

Assessment of Potential Risks from Consumption of Fish for the Population Living in the Chemical Weapon Dumping Area in the Baltic Sea

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Abstract

Chemical weapon dumped during the World War II in the Baltic Sea is causing anxiety of the world community and the population living in the countries located in the vicinity of the dumping sites. One of such areas is the part of water area close to the Bornholm Island. The experimental studies in this area have been carried out during 2007-2008 within the frameworks of the EU MERCW project «Modelling of Environmental Risks related to Sea-Dumped Chemical Weapons», and also with possible impact of the flooded chemical weapon on the Baltic Sea ecology. The basic goal of present paper is to assess the risk for the population from consumption of fish caught in the chemical weapon dumping area in the Bornholm Deep. The estimation of risk for the population from consumption of fish containing arsenic compounds was made. It is shown that the level of risk perception for the population makes the amount at which (according to the classification of cancerogenic risks) it is recommended to the persons making decisions to take measures for its decrease.

Key words: the chemical weapon, arsenic, island Bornholm, risk assessment

Introduction

Numerous wars and war conflicts with the use of chemical weapons (CW) occurred in the first half of the 20-th century that caused its considerable accumulation.

Later on the accumulated CW was partially buried in the territories of different countries and damped in the seas. It remains a source of human health risk for the population living in these countries and for the environment.

The problems connected with the dumped CW have been buried in oblivion and only in the end of the 1980-th special attention was attracted to this problem. Since this time the activities on the assessing real danger of the dumped CW and inspection of the dumping sites have been started.

It is known at present that CW, besides the Baltic Sea and Danish gulfs, lies on the bottom of the La Manche to the west of Scotland, in the White, Barents, Karsk, Black, North, Japan Seas, in the Pacific ocean near the Californian coast.

Most complete, though with some gaps, is the information presented in the HELCOM materials on dumping of CW (produced by Germany before the World War II and during it) in the Baltic Sea and the Danish Gulfs. The volume of CW produced in Germany exceeded 65 thousand tons. The types and amounts of damped CW are given in Table 1 (**Paka V.,2004**).

Table 1. Poisonous Substances Produced in Germany in 1935-45 (thousands tons)

CAP (2-chloracetophenon	Clark I	Clark II	Adamsite	Arsine oil *	Phosgene	Yperite	Azotic yperite	Tabun
7.1	1.5	0.1	3.9	7.5	5.9	25.0	2.0	12.0

After demilitarization of Germany almost 300 thousand tons of CW became at the disposal of the USA and Great Britain and was dumped in the Skagerak and Kattegat Gulfs at the depths of 200 m to 700 m.

Trophy weapons withdrawn by the Soviet troops in 1947-1948 were dumped in the Bornholm Deep of the Baltic Sea at the depths of 70-105 m (2 thousand tons) and in the northern part of the Gotland Hollow at the depths of 70 – 105 m (2 thousand tons). Table 2 shows the amounts and types of CW dumped in the Baltic Sea (**HELCOM,1993a; 1993b; 1993c**).

Table 2. Amounts and Types of CW Dumped in Region of the Bornholm Island

	Chemical Munitions, (t)	Warfare Agents, (t)	Warfare Agent Types
Bornholm Basin (East of Bornholm)	~32000	~11000	mustard gas, viscous mustard gas, Clark I, Clark II, Adamsite, chloroacetophenone; (less certain: phosgene, nitrogen mustard, tabun)
East of Bornholm	8000 (n.v.)	-	no information
Area SW of Bornholm	~15000 (n.v.)	-	no information
* (estimated at 15%), n.v. - not verified			

Dumping east of Bornholm in the Bornholm Basin was primarily inside a circular area with a radius of 3 nautical miles. However, it must be assumed that the chemical munitions were spread over a considerably larger area during dumping. Several factors indicate this, e.g., the positions where fishermen have caught munitions in their nets and the circumstances of the dumpings.

