Research Article

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Analysis of the risk of exposure to methyl-mercury due to non intentional consumption of shark meat in males of Mexico city's metropolitan area

Abstract

In this paper we estimate the probability and risk coefficient of methyl mercury exposure due to unintentional consumption of shark meat for the male inhabitants of Mexico City's metropolitan area. Using statistical and numerical methods, we built a risk function in terms of the concentration and life stage variables. Using mathematical results from the singularity theory, dynamical systems and differential geometry, we obtained that both, the risk average (2.96) and the risk probability (85%) are high. We also obtained the critical ages or risk which are 5.1 years for boys and 87 years for senior men, but this will be relevant only to those men who reach this age. All this, means that in the analysed sample, there is a high probability of developing deleterious health effects. So, if men want to consume fish products, they must buy whole fish to avoid the replacement.

Keywords: Methyl mercury, Risk coefficient, Risk smooth stable function, Risk surface, Critical ages of risk.

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Introduction

In the work[1–18] carried out by Silbernagel et al., the authors the authors alert physicians the danger of consuming fish, shell fish, and seafood in general, because all of them contain certain amounts of methyl mercury. In particular, they mention that at the top of the the food chain animals such as sharks contain the highest amounts of this element. Furthermore, the authors mention that the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) of the United States issued a food advisory for women of different ages in regards to fish consumption and MeHg.

In another study, Elizalde et al.,[15] carried out a study of the risk of MeHg exposure due to the unintentional consumption of shark meat for Mexico City's metropolitan area females. They obtained the critical ages of risk and children exhibited the highest risk (5.37 yr.), followed by senior women (74.4 yr.) and adult women in reproductive age (32.64 yr.).

Here, we continue the study begun by Elizalde et al. of characterizing the risk of exposure to methyl-mercury due to non intentional consumption of shark meet in Mexico City's metropolitan area inhabitants, but now for males. To avoid some originality problem of the work, we mentioned that we will use the same methodology as in the mentioned previous work to obtain the important results.

In Mexico, concentrations of methylmercury in shark meat have been re-ported in concentrations ranging from 0.27 to 3.33 ppm.[14] Because fish products are sold without any morphological characteristics that could help the consumer to differentiate between fish or shark this becomes a problem. The largest distribution center in Mexico City (CDMX) is the Central de Abasto de Pescados y Mariscos where you can obtain fish meat in various presentations (chunks, fellets, smoked, ground, minced or nuggets). In the work carried out by Elizalde,[4] 53 samples of fish offered from this site were obtained and were analyzed using the Polymerase Chain Reaction (PCR) technique with universal shark oligonu-cleotides. The results indicated that 60.37 % of the samples turned out to be some shark species. The reference dose used was the one the USEPA suggested based on the Faroe Islands case.[20] Based on a previous study for girls and women, the objective of this study was to calculate the health risk for men in the Metropolitan Area of Mexico City due to uninten-tional exposure to methylmercury through the consumption of shark. A less biased approach to risk assessment uses uncertainty analysis to assess the

degree of confidence that can be given to the risk estimate. A mathematical analysis of numerical and analytical methods was also carried out to give a quantitative indication of the quality of this estimate.[15]

Methods

Data acquiring: The analyzed samples were collected from Mexico City's Central de Abasto. The sampled products included \ fish " meat to make ceviche, meat to make fish broth, meat to make fish quesadillas, smoked fellet, inexpensive steak (sea bass, Nile fish white fellet, cat fish, etc.) and breaded fellet.

Positive control shark samples (Carcharhinus. limbatus, Carcharhinusleu-cas, Carcharhinusfalciformis, Galeocerdocuvie, Isurusoxyrinchus) were do-nated by the UNAM Genetics Laboratory. Negative control samples were sh from di erent species: red snapper (Lutjanuscampechanus), marlin (Is-tiophoridaesp), cat fish (Siluriformes), Nile sh (Oreochromismossambicus), sea bass (Centropomusundecimalis) and salmon (Oncorhynchussp).

Survey design: A non-probabilistic sampling was done, also called discretionary sampling,[13] in order to identify the population characteristics and consumption habits (quantity and frequency of fish prod-ucts consumption). The surveys were applied in ve municipalities of Mexico City and in two municipalities of the State of Mexico, in the markets where home-makers buy these products, according to what was described in the work.[5] The information collected was the frequency of fish consumption, portion size (weight in grams), species and presentation type; age, gender and weight of the respondent and his entire family. A total of 777 surveys were applied.

