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Mercury and methylmercury in fish from the eastern central Adriatic

Sanja ČULIN[1] and Tomislav ZVONARIĆ[2]

[1] *Public Health Institute, Split, Croatia*
[2] *Institute of Oceanography and Fisheries, Split, Croatia*

An attempt was made to determine mercury in some commercially important fish species (hake, red mullet and pandora) from the central Adriatic Sea (Kaštela Bay, Split Channel, Bay of Mali Ston and Vis Island - open waters). It is well known that inorganic mercury is easily transformed into very toxic methylmercury. One of the main media through which mercury reaches man is contaminated seafood in which it acumulates as methylmercury.

The highest mass concentrations of both total and metilmercury were recorded from fish from Kaštela Bay and Split Channel. This area used to receive considerable amounts of completely untreated mercury from the chlor-alkali plant. Mass concentrations were lowest in fish from Bay of Mali Ston.

Pandora showed the highest and hake the lowest mass concentrations among fish species studied. As to the sex, male pandora had higher mass concentrations, most probably due to protogyny. Red mullet showed the lowest concentrations.

Comparing these values with the upper concentration limits for mercury in seafood set by our country (Official Gazette of the Republic of Croatia, No. 46/1994) shows that they highly exceed the limits beyond which no sale and consumption is allowed.

INTRODUCTION

The increase of human population affects the growth of its demand for food, particularly seafood. Unfortunately, human activities, industrial development at a growing pace and population increase are accompanied with an increase of waste water and sewage inputs and consequently the accumulation of pollutants in the sea, particularly heavy metals.

The most dangerous property of heavy metals is food chain magnification, that is an increase of most of heavy metals through the food chain. Their concentration in marine organisms is of most concern since seafood is one of the main media through which mercury reaches man.

Mercury and its natural background

Mercury is one of the most widely distributed and most toxic heavy metals in the nature. Its cycling in earth's crust includes the lithosphere, hydrosphere and biosphere, where it occurs in three oxidation states: elementary mercury (HgO), monovalent mercury (Hg_2^{2+}) and bivalent mercury (Hg^{2+}) and in organic and anorganic forms dependently on the anions it is bound to. Even though it normally occurs in both forms it is believed that anorganic mercury

is dominant in an abiotic environment (minerals, air, soil, sediment), and methylmercury in the biosphere (BERHARD *et al.*, 1990; WHO-FAO, 1987). The overall picture of the migration of mercury in the nature is the geochemical cycle. However, the mechanisms of biogeochemical cycle of mercury is to date unknown (CRAIG, 1986). Fig. 1 shows the biogeochemical mercury cycle in the nature.

shown that about 12% of methlylmercury formed in sediment, is removed therefrom in this way. However, it sulfide ions are not present the losses do not exceed 0.1% (CRAIG *et al.*, 1984). Owing to these properties dimethylmercury plays an important part in the geochemical cycle of mercury.

Total mercury and methylmercury levels differ in sediment, air, water or food.

