METAL POLLUTION INDEX AS A TOOL FOR ASSESSING WATER QUALITY OF BOKA KOTORSKA BAY

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INDEKS ZAGAĐENJA METALIMA KAO SREDSTVO ZA PROCENU KVALITETA VODE ZALIVA BOKA KOTORSKA

Apstrakt

Zaliv Boke Kotorske nalazi se u jugoistočnom delu Jadranskog mora i jedan je od najlepših zaliva sveta. Uzak i dugačak zaliv koji se u kopno urezuje u dužini od 20 km ima oblik strele i sastoji se od četiri manja zaliva: hercegnovski, tivatski, risanski i kotorski zaliv. Svaki od ovih zaliva ima specifične hidrografske i reljefne karakteristike i, u odnosu na otvoreni deo crnogorskog primorja, ove vodene površine pokazuju veliku različitost, a samim tim poseduju i specifičan morski život. Kao i ostala područja Mediterana i Jadranskog mora, i Bokokotorski zaliv je pod velikim uticajem antropogenog faktora i aktivnosti koje se odvijaju na njegovoj obali. Poslednjih decenija evidentna je sve veća urbanizacija i industrijalizacija, koja je dovela do obimnog naseljavanja crnogorskog primorja, naročito Bokokotorskog zaliva, što je uslovilo zagađenje životne okoline zaliva, naročito morske vode za koju je karakteristično slabo strujanje i cirkulacija sa otvorenim morem. Otpad iz različitih industrija, brodogradilišta, hotela i bolnica stacioniranih unutar samog zaliva, ispuštaju se u more i predstavljaju konstantan izvor zagađenja vodene sredine. Ova regija je poznata kao područje sa najvećom prosečnom količinom padavina u Evropi, pa udeo zagađujućih meterija koje spiranjem zemljišta (vodena erozija, rastvaranje stena i abiogene podloge), usled velikih količina atmosferskih padavina, dospevaju u more nije zanemarljiv. Na ovaj način u morsku sredinu se unose različite vrste zagađujućih materija, među kojima su najopasniji teški metali, kao što su živa, olovo, kadmijum, kobalt, nikl, itd. Teški metali predstavljaju ozbiljne zagađujuće materije morske sredine, pre svega zbog svoje toksičnosti, teške biorazgradivosti i dugog zadržavanja u biogeohemijskom ciklusu.

Neki vodeni organizmi, među kojima i dagnja *Mytilus galloprovincialis*, imaju sposobnost da apsorbuju razne zagađujuće materije iz vode i predstavljaju veoma pogodan indikator za analizu zagađenja sredine koju nastanjuju, odnosno, u slučaju dagnji, mogu se koristiti kao sredstvo za procenu kvaliteta vode.

Cilj ovoga rada bio je određivanje sadržaja teških metala (Pb, Ni, Co, Cd i Hg) u dagnjama *M. galloprovincialis* sa određenih lokacija Bokokotorskog zaliva u tri sezone 2008. godine. Na osnovu dobijenih vrednosti koncentracija teških metala određivan je indeks zagađenja metalima (*MPI*) kao sredstvo za procenu kvaliteta vode zaliva Boka Kotorska.

Indeks zagađenja metalima predstavlja ukupni kvalitet posmatrane životne sredine u odnosu na koncentraciju teških metala i njegova upotreba se pokazala kao veoma korisno sredstvo u proceni nivoa zagađenja. Ovaj indeks pruža mogućnost da se na jednostavan način uporedi stepen zagađenja različitih lokacija i mesta uzorkovanja.

Najveće koncentracije ispitanih teških metala u većini ispitanih uzoraka izmerene su u zimskom periodu 2008. godine. Ovaj podatak se može objasniti smanjenjem mase jestivog dela dagnje tokom zimeodnosno činjenicom da se zbog smanjene količine hrane u zimskom periodu masa jestivog dela školjke smanjuje, dok sadržaj već akumuliranih teških metala ostaje isti, pa se stoga koncentracija teških metala u odnosu na masu jestivog dela školjke povećava.