Modeling the dose: The lifetime average daily dose (LADD) or the chronic daily intake (CDI), is a function of the average concentration of the contaminant and the ingestion rate. Body weight, age, sex, consuming preferences and frequency were obtained from the aforementioned surveys. In addition, the average life expectancy of Mexican male consumers (78 years) was obtained from national statistics available on line.[11] The total dose and the average daily dose (ADD) were calculated with following equations:[17]

$$Total\ dose = (concentration)(ingestion)(duration)(frequency) \quad (1)$$

$$Average\ Daily\ Dose = (Total\ dose)/(Body\ weight \times Life\ expectancy) \quad (2)$$

$$(mg/k/-\text{day})$$

The total dose was calculated for three concentrations of methylmercury (0.27 mg / Kg, 2.43 mg / Kg, 3.33 mg / Kg), obtained from the study by Ramirez-Romero et al.[14]

Reference dose: The quantitative assessment of the health risk of a non-carcinogenic agent is based on a reference dose. In this study we chose the reference doses suggested by[20] in the Faroe Island study of 0.0001 mg / Kg / day for children and older adults, and 0.0003 mg / Kg / day for the adult population.

Calculation of risk for unintentional consumption of shark meat: We used the[20] formulas to calculate the weekly and monthly consumption of unintentional consumption of shark meat

$$CR_{mm} = \frac{CR_{lim} \times T_{ap}}{M\ S} \quad (3)$$

To determine the maximum consumption allowed for the sensitive population (children under 15 years of age) and of reproductive age from (16 to 50 years), in portions of fish, in kilograms per day, the following equation was used

$$CR_{lim} = \frac{RfD\ BW}{C_m} \quad (4)$$

where,

BW = Consumer body weight(Kg)

Cm = Concentration of mercury in fish species (mg=Kg)

RfD = 0:0001 mg=Kg reference dose day:

where the reference dose-day is for the developing foetus and men of child-bearing age.

We remark that the reference dose is 0.0001 mg / Kg according to the toxicological effects of methylmercury (EPA)[19]

For the calculation of weekly and monthly consumption in Kg / day for the adult population, equations (3) and (4) were used, but with the reference dose of 0.0003 mg / kg / day proposed by the USEPA in 1980, which is based on the methylmercury poisoning in Iraq in 1970, when wheat grain was treated with fungicides with methylmercury, which was ground and turned into our for consumption.

Health risk characterization: For the health risk analysis, the hazard or risk coefficient was calculated with the following relation.[7]

$$Risk\ coefficient = \frac{Exposure}{RfD} \quad (5)$$

which is equal to the risk (R). The exposure (E), is obtained through the equation:[1]

$$E = \frac{C \times TI \times FE}{PC} \quad (6)$$

Where

C= Concentration of the contaminant in sh (mg=Kg=day)

TI = Intake rate (mg)

FE = Exposure factor (without units)

PC = Body weight (Kg)

The exposure factor allows us to calculate the dose of contaminant that is ingested. However, it is compared with the administered dose used in experimental animal studies designed to obtain the dose-response relationship. The exposure factor was calculated using equation 7 for the different groups, separated by age of the analyzed population.[1] According to Elizalde[4] the genetics results showed an average of 60.37 % substitution of fish meat for shark meat which was considered in the analysis.

$$FE = \frac{(exposure\ in\ days = weeks)(52\ weeks = year)(exposure\ years)}{(years\ exposure)(365\ days = years))}$$

According to Evans et al.,[17] the result of the value for the risk coefficient is interpreted as follows:

R< 1 (acceptable risk)

R> 1 (unacceptable risk)

Results

Survey: The total number of people included in the survey was 1976, where men consume fish meat more frequently and in greater quantity: 262.60 g / month, followed by men and seniors:194 g / month and 193 g / month respectively (Table 1).

In such that Table, NPS is the number of people surveyed, AG is the age (in years), ABW is the average body weight (in Kg), AIR is the average intake rate (in g) and AFP is the average Fish portions consumed per month.

The consumption habits of the analyzed population showed that the most preferred product is the fish fellet (Table 2), followed by fish nuggets population and smoked fish.

Dose modeling: The average daily dose calculated for the minimum, average and maximum methyl-mercury concentrations are shown in Table 3 of reproductive age are at a minimum consume a dose that does not exceed the reference dose when the minimum MeHg concentration was considered; however.