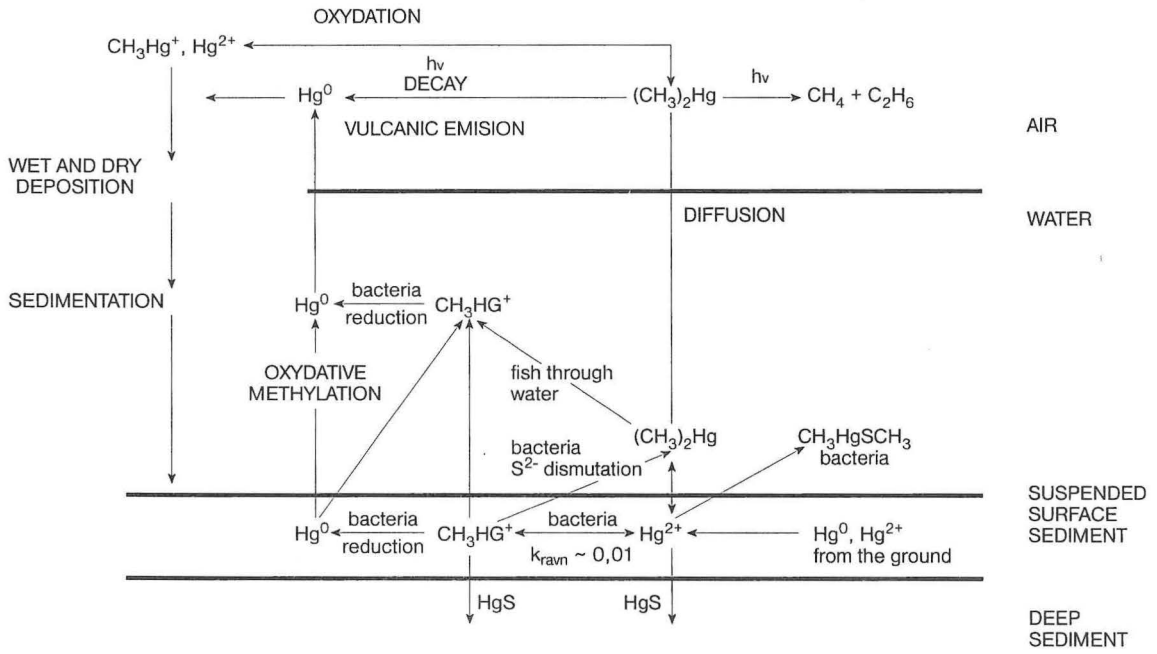

Fig. 1. Biogeochemical cycle of mercury in the nature

Anorganic mercury is the predominant form of mercury. For the most part it is deposited at lower sediment levels as HgS, since in "anoxic" sediment (with low redox potential) it is easily bound to sulfide ion. It is present as methylmercury, mercury (II) or elementary mercury in surface sediment.

$$2CH_3Hg^+ + S^{2-} \leftrightarrow (CH_3Hg)_2S \leftrightarrow (CH_3)_2Hg + HgS$$

Demethylmercury is easily re-emitted from sediment through the water to the atmosphere. It is very unstable in the air and therefore easily transformed into elementary mercury, methane and ethane. Some studies have

The relationship between total mercury level in the sea water and mass fraction in marine organisms is given as the bioconcentration factor (Table 1) (HORVAT, 1989; CRAIG, 1986).

Table 1. Bioconcentration factor for total mercury

Sample	Bioconcentration factor
sea water	1
algae	10^3
microphytes	10^3
sea weeds	10^4
fish	10^4- 10^5
invertebrates	10^5
oysters	10^4 - 10^5
marine mamals	10^5 - 10^6
sea birds	10^5 - 10^6

Sediment	Air	Water	Food
Total mercury content in the Mediterranean sediment ranges from 0.05 - 0.1 mg kg^{-1} of which methylmercury makes up not more than 0.05%. These ranges are 1 - 20 mg kg^{-1} and 0.01 - 3 mg kg^{-1} for total and methylmercury respectively in contaminated areas (HORVAT, 1989).	Mercury is believed to be present mostly as elementary mercury in the air even though some sources report the presence of up to 30% of methylmercury (SCHROEDER *et al.*, 1987; CLARKSON *et al.*, 1988). Values for clean air vary from 0.5 to 5 ng m^{-3}, whereas they amount up to 50 ng m^{-3} in polluted air.	Mercury mostly occurs in the form Hg^{2+} complex with Cl^- ion in the sea water . Mass concentration of mercury in the open sea ranges from 0.5 to 3 ng dm^{-3} and in the coastal waters from 2 to 15 ng dm^{-3}. Afler some recent studies its levels in the Adriatic Sea waters have been increasing from the south northwards. So its levels are 3 ng dm^{-3} in the southern, 3.7 ng dm^{-3} in the middle and 4.1 ng dm^{-3} in the northern Adriatic (FERARRA *et al.*, 1992). River and lake content varies from 1 to 3 ng dm^{-3} whereas the rainfall contains from 5 to 100 ng dm^{-3} (WHO, 1990).	Mass mercury fraction in food varies dependently on the type of food-stuffs. Corn, fruit and vegetables usually contain from 0.001 to 0.02 mg kg^{-1} dependently on whether the area of their growing is polluted or not and whether the plants were treated by mercury pesticides. In fish, shellfish and fish products, which are dominant methylmercury sources among food stuffs, total mercury mass fraction ranges from 0.01 to 1.2 mg kg^{-1}, with respects to fish species and fishing area. Values for polluted areas were considerably higher (up to 50 mg kg^{-1} Minamata). Methylmercury fraction also varied from 40 to 95% (HORVAT, 1989).