Na osnovu vrednosti *MPI*a možemo reći da se lokacije iz Tivatskog zaliva, pre svega lokacija Tivat, izdvajaju kao lokacije sa najvećim indeksom zagađenja metalima u odnosu na druge ispitivane lokacije. Ovaj podatak ne iznenađuje, jer se radi o zalivu sa najvećim brojem antropogenih izvora zagađenja, pogotovu lokacija Tivat (aerodrom, vojna luka, brodogradilište, poljoprivredna aktivnost). Hercegnovski zaliv je sledeći po zagađenju morske vode, dok je najmanje zagađenje dobijeno za lokaciju Sv. Stasija iz Kotorskog zaliva.

Na osnovu dobijenih podataka, a na osnovu njihove analize može se zaključiti da indeks zagađenja metalima predstavlja korisno i moćno sredstvo za procenu kvaliteta vode zaliva Boka Kotorska.

Ključne reči: dagnja, olovo, nikl, kobalt, kadmijum, živa, MPI, Bokokotorski zaliv
Keywords: mussel, lead, nickel, cobalt, cadmium, mercury, MPI, Boka Kotorska bay

INTRODUCTION

Living organisms have been used as water pollution bioindicators (Lafabrie et al., 2007; Kouba et al., 2010; Yap et al., 2011, Stanković and Jović, 2012). Many microelements are found in trace amounts in sea water, but often at elevated levels in aquatic organisms, making them even more attractive for bioindication (Morillo et al., 2005). Currently, there is a great interest in the use of living organisms as pollution bioindicators in aquatic ecosystems in order to evaluate the quality of a marine environment.

Human and industrial activities in the coastal area of the southeastern Adriatic have increased and resulted in the different types of pollutants. As the Montenegrin coastal area, especially the Boka Kotorska bay, receives a heavy influx of sewage and industrial effluents as well as domestic and agricultural wastes (Jović et al., 2011), it is a great entry of a diverse array of polluting agents including trace metals, which are potentially toxic. Due to its specific structure, semi-enclosed bay system and low flow of water through the Bay, the anthropogenic impact is more pronounced and this pollution leaves direct effects on this unique ecosystem and organisms.

Mussel *Mytilus galloprovincialis*, native species of the Mediterranean Sea, of the Black Sea and of the Adriatic Sea, is a sedentary, filter-feeding animal that through

feeding, not only assimilates the food necessary for growth and development, but also accumulates contaminants present in the water (Jović et al., 2011). The Metal Pollution Index which represents the overall quality of environmental compartments with respect to metals and its use has proved to be a very useful tool in evaluating pollution level (Usero et al., 2005; Wang,.2007; Sharma et al., 2008).

The aims of this study were to determine the concentrations of Pb, Hg, Ni, Co and Cd in the soft tissue of mussels *M. galloprovincialis* from Boka Kotorska bay and to calculate the Metal Pollution Index (*MPI*) in order to compare the pollution status of different places and to establish locations in Boka Kotorska bay with the highest or lowest level of pollution.

MATERIALS AND METHODS

Fresh mussels (*M. galloprovincialis*) were sampled from five different locations within the Boka Kotorska bay: Herceg Novi (H1), Sv. Stasija (K1), Krasici (T1), Tivat (T2) and Opatovo (T3). From each location more than 2 kg of mussels of similar length were collected, placed in plastic bags together with the sea water and transported to the laboratory. The 25–30 mussels from each station were pooled. Mussels were cleaned and rinsed with deionized water, dissected fresh and the soft tissue was rinsed with Milli Q water. Pooled samples were pulverized and homogenized using a mill.

About 0.5 g of the mussel samples were digested with 7 ml of HNO_3 (65%), 2 ml of H_2O_2 (30%) in a microwave digestion system for 30 min and diluted to 25 ml with deionized water. A blank digest was performed in the same way.