Analysis of health risks due to unintentional consumption of shark meat: To obtain the maximum allowed number of portions that can be consumed without causing adverse health effects, equations (3) and (4), described in the method,[20] were used. Taking into account the result of the genetic analysis of the different sh presentations, in which a 60.37 % substitution of sh meat for shark was obtained,[4] the maximum consumption allowed for all population groups was recalculated, for the minimum, average and maximum concentrations of methylmercury in shark meat.

Risk coefficient: The health risk for men due to unintentional shark meat consumption for the different age groups, was calculated for the three concentrations; for the calculation of the risk Coefficient, equations (5), (6) and (7) were used, the results can be seen in Table 4; for the low methylmer-cury concentration with a 60.37 % substitution for shark meat, the risk Coefficient is less than one, which means, that in general, the unintentional consumption of shark meat does not pose a risk or is an acceptable health risk; however, for children from 0 to 5 years old, the calculated value (0.785) is closer to one, which alerts us to the possible risk that slightly higher may represent. For example with a MeHg of (0.45 mg/kg) the RC exceeds one. The risk coe cient for the medium and high MeHg concentrations was always well above 1, which means that the consumption habits represent a risk for the entire population (Table 5).

Table 1 Population characteristics and consumption habits

Surveyed	NPS	AG	ABW	AIR	AFP
Children	421	0 14	34:94	188:17:00	1:03
Men	546	15 59	73:44:00	262:60	2:06
Senior	396	60 90	68:85	193:38:00	2:01

Table 2 Fish product preferences of people of Mexico City's Metropolitan Area

Product	Adult	Sensible population
Fish llet (g)	65%	31%
Fish Meat for ceviche (g)	12%	16%
Fish Meat for sh broth (g)	10%	17%
Smoked sh (g)	8%	18%
Fish nuggets	14%	18%

Table 3 Average and reference of daily methylmercury (MeHg) dose for di erent age groups

	Average daily dose			Reference dose
Age group	[0.27 mg/Kg] HgMe	[2.43mg/Kg] MeHg	[3.33 mg/Kg] MeHg	mg/Kg MeHg
Boys	0:03	0:23	0:32	0:01
Men	0:02	0:15	0:21	0:03
Senior Men	0:01	0:12	0:17	0:01

Table 4 Risk coefficient of men's unintentional consumption of shark meat

	Risk coefficient	Risk coefficient	Risk coefficient
Age group years	[0.27 mg/Kg] HgMe	[2.43mg/Kg] MeHg	[3.33 mg/Kg] MeHg
Babies (1 6)	0.558333	0.45625	1.0125
Boys (6 12)	0.2375	3:077	0.316667
Men (12 60)	0.141667	0.620833	0.439583
Senior (60 90)	0.269444	0.465278	0.710417

Table 5 Interpolating polynomials

Concentration	Associated polynomials of degree 4 in the variable t		
	4	3 2	
[0.27] Hg	$R_{0:27}$(t) = 0:0663 t_4	+ 0:9283 $t_3$4:5447 t_2	+ 8:9347 t 5:252
[2.43] Hg	$R_{2:4}$3(t) = 0:5972 t_4	+ 8:3573 $t_3$40:913 t_2	+ 80:433 t 47:28
[3.33] Hg	$R_{3:33}$(t) = 0:8185 t	+ 11:455 $t_5$6:078 t	+ 110:24 t 64:802

The scalar field of risk

In this section we nd the scalar eld which will give us information of the process.

The escalar eld. Life stages [1; 90] are conveniently reparametrized so that they adapt to an interval [1; 5], this is, if s 2 [1; 90] is the real age, we will use the variable t 2 [1; 5], and the functional relation is given by.

$$s(t) = \begin{cases} 5t-4 & \text{if } 1 \le t \le 2 \\ 6t-6 & \text{if } 2 \le t \le 3 \\ 48t-132 & \text{if } 3 \le t \le 4 \\ 30t-60 & \text{if } 4 \le t \le 5 \end{cases} \tag{8}$$

This later is because the sh consumption begins after the rst year of life. Therefore, with such reparametrization (8), the intervals of stage age are applied:

Babies, [1; 6) years, into the interval [1; 2),

Boys, [6; 12) years into the interval [2; 3),

Men, [12; 60) years into the interval [3; 4),

Senior men, [60; 90] years into the interval [4; 5].