The effects of mercury on marine organisms

Mercury generally passes through skin, gills, food and water into an organism. Phytoplankton absorbs inorganic mercury by passive diffusion directly from the water so that the absorption is directly proportional to the concentrations in the surroundnig sea water (TUDOR, 1989).

Mercury is generally believed to pass through the food chain, being accumulated first at low (primary-producing) trophic levels and passing gradually and in increasing amounts to organisms at higher trophic levels so that it is clear that mercury concentrations increase in organisms at higher trophic levels and are dependent more on the species size than on the pollution of the surrounding environment. As, for instance, mercury, chiefly metylmercury, values are high in big fish from the oceans where levels of mercury are relatively low. These fish feed on fish from lower trophic levels and have much greater life-span. The highest concentrations of mercury were recorded from carnivorous fish, such as tuna and sharks or from relatively static fish as sole (HORVAT *et al.*, 1989).

The range of susceptibilty of marine organisms to mercury is very wide. Already low mercury concentrations in the sea water are very harmful to phytoplankton, in crustaceans and mollusks the susceptibilty is slightly lower whereas in fish it is related to their position in the food chain, their age, time exposure etc. (HORVAT *et al.*, 1989; CRAIG, 1986).

Methylmercury makes up the highest percentage of total mercury in fish. Commercial fish species from unpolluted areas contain from 0.01 to 0.4 mg Hg kg^{-1}. In the cases of high mercury contamination (Minamata and Niigata) fish concentrations amounted to abot 50 mg kg^{-1} (WHO, 1976). Different marine organisms show different total mercury values and methylmercury percentages (Table 2) (HORVAT, 1989; CRAIG, 1986).

Table 2. Mean values of total mercury mass fraction and percentages of methyl mercury in some marine organisms

Organisms	Total mercury mg kg^{-1}	Methylmercury %
zooplankton	0.14	0
tuna	0.3 - 1.00	60 - 95
marine fish	0.01 - 1.50	60 - 90
marine fish (Minamata)	50.00	60 - 90
shellfish (unpolluted water)	0.14 - 0.74	0 - 90
shellfish (polluted water)	11.00 - 40.00	40 - 90
whale	0.10	0

Mercury toxicity and its human health effects

Only seven percentages of total mercury ingested amounts are retained by a human body, whereas methylmercury is absorbed through the gut with high efficiency (90 - 100%). Methylmercury mainly bounds to red blood cells, so that the erythrocyte-serum plasma ratio is about 300. This allows for very rapid distribution of mercury throughout the body tissues and an even distribution among body tissue and organs DOI *et al.*, 1983; CLARKSON, 1983). Apart from being much more poisonous, methylmercury is absorbed with much better efficiency, and is retained in the body for relatively long period with a bioaccumulation tendency (JUNGHANS, 1983; GERSTNER *et al.*, 1977; DOHERTY *et al.*, 1977). It shows great affinity to proteins, amino acids and nucleic acids. Linking to sulfhydryl group of proteins by bisulfide bonds, mercury compounds cause selective membrane permeability to ions and nutrients blocking a lot of transport processes through cell membrane (KOOS *et al.*, 1976).

