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A study on dietary intake of mercury through fish consumption in villagers of Alimgarh residing along Ulhas River Estuary, Maharashtra, India and recommendations on fish meals to be consumed.

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A study on the dietary intake of mercury through fish consumption in Alimgarh villagers revealed an average of 3.146 $\pm$ 2.27 µg/kg body wt/week in this population. 40% of the population of Alimgarh exceeded the PTWI limit of 3.3 µg/kg body weight /week as proposed by JECFA (2003). High consumption of carnivorous fish and high rate of fish consumption were the factors influencing high dietary intake of Hg in this population. In order to place them within the safe limit, it is found necessary to limit the consumption of carnivorous fish.

[Keywords: Mercury, Dietary intake, fish, Alimgarh, safe-limit, recommendations]

Introduction

Mercury can be a threat to public health even in environments that are not much polluted[1]. Most of the fish of Ulhas river estuary in Maharashtra, India, are contaminated with Hg[2]. Fish being the staple diet of indigenous fishing population of Alimgarh village located along Ulhas River Estuary, large quantities of contaminated fish caught from this water body are consumed by them[3]. These local fish-eaters are therefore vulnerable to Hg poisoning as consumption of Hg contaminated fish has been identified to cause many health hazards[4]. In foods (other than fish) Hg is almost entirely in inorganic form which is usually easily eliminated from the body whereas in fish and shell fish, 90% of Hg is in its most toxic form, methyl-Hg[5] which remains bound to the body proteins and is not easily eliminated[6]. Thus fish consumption is a major route of entry of Hg into humans[7], second only to occupational exposure[8]. In Alimgarh village, the population rarely consumes foods like meat, eggs, poultry etc. So the only source of Hg exposure in this population is through fish consumption.

The amount of Hg entering the body through fish consumption is known as Dietary intake (DI) of Hg. Dietary intake of Hg through fish consumption is influenced by two aspects, the quantity of fish consumed by the individual and Hg concentration in fish species[9]. These important aspects have been included in this study to determine the dietary intake of Hg in the fish-eating community of Alimgarh village. Present article consists the prevailing fish consumption pattern of the study area, identification of population exceeding Provisional Tolerable Weekly Intake (PTWI) of Hg and recommendations on the number of fish meals to be consumed based on PTWI limits.

Materials and Methods

A small village on the northern bank of Ulhas River Estuary, Alimgarh lies 19^0 12' N and 73^0 02' E at a distance of 12 kms from Thane city (Fig.1). High frequency of estuarine fish consumption is observed among the local people. But as one moves farther

from the bank, people consuming both estuarine and sea fish can be met. Out of a population of 1800, 213 were interviewed randomly.

The present study was carried out with the help of a questionnaire. The survey was based on a house-to-house visit and the houses were randomly selected.

fish consumed and weight of the subject were covered in the questionnaire while Hg concentration of the fish species caught from the estuary was determined by APHA[10] method. Hg concentration was further estimated on Mercury analyzer (AAS) Model no. MA 5804 at BARC and expressed in µg/g on a wet weight basis.

For determining the dietary intake of Hg through fish consumption in an individual, the information about four elements is necessary.viz. Species of the fish consumed, Hg concentration in each species, quantity of fish consumed per week and weight of the subject. Out of these, species and quantity of

Accuracy and precision of the analyses were assured using NRC, Canada Certified Standard Reference Material, DORM-3.

Depending on the types of fish consumed by the subject as recorded in the questionnaire, average mercury concentration of those fish consumed by each subject was calculated.

