983	5764	10012	6102	6612

where maximal copepod density through August, in the Kotor Bay (Vukanić, D. and D. Regner, 1995) is found in the last ten-years period. In the outer part of



the Bay (Herceg Novi area), which is exposed to stronger influence of the open South Adriatic, summer values are higher, but annual maximum is during colder part of the year - in autumn and winter. Besides, changed ratio between dominant species, was found, too, with high dominance of one or two species. Similar changes were found in the whole eastern Adriatic coastal sea from the beginning of eighties. In the Montenegrin part they are the most visible in the inner part of the Boka Kotorska Bay, as it is exposed to the strongest influence from the land. At last, the number of heterotrophic bacteria - as indicator of eutrophication reached  $10^2$  and  $10^3$ /ml of the sea-water, very often. Such values are characteristics of eutrophic areas, too. Maximal values, found in the Kotor Bay were:  $7 \times 10^3$  (Markov rt),  $4.2 \times 10^3$  (hotel Fjord),  $2.6 \times 10^3$  (Sv. Stasije),  $7.6 \times 10^3$  (Orahovac),  $2.6 \times 10^3$  (Morinj) etc.

During the same five-years period, at 26 beaches outside the Boka Kotorska Bay, some different results were found. So, oxygen saturation was between 54.89% (September, 1996: Mala plaža) and 158.82% (July, 1997: Rafailovići). Predominantly, values were about 100% - typical for eutrophic and extremely eutrophic areas. Sea-water colour was blue (III-IV), blue greenish (VII-VIII) or green-blue (V-VI), changeless, with very rare exceptions (in Bigovo and in the area near the Bojana river mouth). Transparency was almost always "to the bottom". In front of Budva (2.5 km from the coast), it was to 11.5 m during summer. In front of Petrovac, it was to 10m in the same season, but it reaches 23 m in 1999. The exceptions were beaches: "Plavi horizonti" and "Buljarica", where intensive summer bloom and increased mud content were found. Microphytoplankton density was between  $2 \times 10^3$  cells/dm<sup>3</sup> (Petrovac, during summer) and  $9.8 \times 10^4$  cells/dm<sup>3</sup> (in front of Budva in the same season). The percentage of dominant species: *Chaetoceros affinis*, *Leptocylindrus danicus*, *L. minimus* and *Nitzschia seriata* was lower than in the Bay. Annual density oscillations of copepods (zooplankton) showed usual spring maximum and usual composition with typical dominant species, widely distributed in the eastern Adriatic coastal sea: *Ctenocalanus vanus*, *Paracalanus parvus*, *Acartia clausi*, *Oithona* sp., etc. The number of heterotrophic bacteria was lower than in the bay, with maximal value in 1996:  $1.8 \times 10^3$  HT/ml of the sea-water.

In comparison with the bay, we can conclude that eutrophication level is not so high, as: higher transparency, lower oxygen saturation at the surface, lower phytoplankton density, smaller number of microphytoplankton species - indicators of eutrophication, lower percentage of dominant species in composition of microphytoplankton, spring maximum of copepod (zooplankton) density and lower density of heterotrophic bacteria were found outside the Bay.

Investigations at the area of the Bojana river mouth in 1995-2000 period have shown that: Oxygen saturation was between 79.50% (September,

1998) and 127.97% (July, 1997). Very often, it is lower than in the bay, but usually it overflows the value of 100%. Transparency was decreased almost always, and sea-water color changed from yellow-greenish (XI-XII) to even yellowish (XV-XVI, XVIII-XIX) and brownish (XXI). Microphytoplankton density was up to  $3.9 \times 10^5$  cells/dm<sup>3</sup>, typical for eutrophic coastal sea. The copepod density was high, too. Values up to  $6 \times 10^4$ /m<sup>2</sup> are typical for the most eutrophic bays along the eastern Adriatic coast and we find them in the region of the Bojana river mouth, permanently. The number of heterotrophic bacteria was between  $1.5 \times 10^2$  and  $1.9 \times 10^3$ /ml - characteristic for eutrophic coastal regions, too.