The usual toxic effects of mercury are primarily manifested in damage to the central nervous system, with early clinical signs of parasthesia, ataxia, tremor in hands, tongue, lips, visual disturbances (constriction of visual fields and blurring leading to blindness), loss of memory, headaches, reddish face, appetite loss (ZVONARIĆ, 1989; JUNGHANS, 1983; INSKIP *et al.*, 1985; BAKIR *et al.*, 1973).

The reviews of data from the poisoning incidents in Iraq (1971-72) and Japan (Minamata, in the 1950s and 1960s) have been useful in establishing apparent threshold levels of response. An international committee of FAO/WHO food experts established PTWI (Provisonal Tolerable Weekly Intake) of 300 μg and 200 μg of total and methylmercury respectively for man of about 70 kilos. On the basis of PTWI mercury and methylmercury values maximum permissible mass fractions were legally established at a national basis in our country (MDK, Official Gazette, No. 46/94). These values are given in Table 3.

Table 3. Maximum permissible mass concentrations of the total mercury and methylmercury in the food from the sea

Fish species	Total mercury mg kg^{-1}	Methylmercury mg kg^{-1}
fresh fish	0.5	0.4
fresh tuna and shellfish	1.0	0.8
tinned fish	0.8	0.6
tinned tuna and shellfish	1.5	1.0

MATERIALS AND METHODS

Sampling

Fish sampling stations (Fig. 1) were located at four sites in the middle Adriatic: a) Kaštela Bay, b) Split Channel, c) Bay of Mali Ston and d) the area of Vis Island. The positions of stations were selected with respect to the presence of land-based pollution sources (a and b) and acceptable purity of the sea water (c and d). Three fish species, *Merluccius merluccius, Mullus barbatus* and *Pagellus erythrinus* were examined. Samplings were performed in spring 1991 and 1993. Immediately upon sampling fish species were selected, fork length taken and sex determined. Thereupon specimens were frozen in polyethylene bags and preserved until analyses. Age of fish was determined from the fork length and the age-length curves (RIJAVEC *et al.*, 1965; ŽUPANOVIĆ, 1968; HAIDAR, 1970). Composite sample was made of two filletes of fish of the saline length, species and sex (ODŽAK, 1991). Numbers of samples are given in Tables 5 through 8.

Reagents and apparatus

a) for total mercury determination

Laboratory glassware comprised flasks with screw caps, cuvettes with screw caps, Leibig cooler, pipettes, graded flasks, funnels.

All the chemicals were of high purity:

HNO_3 conc. - nitric acid, Merck
H_2SO_4 conc. - sulphuric acid, Merck
$NaBH_4$, natrium bhor hydride, Merck
$HgCl_2$, mercury (II) chloride, Merck

b) for methylmercury determination

Laboratory glassware comprised cuvettes with screw caps for extraction and cuvettes for separation in centrifuge and different measurement pipettes

All the chemicals were of high purity:

$C_6H_5CH_3$ toluene, freshly redistilled, Kemika

NaBr, sodium (I) bromine, Kemika

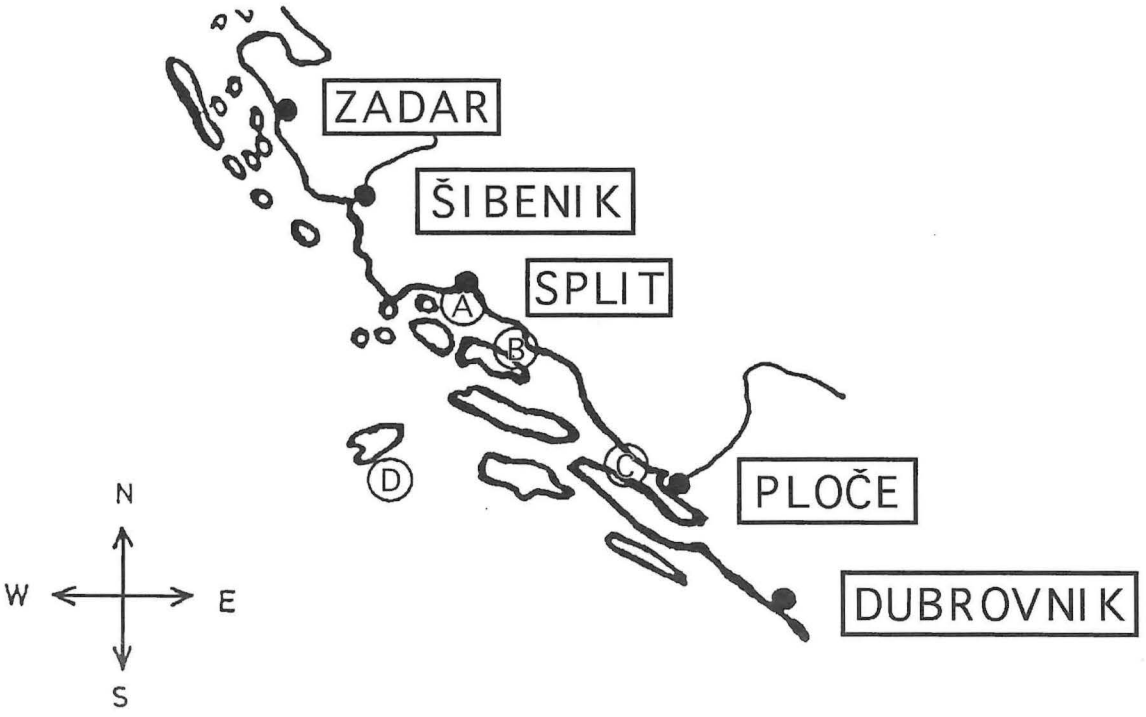

Fig. 2. Study area with sampling stations

HCL, concentrated chloric acid, Kemika

$C_3H_8ClNO_2S.H_2O$ L cysteine hydochloride monohydrate, MERCK

Na_2SO_4, sodium (II) sulphate, Kemika

Carbowax 20 m, Merck

Chromosorb WHP -AW DMCS - 100-120 mesh, MERCK

$CHCl_3$, chloroform, predistilled, Kemika

CH_3HgCl, methylmercury (II) chloride, Merck

Methods

Total mercury in fish was measured by flameless AAS with digestion in concentrated sulphuric and nitric acid in a closed system. Five mg of sample was weighed to which 25 ml of concentrated sulphuric acid and 30 ml of nitric acid were carefully added. It was then boiled in a closed system with a cooler for two hours. Atter adding 20 ml of distilled water sample was boiled for another hour. Sample aliquot (lO ml) was transfer red to a graded 100 ml flask was then analyzed on AAS. Ionic mercury was reduced to elementary mercury with sodium boron hydride and swept by air stream into the quartz chamber where the absorption was measured (A.O.A.C., 1980). This method has 0.05 mg kg^{-1} detection limits.

Methylmercury was determined after the procedure recomended by UNEP/ FAO/ IAEA (UNEP/FAO/IAEA, 1992) . Five mg of sample was homogenised with 5 ml of distilled water, 1.5 ml of conc. chloric acid, 1 g of sodium bromine and 8 ml of toluene, blended for 5 minutes, centrifugalized for 10 min at 2000 rev per min, 5 ml of toluene phase was then transferred to another cuvette, to which 5 ml of 1 % aqueous cysteine solution, acified by 5 mg sodium sulphate, was added, blended for 2 min and centrifugalized. Three ml of aqueous phase was transferred to a third cuvette and acified with 3 ml of chloric acid, 1 g of sodium bromide and 5 ml toluene. It was blended for 2 min and centrifugalized. 2 µl of toluene phase was then injected into GC (with ECD detector) (WESTOO, 1968). This method has detection limits of 0.02 mg kg^{-1}.

Method accuracy was tested by parallel analysis of reference material and obtained data are tabulated in Table 4.