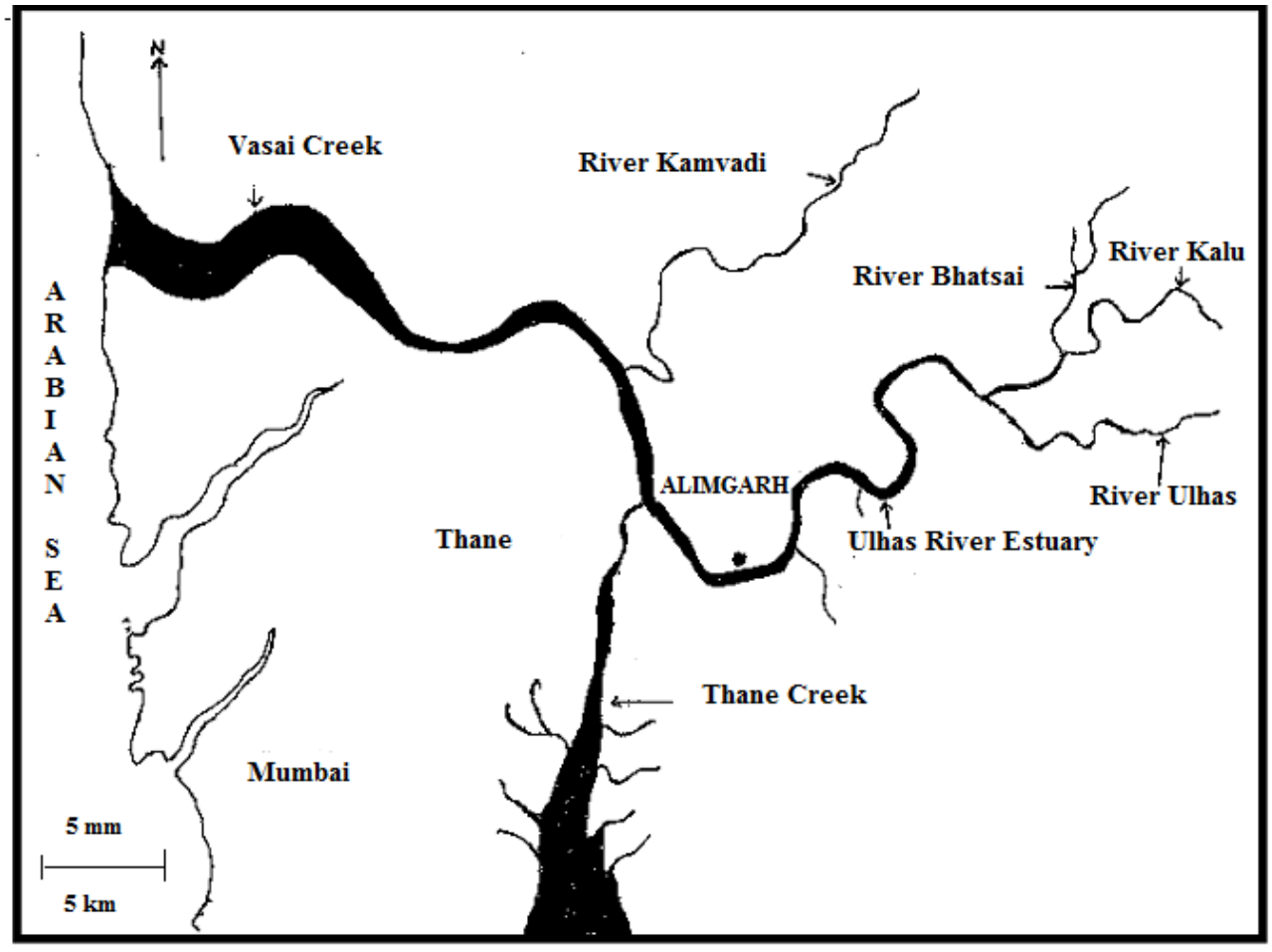

Fig 1 : Map of Ulhas River Estuary, Thane Creek and the study village (Alimgarh)

Uncooked fish weighing 100 gm; 200gm and 500 gm were separately packed in transparent polythene bags, sealed and carried to Alimgarh in ice-boxes. The bags were then displayed in the households and the subjects and/or the housewives were asked to identify the approximate quantity of fish consumed by each person in the household during each meal or day in relation to the quantity contained in the packets. If local catch was available in the households, the portion size consumed by each

member during one meal was identified and weighed. Muscle was the major portion of the fish consumed by the fish eaters. The viscera, bones, gills, scales, fins etc. were often discarded. Therefore, the quantity of fish muscle consumed by the subject was calculated as follows.