Since it is recommended not to give sh meat to infants under one year of age, we associate the zero risk with age t = 1 and using the data from the Table 4 and the Interpolation method,[15] we will construct three polynomials of degree 4 in the variable of age for each given concentration of methylmercury (MeHg): 0.3, 2.7, 3.7 mg / Kg respectively, as it is shown in Figures 1– 3.

For the mentioned cases we obtain the following particular polynomials.

In order to construct a global smooth scalar function R(t; c) in the stage and concentration variables (t; c) that estimates the risk in the domain D = [1; 5] [0:2; 3:5], such that for each value of concentration c we have a polynomial relation R_c(t) that depends only on stage t, we propose it with the following type:

$$R(t, c) = f_4(c)t^4 + f_3(c)t^3 + f_2(c)t^2 + f_1(c)t + f_0(c). \tag{9}$$

Here, the coefficient functions f_k(c) are obtained by the linear regression method according to the imposed conditions of the obtained polynomials:

$f_4(0:27) = 0:0663$; $f_4(2:43) = 0:5972$; $f_4(3:33) = 0:8185$;

$f_3(0:27) = 0:9283$; $f_3(2:43) = 8:3573$; $f_3(3:33) = 11:455$;

$f_2(0:27) = 4:5447$; $f_2(2:43) = 40:913$; $f_2(3:33) = 56:078$; etc...

The first coefficient function $f_4(c)$ in (9) is given by the linear relation,

$$f_4(c) = 0:2458c \tag{10}$$

The other coefficient functions are also linear and are obtained in a similar way,

$$\begin{aligned} f_3(c) &= 3.44c - 0.0008 \\ f_2(c) &= 16.84c + 0.0037 \\ f_1(c) &= 33.105c - 0.0058 \\ f_0(c) &= 19.46c + 0.0036 \end{aligned} \tag{11}$$

Therefore, the searched scalar eld (9) that estimates the risk of methyl-mercury in region D becomes,

$$R(t,\, c) = 0.2458\, ct^4 + (3.44\, c - 0.0008)\, t^3 + (-16.84\, c + 0.0037)\, t^2 + (33.105\, c - 0.0058)\, t + (-19.46c + 0.0036) \tag{12}$$

For any fixed given value of the concentration c the corresponding function $R_c(t)$ has a graphic in the plane t, R as it is shown in the interpolation process (Figures 1–3).

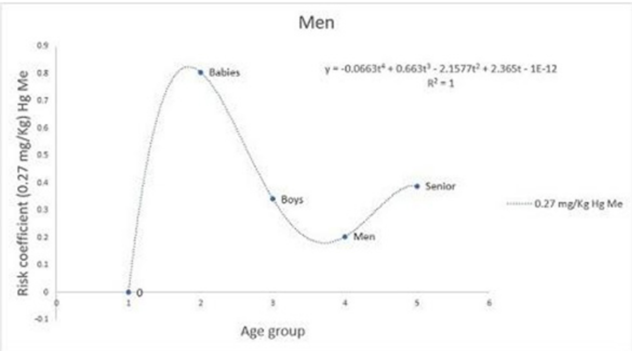

Figure 1 Risk Coe cient for men of di erent life stages considering the concentration 0.27.

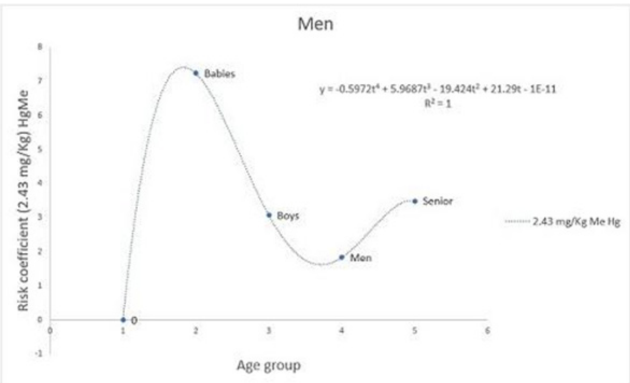

Figure 2 Risk Coe cient for men of di erent life stages considering the concentration 2.43.