Table 4. Results of analyses of standard reference material

Reference material	Total mercury (µg kg^{-1}) a*	b**	Methylmercury (µg kg^{-1}) a*	b**
Fish tissue (MA-A-2/TM)	470±20	448±18	312±17	337±47
Fish tissue (MA-B-3/TM)	510±70	486±29	439±16	438±36
Sharks (DORM 1)	798±74	714±15	749±35	770±19
FISH TISSUE (TORT - 1)	330±6	363±21	126±4	142±52

a* - recognized value, b** - our value

RESULTS AND DISCUSSION

The highest total and methylmercury concentrations were recorded from Kaštela Bay (Table 5) and Split Channel (Table 6). This is due to the former chlor-alkali plant "Jugovinil" which used to discharge considerable quantities ol untreated inorganic mercury. Even though mercury emmission ceased in 1990 large quantities of mercury are still deposited in sediment which will for long time be the main source of this metal in Kaštela Bay. Similar results were reported by ZVONARIĆ *et al.*, 1987 for the study period 1985-1988. ORLOV *et al.*, 1991 reported considerably lower values for pandora from this area, ranging from 0.2-0.6 mg kg^{-1}. Age and sex of fish were not determined in any of the earlier studies. MIKAC *et al.*, (1985) analyzed pandora and red mullet. They measured the length of specimens, which may allow for the determination of age, but they did not analyse either mercury or methylmercury levels with respect to sex. However, the values reported for pandora and red mullet by all the above mentioned authors are, in general, similar to present results (red mullet 0.6-0.7 mg kg^{-1}; pandora 0.8-0.9 mg kg^{-1}).

The lowest values were recorded from Bay of Mali Ston (Table 7). Similar values were reported by HORVAT *et al.*, (1989), who reported the greatest differences for the data from the Vis Island (Table 8) where pandora levels amounted to 1.3 mg kg^{-1}. However, morphometric data such as age and sex were not then observed and they are extremely important.

Higher mercury concentrations in Split Channel may be affected by currents and fish living and feeding behaviour. Currents may exchange the whole body of Kaštela Bay water once in a month's period. Therefore it was to be expected that mercury would be distributed out of the bay in the direction of currents (TUDOR *et al.*, 1987).

Since Bay of Mali Ston is only a spawning ground and not the habitat of fish and since

Table 5. Mean levels of total and methylmercury in fish from Kaštela Bay

SPECIES	SEX	AGE (yrs)	No. of fish	TOTAL MERCURY (mg kg^{-1})	MEHTYL MERCURY (mg kg^{-1})	MeHg/Hg (%)
Merluccius merluccius	Females	3.5	5	0.162(0.005)*	0.154(0.019)	92.2
Hake	Males	3.5	5	0.175(0.016)	0.151(0.018)	84.2
Mullus barbatus	Females	5.5	5	0.416(0.037)	0.366(0.045)	81.3
Red mullet	Males	5.5	6	0.329(0.022)	0.244(0.038)	73.3
Pagellus erythrinus	Females	2.8	5	0.962(0.013)	0.792(0.031)	79.5
Pandora	Males	3.0	5	1.010(0.020)	0.812(0.037)	78.8

* Standard deviation

Table 6. Mean levels of total and methylmercury in fish from Split Channel

SPECIES	SEX	AGE (yrs)	No. of fish	TOTAL MERCURY (mg kg^{-1})	MEHTYL MERCURY (mg kg^{-1})	MeHg/Hg (%)
Merluccius merluccius	Females	2.8	5	0.263(0.010)*	0.206(0.031)	81.1
Hake	Males	2.0	5	0.303(0.012)	0.229(0.041)	81.2
Mullus barbatus	Females	4.0	5	0.234(0.008)	0.195(0.048)	77.1
Red mullet	Males	5.0	7	0.416(0.024)	0.339(0.040)	79.2
Pagellus erythrinus	Females	2.5	5	0.903(0.016)	0.657(0.029)	71.9
Pandora	Males	4.0	6	1.230(0.070)	0.844(0.029)	70.4