As muscle was the main part consumed by the population, it was necessary to estimate the quantity of muscle consumed by each subject. To estimate this, 100 g of one particular species of fish was taken and the muscle tissue was separated and weighed. This was repeated three times and the average reading was taken as the amount of muscle present in 100 g of that fish. This was done in the case of other species of fish also. A table was made for the same. Then, from the calculated data, the amount of fish muscle consumed by every subject was calculated as per the steps below.

Knowing the different types of fish consumed by the subject, an average of the muscle quantity in those fish was calculated. From the amount of fish consumed per day (as in questionnaire), the intake of fish muscle per day in grams was then calculated. Finally the weekly intake of fish muscle was calculated on individual basis depending on the number of days of fish consumption of the individuals which was recorded in the questionnaire.

Dose of the toxic element is very important in toxicological evaluation. It is calculated per kg body weight which gives a more relevant result in comparative studies. Therefore it was necessary to find out the weight of individuals which was recorded in the questionnaire during the survey with the help of a weighing machine. Quantity of fish consumed by an individual per kg body weight was then calculated by using the following formula —

Qty. of fish muscle consumed per day x no. of days of fish consumption/Wt of the person = Qty. of fish consumed in g per kg body wt per week.

The dietary intake of Hg was then calculated using the formula,

Dietary intake of mercury in µg/kg body wt/week = Avg Hg in fish in µg/g x Qty of fish consumed in g /kg body wt/week

This calculation can be better explained with an example as follows:

Step I - Subject A from Alimgarh village consumed *Mugil spp*., *Tilapia spp*. and prawns. So the average mercury concentration in these three fish would be

0.401 µg/g + 0.16 µg/g + 0.05 µg/g / 3 = 0.203 µg/g.(Refer table 1)*(Equation I)*

The average muscle quantity in 100 gms of these three fish (*Mugil spp., Tilapia spp.* and Prawns) = 45g + 44g +22g / 3 = 37 g... (Refer table 2)

Suppose qty. of fish consumed by subject A as per questionnaire is 200 gms.

Therefore, qty. of fish muscle consumed = 37 x 2 = 74 gms

Step II –Average Hg present in 1 gm of fish muscle = 0.203 µg /g

Therefore total amount of Hg consumed by subject A per day = 74 x 0.203 = 15.022 µg / day.

Step III- Suppose the number of days of fish consumption by subject A in a week is 4.

Then total amount of Hg consumed by subject A in a week = 15.022 x 4 = 60.09 µg/ week.

Step IV- Weight of subject is 60 kg.

Then, dietary intake of Hg per kg body weight on a weekly basis = 60.09 / 60 = 1.001 µg / kg body weight per week.

For comparative studies, Daily dietary intake of Hg can also be calculated by dividing the above answer by 7(number of days in a week) = 1.001 / 7 = 0.143 µg / kg body weight per day.

Subsequently, weekly dietary intake of Hg of every subject and the population on a whole was determined (using MS excel).

Results and Discussion

Table-1 shows the average Hg concentration in the different species of fish from the study area and Table-3 shows the weekly dietary intake of the surveyed population in Alimgarh village.