The behavior of chemical substances in the marine environment depends both on the chemical and physico-chemical properties of the substances and on environmental factors, such as temperature, salinity and the pH value of the water. As the pH value of sea water is rather constant around 8, salinity and temperature are the main environmental parameters that influence chemical reactions here.

In the Bornholm Hollow the temperature of water near the bottom surface usually makes from 2 to 12^o C. At such low temperatures the solubility of the various chemical warfare agents varies from good (tabun) to very poor (Adamsite, viscous mustard gas). However, it should be noted, that poor solubility retards the process of degradation.

It is known that dumped warfare agents undergo hydrolysis in water. Therefore, high concentrations of primary products may be found in the immediate vicinity of their sources, i.e. in bottom sediments.

In surface waters the primary products of CW have the concentrations that are significantly lower than the thresholds of their detection. Here arsenic, as the end-product of degradation of some CW, is detected both in water and in bottom sediments.

Its increased content may be a peculiar indicator of CW and indicate a possible leakage of a CW agent out of depressurized munitions.

The analysis of information on the contents and behavior of chemical warfare agents in marine components of the Bornholm Basin allows to think that the main potential path of their impact on man is by oral consumption of fish caught in the dumping site. This potential path of chemical agents impact prevails (*Hoening, 2007; U.S.EPA, 1979; Welch et al. 1988; Sanders et. al., 1994; Pongratz, 1998; Redman et al., 2002*).

The goal of the paper is the human health risk assessment for the population living in the region of the Bornholm Island, the source of which can be the consumption of fish containing arsenic compounds.

Materials and methods

Experimental studies in the CW dumping sites been carried out during 2007-2008 under the EU MERCW project "Modelling of Environmental Risks Related to Sea-Dumped Chemical Weapons") in the Baltic Sea around Bornholm. The basic goal of the project was studying possible influence of the dumped chemical weapon on ecosystem of the Baltic Sea and on the basis of the data obtained modeling and estimating a risk caused by CW. Besides, the project included the following problems to be solved:

- Sampling of bottom sediments, surface and prebottom water for a subsequent analysis of the contents of poisonous agents, products of their degradation and heavy metals in the places of dumping (« hot points »);
- Detailed inspection of the places of chemical weapon dumping;
- Acoustic and magnetic resonance inspection of the bottom to detect possible new dumped objects;
- Studying the structure of water and water flows that could be a source of transport of suspended particles containing poisonous agents.

The Region under Study and the Sampling Sites

The region where human health risks were assessed is to the east of the Bornholm Island in the Baltic Sea. Studies of sites where the vessels with CW on board were dumped were carried out. The experimental region was subdivided into several zones. The zone (C+D) (a primary one) was characterized by the sites with dumped chemical weapons. This zone is located within a symbolic circumference (55°21' N. and 15°37'02" W.). Its surface area is about 97 km².

However not all chemical weapon has been flooded in the first zone. It is known for certain that chemical ammunition "is widely scattered" in a much greater territory. This is confirmed by real facts - fishermen pulled out nets with ammunition with poisonous agents in the water area outside the boundaries of the first zone.

The second zone is outside the boundaries, its surface area makes 791 km² (55° 10' 00" N. и 15°24' - 15°55' W.). The samples of bottom sediments, near-bottom, pore and surface waters were taken in all the zones.

Only inorganic arsenic compounds (arsenates, arsenites), the concentration of which decreased in every series, were found in the samples of pore, near-bottom and surface waters.

The concentrations of arsenates and arsenites in near-bottom water were by the order of the value lower than in pore water, and in the surface waters they were by 2-3 times less.

Arsenic, adamsite, Clark 1, Clark 2, components of arsine oil, chloracetophenon, etc. were found in bottom sediments. No yperite, lewisite and products of their transformation were found in the samples.

Fig. 1 shows the inspected region and arsenic concentrations in bottom sediments in these areas.