* Standard deviation

Table 7. Mean levels of total and methylmercury in fish from Bay of Mali Ston

SPECIES	SEX	AGE (yrs)	No. of fish	TOTAL MERCURY (mg kg^{-1})	MEHTYL MERCURY (mg kg^{-1})	MeHg/Hg (%)
Merluccius merluccius	Females	2.0	8	0.111(0.012)*	0.090(0.005)	72.0
Hake	Males	2.0	8	0.091(0.007)	0.081(0.017)	71.1
Mullus barbatus	Females	1.0	5	0.113(0.005)	0.050(0.011)	45.5
Red mullet	Males	1.5	5	0.083(0.006)	0.030(0.003)	38.0
Pagellus erythrinus	Females	1.5	5	0.305(0.010)	0.291(0.012)	90.9
Pandora	Males	1.5	6	0.272(0.027)	0.238(0.043)	83.5

* Standard deviation

Table 8. Mean levels of total and methylmercury in fish from Vis Island area

SPECIES	SEX	AGE (yrs)	No. of fish	TOTAL MERCURY (mg kg^{-1})	MEHTYL MERCURY (mg kg^{-1})	MeHg/Hg (%)
Merluccius merluccius	Females	3.5	8	0.190(0.008)*	0.152(0.020)	79.0
Hake	Males	3.0	5	0.226(0.097)	0.189(0.015)	79.4
Mullus barbatus	Females	3.0	6	0.380(0.008)	0.368(0.068)	72.0
Red mullet	Males	5.5	5	0.210(0.008)	0.199(0.027)	74.6
Pagellus erythrinus	Females	1.5	6	0.251(0.012)	0.220(0.046)	75.1
Pandora	Males	1.5	5	0.262(0.008)	0.235(0.036)	74.5

* Standard deviation

there is no bigger pollution source in the vicinity, low data obtained was quite expected.

The highest mercury concentrations were found in pandora, which may be, partly, attributed to their living and feeding behaviour. They are migratory and omnivorous fish. In addition, they are hermaphrodites, that is females become males between the third and fourth year of life (protogyny) (RIJAVEC *et al.*, 1965). This throws some more light on the results for Kaštela Bay and Split Channel, since examined males were from three to four years old and their mercury burden was higher than in females. Fish from other study locations were younger so that the differences cannot be ascribed solely to sex change, but also to their habitat. Pandora mainly feed on small crustaceans, Polychaete and shellfish, that is on sessile benthic organisms which are most strongly affected by polluted environments (JUKIĆ, 1972).

With the exception for Bay of Mali Ston, hake from all other localities showed the lowest total and methylmercury levels. This difference may be related to their biological behaviour. As young fish, up to 16 cm in length (age of about a year), they inhabit the open sea waters. Then they migrate to the coast where they remain by the maturity (between the second and third year) returning to the open sea and deeper and colder waters for spawning, to return to the coastal area at the end. Their nutrition is also of importance. Younger fish mainly feed on planktonic crustaceans and adults on sardine and sprat (ŽUPANOVIĆ, 1968). This accounts for the results of mercury levels in hake, since pelagic organisms are least affected by anthropogenic pollution.

The analysis of concentrations of total and methymercury in red mullet from all four study localities showed the highest burden in males from the Split Channel and in females

from Kaštela Bay. It may be partly accounted for by the growth rates of this species, since females grow faster than males (HAIDAR, 1970). So merculy levels were higher in females from Kaštela Bay and Bay of Mali Ston than in males from the same areas which were of almost the same age. Males from the Split Channel were older which explains why their mercury levels were higher. The area of the Vis Island was an exception since total mercury levels were higher in younger females.

As to the dynamics and nutrition, red mullet are slightly less mobile than pandora their food consisting of benthic organisms, small crustaceans, polychaetes and shellfish (JUKIĆ, 1972). The demersal habitat of red mullet (as well as of pandora) and particularly their dependence on sea bottom facies for food, brings them in close contact with mercury polluted sediment in Kaštela Bay. This normally resulted in higher levels of total and methylmercury in the tissue of red mullet from Kaštela Bay and Split Channel.