Considering the PTWI of 3.3 µg/kg body weight/week of methyl-Hg as proposed by JECFA (2003)[11], 40 % of the population exceeded the said limit which included 6 boys, 16 girls, 21 men and 15 women. This categorizes the population under vulnerable group with a risk of Hg poisoning. Out of the 15 women, 1 was a lactating mother who had a dietary intake of 4.584 µg/kg body weight/week. Pregnant women interviewed were mixed consumers i.e. consuming both sea fish and estuarine fish, hence not included in the data. Population of Alimgarh village had Hg dietary intake in the range of 0.0029 µg/kg body wt/week and 11.434 µg/kg body wt/ week with an average of 3.146 $\pm$ 2.27 µg/kg body wt/week. Majority of population had dietary intake in the range of 0.001 to 5 as revealed from the population distribution figure-2. High dietary intake can be attributed to the following reasons. Firstly, fish from Alimgarh had high concentrations of Hg with an average of 0.605 µg/g as per table 1. Carnivorous fish like *Mystus spp.* and *Scylla serrata* had 1.39 µg/g and 1.383 µg/g respectively.

Table- 1: Average Hg concentrations in fish species in µg/g from the Alimgarh site

Fish(N)	Size range	Hg conc. in µg/g(min)	Hg conc. in µg/g(max)	Avg Hg conc in µg/g	SD
Mugil spp.(11)	12.8-14.9cm	0.3	0.6	0.401	0.13
Mystus spp.(15)	11.6-12	1.27	1.46	1.39	0.10
Tilapia spp.(33)	9-14	0.15	0.3	0.16	0.096
Mudskippers(30)	10-10.5	0.63	0.69	0.66	0.045
Prawns(41)	9-10	0.03	0.065	0.05	0.014
Scylla serrata(11)	10.5-11.1	0.95	1.6	1.383	0.37
Lates calcarifer(20)	12-13	0.52	0.68	0.6	0.05
Therapon jarbua (7)	11-11.4	0.2	0.4	0.3	0.14
Megalopus cyprinoidae(20)	14.6-15.6	0.48	0.52	0.5	0.02

SD indicates Standard Deviation

Table-2 Quantity of muscle present in 100 gms of fish

Names of fish	Muscle in gms
Mugil spp.	45
Mystus spp.	45
Tilapia spp.	44
Mudskippers	65
Prawns	22
Scylla serrata	25
Eel	50
Megalops spp.	36
Lates spp.	44
Arius	50
Therapon	45

Table-3-Dietary Intake in µg / kg body weight / week in the population of Alimgarh village

	N	Min	Max	Avg	SD	Exceeding Avg		Exceeding PTWI(3.3)	
						N	%	N	%
Boys	16	0.147	7.858	3.089	2.755	6	37.50	6	37.50
Girls	32	0.318	9.189	3.709	2.758	15	46.9	16	50.00
Men	42	0.0029	8.168	3.253	2.043	20	47.6	21	50.00
Women	55	0.0073	11.435	2.779	1.990	21+1	40	15	27.27
Lactating mothers	2	2.859	4.584	3.722	1.219	(1)	50.00	1	50.00
Total	145	0.0029	11.435	3.146	2.270	63	43.44	58	40.00

* N indicates number of subjects; SD indicates Standard Deviation, Lactating mother included in total women

It was noted that all 58 subjects who exceeded the PTWI limits consumed *Mystus spp*., while 45 subjects consumed a few other carnivorous fish too along with *Mystus spp.* Secondly the quantity of fish consumption was on a higher side with a range of 100 to 300 g per day[3]. Thirdly, frequency of consumption in this population was also high in the range of 6 to 21 fish meals per week[3]. All these contributed to high Hg DI in this population.