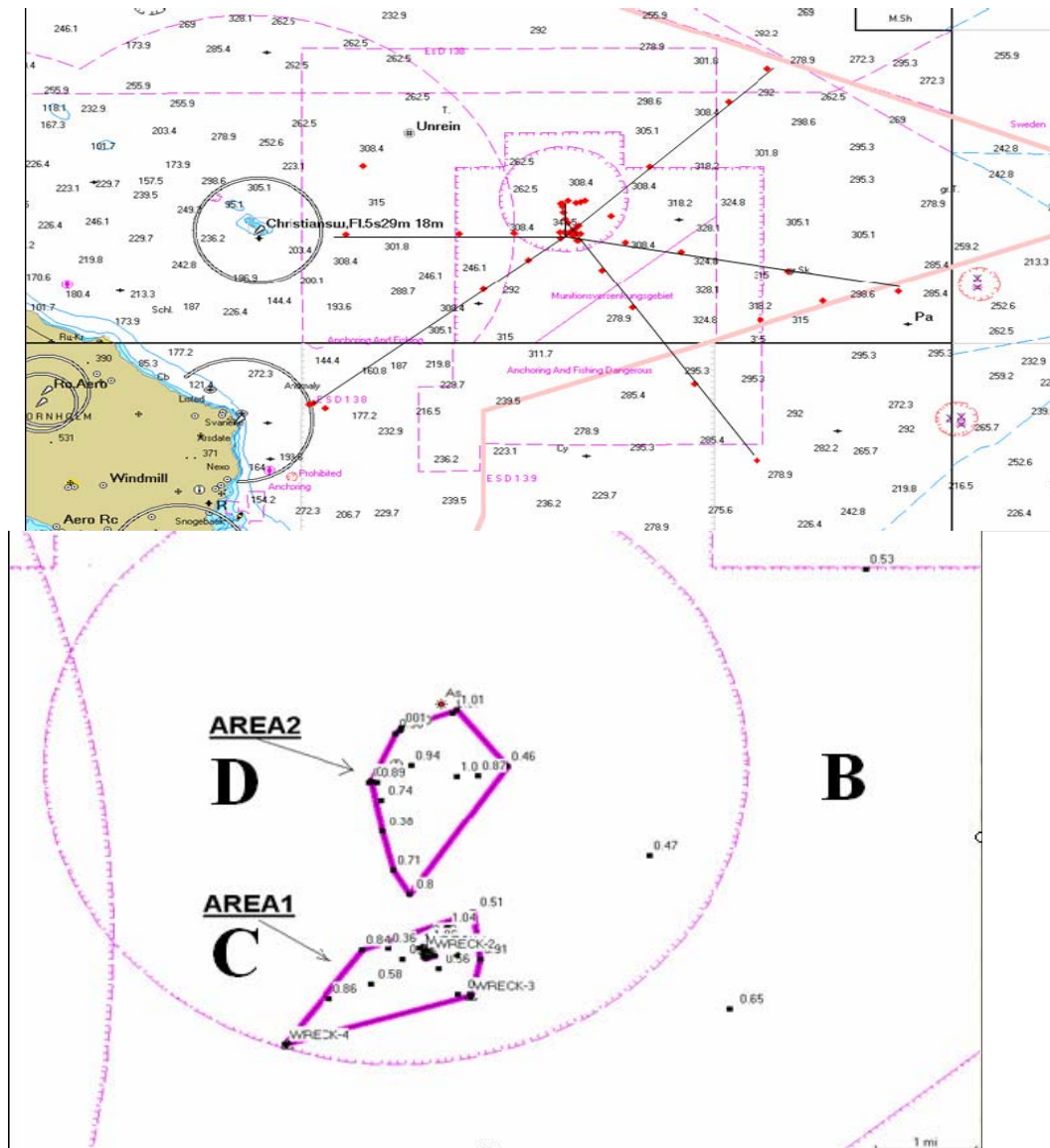


Figure 1. Sampling stations from the expeditions in June 2007 and February 2008. Red dots mark the positions of sampling. Area1(C) - the southern part of the primary dumpsite area (cover 4 shipwrecks); Area2 (D) is located more to the north in the area where CWA and arsenic anomalies had been observed during previous investigations; Area B - bordering area out of the circle (5-30 km); Area (C+D) – the primary (circular) dumpsite area; A-surface water (data of MERCW Project)