Having in mind all mentioned parameters, we can conclude that the area in front of the Bojana river mouth is eutrophic, too.

So, the results of five-years investigations in the Montenegrin coastal sea showed, that the highest level of eutrophication was found in the Kotor and Tivat Bays. The area of the Bojana river mouth came after, and the coastal sea outside the bay at an end.

Additionally, it is interesting to discuss and underline the summer situation in the Montenegrin coastal sea, and the role of the waste-waters discharges in the increasing of the eutrophication level by adding metabolic (excreted) nitrogen and phosphorus. In 1995 (Republic Statistical Office, personal communication), for instance, normal number of inhabitants was 64 799 in the Boka Kotorska Bay. Throughout summer, the number of registered tourists was 177 235. Outside the bay, usual number of inhabitants was 77 437, and 378 307 tourists were registered through three summer months. On the next table, estimated values of metabolic nitrogen and phosphorus are presented for the bay during summer and the rest of the year, separately (having in mind the number of inhabitants and tourists and estimation in UNEP, 1996).

Table 4. Metabolic nitrogen and phosphorus calculated in the Montenegrin coastal sea throughout the year

<b>The Boka Kotorska Bay</b>		<b>The area outside the Bay</b>	
285 tN (yearly)	35 tP (yearly)	341 tN (yearly)	42 tP (yearly)
<u>+ 195 tN (summer)</u>	<u>+ 24 tP (summer)</u>	<u>+ 416 tN (summer)</u>	<u>+ 51 tP (summer)</u>
480 tN total	59 tP total	757 tN total	93 tP total

It can be seen, that during three summer months in the area outside the bay, quantities of metabolic nitrogen and phosphorus are even higher, that during all year. Such calculations do not mean that tourism must be limited. On the contrary, it means that the main problem of the area is the solution of the waste-water discharges.

## CONCLUSION

Having in mind all results mentioned above, we can conclude that the problem of the solution of the waste-waters discharges must be register among the most important problems of the Montenegrin coastal sea. Without the solution of this problem, any tourism activities and development plans cannot be done.

## REFERENCE

- Chiaudani, G., F. G. Gaggiano e M. Vighi (1982): *Caratteristiche trofiche delle acque costiere Adriatiche*. CNR, Roma, AQ/2, 14, 170p.
- Regner, D. (1996): Waste management related with the protection of the marine environment. International symposium on hazardous waste and the environment, Vrnjacka Banja, Proceedings: 93-102.
- Regner, D., N. Vuksanović, M. Dutina and B. Stjepčević (1995): Investigations of the sea-water quality in the coastal Montenegrin Sea that serves for bathing and recreation. Ecological study for Coastal Zone Management Agency: 1-19
- Regner, D. N. Vuksanović, B. Stjepčević and M. Dutina (2001): The recent investigations of the sea-water quality in the Montenegrin coastal sea. *Rapp. Comm. int. Mer Medit.*, **36**: p. 414.
- Ristanović, B. and M. Dutina (1979): *Rasprostranjenost i gustina bakterijskih populacija- indikatora zagađenja i dinamika nekih od abiotičkih faktora u vodi plaža južnog Jadrana*. Drugi Kongres ekologa Jugoslavije (poseban otisak), Zagreb, 1979: 323-333.
- Stjepčević, B. (1994): Faecal coliforms concentration and evaluation of sanitary quality in the Montenegrin areas (1985-1991). MAP Technical Reports Series **86**: 191-193.
- Vukanić, D. and D. Regner (1995): The influence of predominant species of copepods on total biomass in the estuary-neritic areas of the South Adriatic. Symposium: Investigations and protection of Adriatic Sea, Kotor, Conference Proceedings: S:1-7.
- Vuksanović, N., D. Regner, D. Vukanić and M. Dutina (1999): Size-fractions of phytoplankton as eutrophication indicators in the Montenegrin coastal sea. Conference: "Water pollution '99" Soko Banja, Conference Proceedings: 327-331.
- Yamada, M., A. Tsurita and Y. Yoshida (1980): A list of phytoplankton as eutrophic level indicator. *Bull. Jap. Sci. Fish.* **46(12)**: 1435-1438.