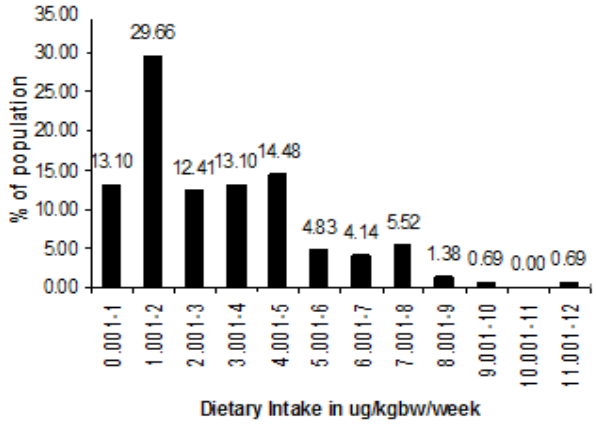

Fig 2. Population Distribution of Dietary Intake of Hg in Alimgarh (N=45)

Figure-2 shows the population distribution of weekly dietary intake of Hg in percentage in Alimgarh village. Most of the population of Alimgarh village fell in the range of 0.001 to 8 µg/kg body wt/week of Hg dietary intake, except 4 subjects. Out of these 4, one female, aged 30 yrs, who consumed 200 g of fish a day was identified to have a Hg intake of 11.435 µg/kg body wt/week. This subject was under weight with only 30 kg. The low weight of this lady was the probable reason for the high dietary intake. Another girl of 7 years weighing 28 kg and consumed 150 g had a dietary intake of 9.189 µg/kg body wt/week. Out of two others who had a dietary intake of 8.168 µg/kg body wt/week and 8.629 µg/kg body wt/week, one of them was a 70 yr old male of 42 kg, who consumed 200 g of fish per day and the other was a 14 yr old with 32 kg who also consumed 200 g of fish daily. These case studies clarified that quantity of fish consumed was a main factor for elevated dietary intake in this area. Thus it can be concluded that population of Alimgarh village is at a higher risk of Hg exposure and immediate measures are required to be undertaken to reduce Hg DI in the population. This can be achieved by restricting consumption of carnivorous fish like *Mystus spp*. and *Scylla serrata* or by reducing frequency of fish meals and/ or by limiting quantity of fish consumption per day.

Many workers have reported Hg dietary intake through fish consumption in other parts of the globe. It has been studied that a high level of precision in determining the dietary intake of a population can only be maintained by calculating dietary intake on an individual basis and then the averages should be taken to determine the dietary

intake of the entire population[12]. The importance of weight-normalized consumption pattern while issuing fish advisories has been emphasized[13]. It was for this very reason that dietary intake of every subject was calculated in µg/kg body wt in the present study.

Many scientists have worked on Hg fish concentration, fish consumption pattern and Hg dietary intake in the populations in the Amazonian river basins which were constantly exposed to heavy Hg pollution due to gold mining activities in the adjoining areas. Among them, Boischio and Henshel (2001)[14] in their studies on the population along Madeira river of Amazon basin, found a dietary intake of 2.6 µg/kg/day which was comparatively higher than the daily dietary intake values of the present work, the method of estimation of dietary intake being same in both cases (when daily dietary intake was calculated). In the studies on methyl-Hg concentrations in fish and fish-eaters from Balbino reservoir in Brazilian Amazon, a daily Hg intake in the range of 11 to 55 µg was discovered[15]. These values were comparable with the daily dietary intake of Hg in Alimgarh (total weight). These studies revealed that on an average, Hg dietary intake in the populations of the present study area was lower than the Amazonian regions. However, Hg daily intake of 7.5 µg/ kg body wt in a population of New Jersey was also reported[16]. The mean fish consumption in each country to calculate the mean weekly intake of Hg in each individual country was used by some workers[17]. Accordingly, the highest dietary intake was estimated in Spain with 49.8 µg/ week and the lowest in Croatia as 19µg/week. This was much lower than the weekly Hg dietary intake of Alimgarh which was 152.60µg/week (when calculated).