Initial Data

For carrying out estimations of risk a plenty of initial parameters is required. The primary goal of the EU MERCW project was the estimation of risk for the population and the environment connected with influence of poisonous agents and the products of their degradation. Thus, in estimations of risk it was necessary to use a complete set of the results of experimental studies obtained during the expeditions. One of the most important parameters used for risk assessment from consumption of fish containing arsenic compounds, is the concentration of arsenic in water.

The contents of inorganic arsenic (arsenites and arsenates) in the samples of surface and prebottom water was determined by the method of inverse voltammetry.

There were 10 samples of surface water taken. The analysis of these samples has shown that the concentration of arsenic in them was lower than a level of detection of 0.5 µg/ l.

The samples of prebottom water have been taken at the depth from 70 up to 97 m. For the subsequent calculations used were the concentrations of inorganic arsenic in the layer near the bottom assuming that shoals of fish can pass through the whole thickness of water. 70 samples of prebottom water taken in the first and the second zones have been analyzed. The highest concentration of arsenic in the second zone located outside a symbolical circle has made 0.55 µg/ l, in

the first zone (inside a circle) an average concentration was 0.68 µg/l. In table 3 the concentrations of inorganic arsenic in prebottom water are There were 10 samples of surface water have been taken. The analysis of these samples has shown that the concentration of arsenic in them was lower than a level of detection of 0.5 µg/l.

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Unfortunately, no sampling of sea biota - fishes and other inhabitants of the sea – was not made within the frameworks of the above-mentioned project. These studies can potentially become the following stage of researches of the area of CW dumping.

For estimations of risk used were the literary data on concentrations of arsenic in fish of the Baltic Sea. In the area of the western part around Bornholm the most representative, trade and ecologically important kinds for all the Baltic are crash (*Gadus morhua*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). For calculations the concentrations of arsenic in these fishes were used.

Behavior and properties of arsenic and arsenic compounds in marine medium

Due to low bioconcentration factors (below 10) the major part of chemical agents is not accumulated in sea organisms.

The part of chemical agents that has a potential for bioaccumulation in the dumping site under consideration is almost biologically unavailable due to decreased oxygen contents in deep waters (at the depths over 89 m are equal to 0.9 mg/l (± 1.2 S.D., n=34) (*H. Sanderson et al., 2008*).

Arsenic is the product of decomposition of some dumped CW agents (lewisite in their number) accumulated in sea organisms. The bioconcentration factor of arsenic components depends on the compound chemical form.

According to (*Nraigu and Simmons, 1990*) the amount of arsenic in the sea fish existing in the inorganic (toxic) form varies from less than 1 up to 20 % (10 % on the average).

Approximately 90 % remaining of this amount are in betain and partly in methylated forms. In papers by (*Kaise and Fukui, 1992; Vahter, 1994; Cullen, 1998, Dabeka et al., 1993, Eisler 1994, Gebel et al., 1998*) described are the results of experiments with animals and people. It is shown that arsinbetain and methylated arsenic in low concentrations are nontoxic for living creatures (LD₅₀ for 50 % of tested animals made more than 10 g/kg).

As for lewisite, there are data that it is not accumulated via food chains (*Rosenblatt et al., 1975*). At the same time, the arsenic being an end-product of lewisite degradation has a moderate potential of biomagnification in food chains.