The results of this paper confirmed the fact that the concentrations of total and methylmercury increase. They were lowest in hake, slightly higher in red mullet and highest in pandora. These results broadly agree with the results published in 1992 for fish species sampled from the middle Adriatic (HORVAT *el al.*, 1992). Total mercury concentrations reported for the Mediterranean fish were much lower (WHO/FAO/UNEP, 1987). However, since neither the sampling sites nor basic morphometric parameters were taken into consideration in these reports but only measured concentrations, our results are not comparable with the earlier published data.

Most of the total mercury in fish is in the methylmercury form, which is in agreement with the literature data. Commercial fish species from uncontaminated areas contain from 0.01 to 0.4 mg kg^{-1} of mercury. In the cases of extreme environmental mercury contamination (Minamata, Niigata) the values amounted to 50 mg kg^{-1} (ZVONARIĆ *et al.*, 1989; HORVAT, 1989).

If the results of analyses are compared to recommended FAO/WHO PTWI values of 0.3 mg of the total mercury and 0.2 mg of methylmercury for a man of about 70 kg and to the Croatian national limits (Narodne novine/ Official Gazette of the Republic of Croatia, 46/94) which allow not more than 0.5 mg kg^{-1} of the total mercury and 0.4 mg kg^{-1} of methylmercury, the values in pandora from Split Channel and Kaštela Bay are almost twice the maximum permissible limits. This is, by no means, encouraging but it is another proof how irrational use of a water ecosystem as a recipient ot waste discharges (as was the case of Kaštela Bay) may have long-term implications for the environment in question.

CONCLUSIONS

The highest levels of total and methylmercury were found in fish from Kaštela Bay and Split Channel and the lowest in fish from Bay of Mali Ston.

Pandora showed the highest total mercury and methylmercury levels and hake the lowest.

The percentage of methylmercury was quite balanced in all fish species examined ranging between 70 and 90% except for pandora from Bay of Mali Ston.

With respect to sex pandora males contained higher levels of total and methylmercury than females (because of protogyny, between the third and fourth year of age females become males). Females of red mullet from Kastela Bay and Split Channel showed higher levels of total mercury and methylmercury than males of the same age.

No data on total and methylmercury will be reliable if at least age and sex of marine organisms are not examined.

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Živa i metilživa u ribama istočnog dijela srednjeg Jadrana

Sanja ČULIN[1] i Tomislav ZVONARIĆ[2]

[1] *Zavod za zaštitu zdravlja, Split, Hrvatska*

[2] *Institut za oceanografiju i ribarstvo, Split, Hrvatska*

KRATKI SADRŽAJ

Namjena rada je bila odrediti udio žive u nekim gospodarstveno značajnim ribljim vrstama (mol, trlja, arbun) lovljenim na području Srednjeg Jadrana (Kaštelanski zaljev, Splitski kanal, Malostonski zaljev i područje oko otoka Visa). Poznato je da se anorganska živa lako transformira u vrlo otrovnu metil-živu. Jedan od glavnih načina na koji živa može dospjeti do čovjeka je onečišćena morska hrana u kojoj se živa akumulira kao metil-živa.

Najveći maseni udjeli ukupne i metil-žive zabilježeni su u ribama Kaštelanskog zaljeva i Splitskog kanala. To je područje dugo vremena bilo opterećivano s nepročišćenim otpadnim vodama klor-alkalne elektrolize. Najmanji maseni udjeli su zabilježeni u ribama iz Malostonskog zaljeva.

Kao riblja vrsta arbun je sadržavao najveće, a mol najmanje masene koncentracije ukupne i metil-žive. S obzirom na spol, muški arbuni su sadržavali najveće koncentracije, vjerojatno zbog proteroginije. Najmanje su vrijednosti imali mužjaci trlje.

Uspoređujući dobivene rezultate s maksimalno dopuštenim koncentracijama žive u morskoj hrani propisanim Pravilnikom u našoj zemlji (*Narodne novine, 46/1994.*), vidi se da su izmjerene koncentracije iznad granice dozvoljene za prodaju i ishranu.