Analyses of lead (Pb), cobalt (Co), nickel (Ni) and cadmium (Cd) were performed using Graphite Furnace AAS (Perkin-Elmer, 4100ZL, with Zeeman background correction). Cold vapor technique was used for analyses of mercury (Hg) (PerkinElmer, AAnalyst 200). The accuracy of the applied analytical procedure for the determination of trace elements in mussels was tested using SRM 2976 (Mussel homogenate; NIST) certified reference material.

RESULTS AND DISCUSSION

The concentrations (range and mean) of Pb, Hg, Ni, Co and Cd found in *M..galloprovincialis* sampled from different locations in the Boka Kotorska bay during different seasons of 2008 are given in Table 1.

Table 1. Range and mean metal concentrations (mg kg^{-1} dry wt) in *Mytilus galloprovincialis* in winter, spring and fall 2008

	Pb	Hg	Ni	Co	Cd
winter	(2.0–5.5) *3.6*	(0.61–1.2) *0.86*	(4.11–8.65) *5.74*	(8.02–12.0) *9.63*	(2.76–3.67) *3.31*
spring	(1.5–5.0) *3.1*	(0.12–0.85) *0.34*	(1.50–4.11) *2.51*	(3.05–4.81) *3.51*	(1.05–1.52) *1.26*
fall	(2.5–9.0) *5.1*	(0.20–0.57) *0.30*	(1.52–3.40) *1.99*	(3.05–6.55) *4.57*	(1.50–1.95) *1.65*

The overall metal content of mussels from the investigated locations was compared using the Metal Pollution Index (*MPI*). MPI is obtained by the following equation:

$MPI = (C_1 \times C_2 \times \ldots \times C_n)^{1/n}$,

where C_n is the concentration of the metal *n* in mussels and *n* is the total number of metals (Usero et al., 2005).

Values of the *MPI* for the investigated mussel samples are shown in Table 2.

Table 2. Metal Pollution Index (*MPI*) of each site in different seasons

	Metal Pollution Index		
	winter	**spring**	**fall**
T1	2.91	1.56	1.52
T2	4.03	1.84	2.40
T3	3.89	1.50	1.98
K1	2.85	1.26	1.41
H1	3.77	1.35	1.68

Nickel, lead, cobalt, cadmium and mercury, the most commonly analyzed toxic trace elements in aquatic environments, are quite sensitive to anthropogenic influences (e.g. urbanization, industrialization, agriculture). *MPI* index is easily evaluated in order to compare the pollution status of different locations and for assessing water quality.

The highest values of *MPI* were obtained for the winter period. Explanation for this could be found in the reduction of dry weight of the edible part of *M. galloprovincialis* with respect to shell weight during the winter. Due to decreased food assimilation in winter the edible body mass decreases and the metal content remains the same, but concentration expressed in relation to edible body mass therefore increases (Klaric et al., 2004).

Comparing the *MPI* values by locations, it can be seen that the highest concentrations and *MPI* values were recorded for the site T2 in Tivat bay for the all three seasons. It comes as no surprise that the highest concentrations of toxic elements were found in mussels from Tivat bay, because the anthropogenic activities (airport, military harbor, shipyards, oil tankers, agricultural, *etc*.) are the highest on this location. According to the obtained metal concentrations as well as of the *MPI values*, location Herceg Novi in Herceg Novi bay is the next most polluted part of the Boka Kotorska bay. This bay also has pollution problems, primarily with urban, touristic and industrial effluents. In the case of Herceg Novi bay, which is located near to the entrance in Boka Kotorska bay, a major impact on the reducing of contamination with toxic metals is because of the mixing of the water from the Bay with the water from the open sea. Location Sv. Stasija in Kotor bay showed the lowest contamination by the investigated metals.

CONCLUSION

Investigated organism, mussel *Mytilus galloprovinciails,* indicated that the highest polluted area is Tivat bay, while the lowest polluted area is Kotor bay. The site Tivat within the Tivat bay stands out with the highest *MPI* values for all three studied seasons.

Based on all, Metal Pollution Index (*MPI*) has proved to be a very useful and powerful tool for assessing water quality of Boka Kotorska bay.

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