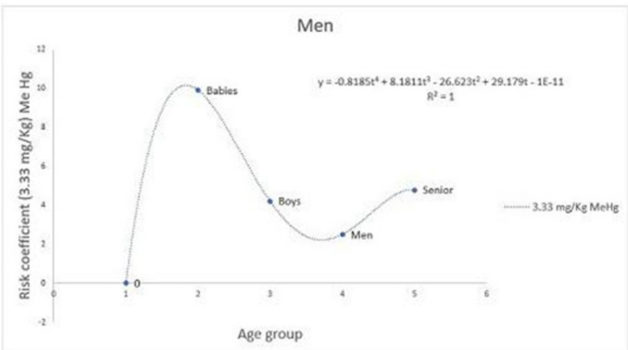

Figure 3 Risk Coe cient for men of di erent life stages considering the concentration 3.43.

When the gradient of the risk function $R_c(t)$ is calculated, we obtain,

$$\nabla R(t,c) = \left(\frac{\partial R}{\partial t}, \frac{\partial R}{\partial c}\right)$$

$$= (0.0058 \quad + 33.105c \; + \; 2(0.0074 - 33.68c)t$$

$$+ (-0.0024 \quad + 10.32c)t^2 - 0.9832ct^3,$$

$$-19:46 \; + \; 33:105t16:84t^2 + \; 3:44t^3 \;\; 0:2458t^4) \tag{13}$$

In order of finding the critical points of (12), we solve the system of algebraic equations in the variables t; c,

$$\begin{aligned} 0 &= (-0.0058 \; + \; 33.105c \; + \; 2(0.0074 - 33.68c)t \\ &+ (-0.0024 \; + \; 10.32c)t^2 - 0.9832ct^3, \\ 0 &= -19.46 \; + \; 33.105t - 16.84t^2 + \; 3.44t^3 - 0.2458t^4 \end{aligned} \tag{14}$$

which, as can be seen easily, has not solutions into the domain D.

We recall that a stable real valued function f defined in the compact set D is such that every nearby real valued function g defined in D is identical to f.[18]

Also, a Morse function is such that one with non degenerate critical points with different critical values (Golubitsky-Guillemin.[8]

Since the risk function R(t; c) has not critical points it follows the following result.

Theorem 1. The risk field R(t; c) is a stable Morse function in the simply connected compact set D

Proof. The whole set D is a regular set for R(t; c) , which proves the Morse property. The stability follows from the Mather-Malgrange Theory (see Proposition 2.2 in[8]).

Therefore, under small smooth deformations of the risk function R(t; c) in D, the deformed function obtained has the same qualitative behaviour. In other words, any small error in obtaining the data would lead to a new risk relationship with the same characteristics.

The Critical Risk Region inside the domain D is the subset

$$R(D) = \{(t,\, c) \;/\; R(t,\, c) \geq 1\} \tag{15}$$

and it is represented as a coloured contour in Figure 4, which shows a high risk region, as expected from the data in Table 4.

The following result shows the risk probability for the whole process.

Proposition 1. The probability of risk of exposure of methylmercury P for the considered stages and concentrations is high of 85%.

Citation: Ramirez LE, Romero PR, Victoria JGR, et al. Analysis of the risk of exposure to methyl-mercury due to non intentional consumption of shark meat in males of Mexico city's metropolitan area. *J Appl Biotechnol Bioeng.* 2022;9(2):49–55. DOI: 10.15406/jabb.2022.09.00284

Proof. We calculate the ratio between the corresponding areas of D and R(D), obtaining the aforementioned probability of risk,

$$P = \frac{Area\left(R\left(D\right)\right)}{Area\left(D\right)}$$
$$= \frac{1}{Area\left(D\right)} \iint_{R(D)} dcdt \quad (16)$$
$$= \frac{11.32}{13.2} = 0:85 = 85\%$$

In other words, at least 4 out of 5 individuals have the probability of risk of consumption.

We show the contour lines or level curves of the scalar risk field which are displayed in domain D in Figure 5. In such that Figure, the darker region indicates less risk, while the lighter region indicates greater risk.

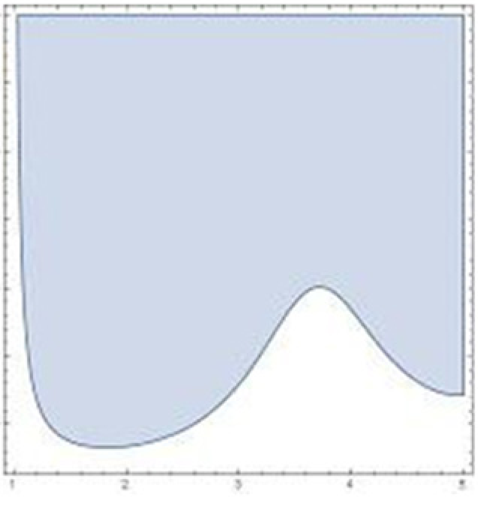

Figure 4 Critical risk region R(D).