It is evident from the above discussion that dietary intake of Hg varies with Hg concentration in fish species and types of fish consumed. Quantity of fish consumption also plays an important role in dietary intake of Hg. All these aspects should be well considered while declaring the safety dose of fish consumption at a particular place. For instance, EPA, US had proposed a reference dose (Rfd) of 0.1 µg/kg body wt/day for Hg exposure on the basis of various studies undertaken in U.S.[18].But this recommendation may not be applicable in all areas. It was observed that the application of this recommendation in Amazonia would result in the total ban on fish consumption in these regions [9]. This was irrelevant as the communities in these regions depend on fish for their sustenance. Therefore, it is necessary that separate advisories be formulated for every village according to their fish consumption pattern in order to avail maximum benefits of fish consumption while abstaining from the hazards of mercury exposure.

Regulatory guidelines to limit environmental Hg exposures have been developed by many governmental agencies throughout the world. But no such advisory has been developed in India[19]. Based primarily on the results of toxicity studies conducted in New Zealand, Seychelles and Faroe islands and also using varying interpretations of the epidemiological evidence, it was recommended that Provisional Tolerable Weekly Intake (PTWI) of methyl-Hg for adults should not be more than 3.3 µg /kg body wt /week which is equivalent to a weekly intake of 400 g of fish with 0.5 µg/g of Hg for a person with a body wt of 60 kg[20]. The Joint FAO/EPA Executive Committee for Food Additives: JECFA (2003)[10] based on a consensus decision of an international panel has established this value of 3.3 µg/kg body wt /week as the Provisional Tolerable Weekly Intake(PTWI) of Hg for adults. An attempt has been made in the present work to put forward recommendations on fish consumption for the villagers of Alimgarh in particular (Table 4), so that they can avail maximum benefits of fish nutrition and at the same time be within the safe limits. It has been calculated as follows. A similar pattern of calculation for the recommendation of fish consumption has also been carried out by FSANZ[5] while assessing the Hg contamination in foods.

Calculation to estimate the maximum number of fish meals allowed per week for the population of Alimgarh

Considering 3.3 µg/kg body weight /week as the safe limit of dietary intake of mercury, a recommendation on the number of fish meals to be consumed has been proposed for the individuals of Alimgarh village based on three important elements affecting the dietary intake viz:

Table 4 : Recommendation on the number of Fish meals / week to be taken by the population of Alimgarh

Fish Muscle Consumption in grams / meal	Fish	Body weight in kg					
		21-30	31-40	41-50	51-60	61-70	71-80
1 - 100	Prawns	13	20	No restriction	No restriction	No restriction	No restriction
	Tilapia spp.	4	6	8	10	12	14
	Lates spp.	1	1	2	2	3	3
	Mugil spp.	1	2	3	4	5	5
	Boleophthalmus spp.	1	1	2	2	3	3
	Scylla serrata	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1	1
	Mystus spp.	Once in 2 weeks	Once in 2 weeks	1	1	1	1
101 - 200	Prawns	6	10	13	16	20	No restriction
	Tilapia spp.	2	3	4	5	6	7
	Lates spp.	Once in 2 weeks	Once in 2 weeks	1	1	1	1
	Mugil spp.	3	1	1	2	2	2
	Boleophthalmus spp.	Once in 2 weeks	Once in 2 weeks	1	1	1	1
	Scylla serrata	Once in 4 weeks	Once in 3 weeks	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks
	Mystus spp.	Once in 4 weeks	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks
201 -300	Prawns	4	6	9	11	13	15
	Tilapia spp.	1	2	2	3	4	4
	Lates spp.	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1
	Mugil spp.	5	Once in 2 weeks	1	1	1	1
	Boleophthalmus spp.	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1
	Scylla serrata	Once in 7 weeks	Once in 4 weeks	Once in 4 weeks	Once in 3 weeks	Once in 3 weeks	Once in 2 weeks
	Mystus spp.	Once in 7 weeks	Once in 4 weeks	Once in 3 weeks	Once in 3 weeks	Once in 3 weeks	Once in 2 weeks
301 - 400	Prawns	3	5	6	8	10	11
	Tilapia spp.	1	1	2	2	3	3
	Lates spp.	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1
	Mugil spp.	6	Once in 2 weeks	1	1	1	1
	Boleophthalmus spp.	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1
	Scylla serrata	Once in 7 weeks	Once in 4 weeks	Once in 4 weeks	Once in 3 weeks	Once in 3 weeks	Once in 2 weeks
	Mystus spp.	Once in 7 weeks	Once in 4 weeks	Once in 3 weeks	Once in 3 weeks	Once in 3 weeks	Once in 2 weeks
401 - 500	Prawns	2	4	5	6	8	9
	Tilapia spp.	Once in 2 weeks	1	1	2	2	2
	Lates spp.	Once in 5 weeks	Once in 4 weeks	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks
	Mugil spp.	8	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks	1	1
	Boleophthalmus spp.	Once in 5 weeks	Once in 4 weeks	Once in 3 weeks	Once in 2 weeks	Once in 2 weeks	Once in 2 weeks
	Scylla serrata	Once in 10 weeks	Once in 8 weeks	Once in 6 weeks	Once in 4 weeks	Once in 4 weeks	Once in 3 weeks
	Mystus spp.	Once in 10 weeks	Once in 7 weeks	Once in 5 weeks	Once in 5 weeks	Once in 4 weeks	Once in 3 weeks