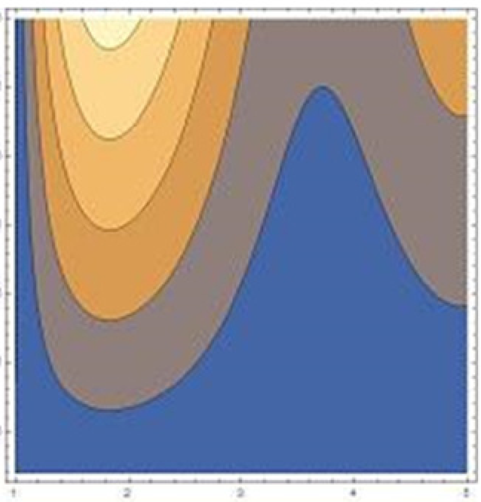

Figure 5 Level curves due to unintentional shark consumption for men.

We obtain also the following crucial and important result.

Theorem 2. The average value R = 2:96 of R(t; c) in the whole set D represents a high risk for the population.

Proof. The average value R of the risk in domain D is calculated by apply-ing the formula

$$R^* = \frac{1}{Area\left(D\right)} \iint_D R(t,c)dcdt$$
$$= \frac{1}{Area\left(D\right)} \int_{t=1}^{t=5} \int_{c=0.2}^{c=3.5} [0:2458\ ct^4 + \left(3:44\ c0:0008\right) t^3 \quad (17)$$
$$+ \left(16:84\ c + 0:0037\right) t^2 + \left(33:105\ c0:0058\right) t + \left(19:46c + 0:0036\right)]\ dc\ dt$$
$$= \frac{39.17}{13.2} = 2:96$$

Such that number represents a high risk in the whole set D.

4.2. The risk vector field. Because there are not critical point for the risk function, we study the risk gradient vector field (13) for understanding the behaviour of the risk function. The flow of such risk vector field shows how the process is changing along the solutions of the associated system of differential equations,\

$$\frac{dt}{dT} = (-0.0058 + 33.105c + 2(0.007433.68c)t + (-0.0024 + 10.32c)t^2 - 0.9832ct^3, \quad (18)$$
$$\frac{dc}{dT} = -19.46 + 33.105t - 16.84t^2 + 3.44t^3 - 0.2458t^4$$

where τ is the dynamic time (Figure 6).

Lemma 1. The dynamical system (18) does not have neither equilibrium points, nor closed orbits in the compact simply connected region D (Figure 6).

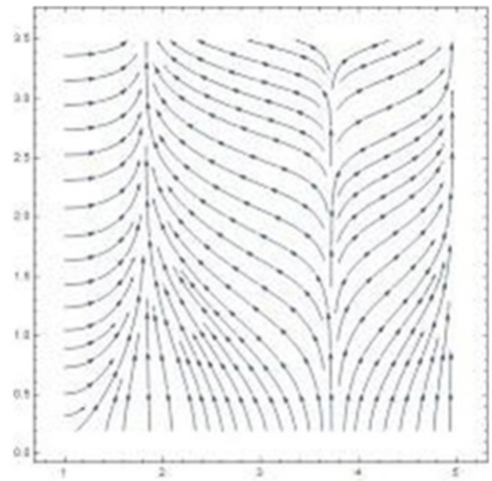

Figure 6 Vector eld of risk rR(t; c) for unintentional consumption of shark for men.

Proof. Since the risk function does not have critical points in the considered domain, it follows that there are not equilibrium points in D for such system. From the Poincare-Bendixon Theorem follows that there are not periodic orbits, since in other case, if there is one periodic orbit inside D, the simply connected region bounded by this orbit must contain one equilibrium point.

Figure 6 shows vertical lines as separatrixes in the flow of the vectorfi eld of risk and are understood as the ages where there is a signiffcant risk. These ages will be calculated later using geometric methods.

The risk surface: The so-called associated risk surface S is the graphic of the risk function (12), and it is a two dimensional surface em-bedded in the three dimensional Euclidean space R^3, shown in Figure 7.

We use the Gaussian curvature function K(t; c)[3] of the Risk Surface to determine the critical ages of the global risk function. We recall that one Hadamard surface has non positive Gaussian curvature in all its points. We have the following important result.

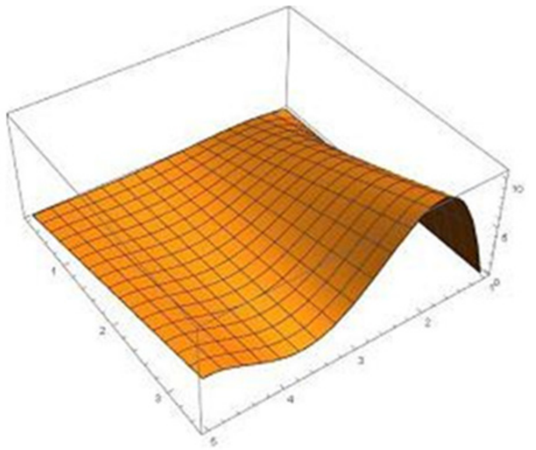

Figure 7 Risk surface for men due to unintentional expo-sure to MeHg.

Theorem 3. The associated risk Surface S is one Hadamard surface em-bedded in the three dimensional Euclidean space R^3.

Proof. If we parametrize the surface S on the domain D in the canonical way.

$$\varphi(t,\ c)\ =\ (t,\ c,\ R(t,\ c)),\quad (t,\ c)\ \in\ D, \tag{19}$$

The Gaussian curvature is calculated with the equality.[3]

$$K(t;\ c)=\frac{\left(\frac{\partial^2 R}{\partial t^2}\right)\left(\frac{\partial^2 R}{\partial c^2}\right)-\left(\frac{\partial^2 R}{\partial t \partial c}\right)^2}{\left(1+\left(\frac{\partial R}{\partial t}\right)^2+\left(\frac{\partial R}{\partial c}\right)^2\right)^2}$$
$$=\frac{\left(33.10533.68t\ +\ 10.32t^2\ 0.9832t^{3\ 2}\right)}{\left(1+\left(\frac{\partial R}{\partial t}\right)^2+\left(\frac{\partial R}{\partial c}\right)^2\right)^2} \tag{20}$$

Because

$$\left(\frac{\partial^2 R}{\partial c^2}\right)=0$$

and

$$\left(\frac{\partial^2 R}{\partial t \partial c}\right)=\ 33:105\ 33:68t\ +\ 10:32t^2 0:9832t^3$$

in the whole set D.

Therefore, S has a non positive curvature and consequently it is one Hadamard surface. It is also embedded in the three dimensional space because it is the graphic of the smooth risk function. This ends the proof.

A consequence of this result is the important following result for the process.

Corollary 1. The critical ages for the process are, in the biological time s,

$$s\ =\ 5.4\ (years),\ s\ =\ 45.6\ (years),\ s\ =\ 87\ (years) \tag{21}$$

Proof. The expression of the Gaussian curvature K(t; c) in (20) shows that the sign of such a curvature function is completely determined on the whole domain D by the reduced smooth function.

$$k(t,\ c)\ =\left(33.10533.68t\ +\ 10.32t^2-0.9832t^3\right)^2 \tag{22}$$

The graphic of k(c,t) is shown in Figure 8.

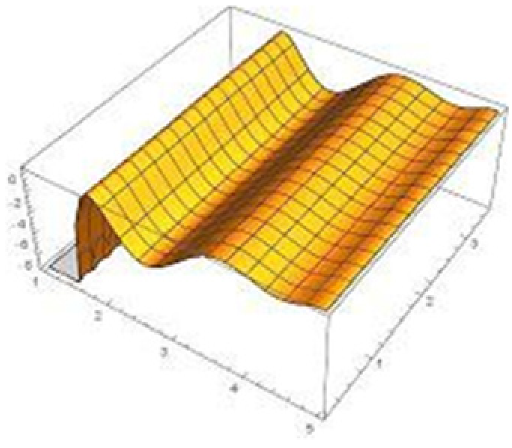

Figure 8 Curvature of the risk surface for men.