the quantity of consumption, the species of fish consumed and the weight of the consumer. Care has been taken to place the individuals well within the safe limits.

Method of Calculation for the recommended number of fish meals per week:

The number of fish meals of Mugil (fish) that can be safely consumed by a subject weighing 60 kg who takes 100 g of fish per meal, is calculated as follows, so that his intake of Hg is within the PTWI.

Average Hg of the species Mugil (in Alimgarh)= 0.40 µg/g in muscle(Refer table 1)

Quantity of fish consumed by the subject per meal =100 g = 45 g of muscle (Refer table 2)

Therefore, Dietary intake of Hg per meal =0.40 x 45 = 18 µg per meal

Weight of the subject =60 kg

Therefore, Dietary intake of Hg in kg body weight/meal =18 /60 = 0.3 µg/kg bwt/meal

PTWI value is 3.3 µg/kg bwt/week.

Therefore, no. of fish meals that can be consumed = 3.3 (PTWI) / 0.3= 11 meals
That is 11 fish meals of 100g Mugil per week

To make it simpler, the number of fish meals can be calculated using the formula,

Avg. Hg conc. in fish x Qty. of fish consumed per meal x No. of fish meals consumed per week (unknown value) / Wt. of individual = 3.3 µg/kg body wt/week (PTWI as per JECFA)

Therefore, Number of fish meals per week(X) = 3.3 (PTWI) x Weight of individual / Average Hg conc. Of the fish x Quantity of fish consumed per meal

After the number of serves of fish was calculated for each type of fish, the numbers were rounded off to the lower nearest whole number (eg.12.96 to12 meals/week). For public health reasons, the number was not rounded up to 13 meals per week, as consuming the higher number of serves could result in consumers exceeding the PTWI. The recommendations on the number of meals of a particular fish for an individual with reference to his weight and quantity of fish consumption has been given in Table 4.

Conclusion

Villagers of Alimgarh presented high levels of dietary intake and therefore exposed to a greater risk of Hg toxicity. The Alimgarh village had 40 % of the population exceeding the Provisional Tolerable Weekly Intake (PTWI) limit of 3.3 µg/kg body weight /week. This population consumed carnivorous fish and so presented with larger intake of Hg. Therefore, consumption of carnivorous fish like *Mystus spp.* and *Scylla serrata* should be limited, depending on the quantity of consumption and weight of the individual. On the other hand, people can relish on several fish meals of herbivorous fish like Prawns and *Tilapia spp.* while *Mugil spp.*, *Gobius spp*. and *Boleophthalmus spp* should be consumed in moderation in order to place them within the safe limit of 3.3 µg/kg body wt/week.

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