The points where the Gaussian curvature (20) is zero determine the critical ages of the risk function and are obtained by solving equation 14:

$$0\ =\ 33.105-33.68t\ +\ 10:32t^2-0.9832t^3 \tag{23}$$

The solutions of (23) are all real numbers,

$$.83\ (5.1\ years),\ t=3.7\ (45.6\ years),\quad t=4.9\ (87\ ye \tag{24}$$

And they correspond to the vertical lines, separatrix of the risk vector field.

This ends the proof.

Discussion

In this paper, for the risk estimation calculated for men, using EPAs MeHg reference dose (RfD), and the critical region of risk (Figure 4), we obtained in Theorem 2 an average value of 2.96, which is interpreted as an unacceptable health risk (since this result exceeds one). Also, Proposition 1 shows that there's a high probability (of 85%) that some toxic or adverse health effect will develop.

Corollary 1 shows that the age of maximum risk in boys is 5.1 years, then the risk decreases until 45.6 years, and begins to increase again until reaching the maximum risk in senior men at 87 years. This will be relevant only to those men who exceed this age, since Mexican men life expectancy is only 72 years according to official data.[11]

As shown in Figure 8, risk curvatures indicate that the highest risk is for boys and men in reproductive age (life stages 1 and 3); in addition, the critical region of risk is only for the aforementioned stage and to a lesser extent for senior men, although in this last group the risk curve is lower than for boys. The study by Llop and collaborators,[12] recommends, infants and those under 3 years old avoid shark consumption; The study by Clarkson and Magos[2] mentions that the susceptibility to neurotoxicity due to MeHg is related to gender, but has not been widely studied and the results available are inconclusive, but in the poisoning that occurred in Iraq as a consequence of the consumption of grain contaminated with a mercurial fungicide, young men were affected more than men exposed in adulthood. The results obtained in the work of Raimann et al.,[16] coincide with the risk curves of this study where the exposure interval is higher in men mainly in reproductive age and infancy; therefore, these results are expected to coincide with studies in other countries where shark is consumed on purpose or unknowingly. Considering this, special care should be taken since children are more vulnerable to exposure to methylmercury because their nervous system is the main target organ where it bio accumulates; as a pre-cautionary measure the USEPA[19] established an acceptable level of 0.5 mg / kg of methylmercury for fish products.

It is important to mention that risk depends on the consumption habits (frequency of consumption and food preparation), age of the consumer, size of the portion and the product itself. However, the magnitude of bioaccu-mulation of heavy metals in fish tissues is in uenced by biotic and abiotic factors, such as fish habitat, chemical form of the metal, water temperature, pH, concentration of dissolved oxygen, water transparency, fish age, sex, body mass, and physiological conditions.[10] Therefore, a more precise risk assessment will need to considere all these factors.

Conclusion

The estimation of the health risk from consumption of fish substituted by shark meat, based on the results of the risk coeffcient, of which an unacceptable risk was obtained for the average and maximum MeHgconcen-trations for all the population age groups, and an acceptable risk in the low MeHg-concentration for all age groups except for babies, for whom the risk is intermediate (0.804), all this, means that in the analyzed sample, there is a high probability of developing deleterious health effects; so, if men want to consume fish products, they must buy whole fish to avoid the replacement.

The greatest uncertainty of the risk estimation in the present work, is the lack of -direct MeHg quanti cation in the same fish samples that were genetically analized. However, this is an acceptable approximation for decision making in the prevention of health risks because the data used are from samplings done during a period of three years in 10 of the most important fishing ports in Mexico, which provided a good estimate of MeHg in fish muscle sold in Mexico City's Metropolitan Area.[19,20]

To analyze the uncertainties and obtain the risk function of the results obtained in the present study, a mathematical analysis was carried out using the classical interpolation method,[15] which showed that the aforementioned risk function is stable;[8] so any error obtaining the data (uncertainties), will lead us to a risk correlation with the same characteristics (similar results), and in this way we can conclude that the results of the risk coeffcient have a high degree of reliability.

This study analysed the consumption habits of a sample of the population of Mexico City's Metropolitan Area, which showed that with the substitution of 60.3 % of sh meat for shark meat, the overall risk was 1.43 for men, this exceeds one and it could be inferred that men are chronically exposed despite the fact that the population does not frequently consume fish; even more, it implies a health risk for the consumer, so it is suggested to restrict the consumption of fish products to smaller rations, in lower frequency, and more importantly to buy complete fish to facilitate identification of the product and to avoid consuming shark meat with high methylmercury concentrations.

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Conflicts of interest

The authors state that there is no conflict of interest.

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