According to the classification of the International Agency on Research of Cancer (*IARC, 1997*), arsenic (CAS 7447-38-2) refers to the 1-st class of danger of substances for which carcinogenic effect on man is proved. The slope factor for arsenic at oral use is 1.5 mg/(kg-day). (**Slope factor:** An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100 (http://www.epa.gov/iris/help_gloss.htm)). The reference concentration is equal to 0.0003 mg/kg (*IRIS, 2002*). At oral use, the skin, the central nervous system and cardiovascular system are critical.

Methods of Risk Assessment and Parameters for its Calculations

Risk assessment for the population carried out with the use of two known techniques: the technique of the European Community (*EU TGD, 2003*) and the technique of the US Environmental Protection Agency (*U.S. EPA, 1986; U.S. EPA, 1996*).

According to the **US EPA** technique, the calculation of individual carcinogenic risk is carried out with the use of the data on exposure and the values of slope factors. For carcinogenic chemical substances the additional probability of development of a cancer in an individual during its life (CR) was estimated in view of a daily average doze during the life (*I*):

$$CR = I \times SF, \quad (1)$$

I - a daily average doze during the life, mg/(kg-day);

SF - the factor of a carcinogenic potential (slope factor), $(\text{mg}/(\text{kg}\cdot\text{day}))^{-1}$. The value of SF is set separately for inhalation (SFi) and oral (SFo) pathways of the chemical carcinogens.

Calculation of noncarcinogenic risk is carried out by the following formula:

$$HQ = I/RfD, \quad (2)$$

where HQ – hazard quotient;

RfD – reference dose, $(\text{mg}/\text{kg}\cdot\text{day})$.

The formula for the calculation of a daily average dose uptaken via oral pathway of a chemical substance with fish for adult population is as follows:

$$I = \frac{(CW \cdot BF \cdot FI \cdot IR \cdot EF \cdot ED)}{(BW \cdot AT \cdot 365)} \quad (3)$$

Table 3 gives the parameters of equation (3).

Table 3. Parameters and definitions of equation

Parameter	Definition	Default parameter (U.S. EPA, 1986; U.S. EPA, 1996)
I	Uptake with fish, mg/kg-day	
CW	Concentration of substance in water, mg/l	Area (C+D)- $0.68 \cdot 10^{-3}$; Area B – $0.55 \cdot 10^{-3}$
BF	Bioconcentration factor, $((\text{mg}/\text{kg})/(\text{mg}/\text{l}))$	300
IR	Consumption of fish, kg/day	0.02
EF	Frequency of exposure, days/year	350
ED	Duration of exposure, years	30 years
FI	Fraction of contaminated fish	1.0
BW	Weight of body, kg	70
AT	The period of averaging the exposure, years	30 years; carcinogens - 70 years

In the **EU TGD** technique the daily average dose received by the population at consumption of fish is calculated with the simplified formula:

$$DOSE_{fish} = \frac{C_{fish} \cdot IH_{fish}}{BW}, \quad (4)$$

C_{fish} - concentration of a chemical substance in fish, mg/kg;

IH_{fish} - consumption of fish, kg/day;

BW - weight of a body of a person, kg

$$C_{fish} = BF \times CW, \quad (5)$$

где BF - bioconcentration factor, $((\text{mg}/\text{kg})/(\text{mg}/\text{l}))$;

CW - concentration of a chemical substance in water, mg/l.

The concentrations of arsenic in surface water in the site under study varied from 0.13 to 0.29 $\mu\text{g}/\text{l}$, and an average value made $(0.23 \pm 0.09) \mu\text{g}/\text{l}$. The concentration of inorganic arsenic in the zone C was on the average 0.59 $\mu\text{g}/\text{l}$ (0.26-1.06 $\mu\text{g}/\text{l}$), and in the zone D – 0.76 $\mu\text{g}/\text{l}$ (0.38-1.01 $\mu\text{g}/\text{l}$). In the circle joining zones (C+D) an average concentration of arsenic was equal to 0.7 $\mu\text{g}/\text{l}$. In the zone B (5-30 km) outside the circle the concentration of arsenic was on the average 0.55 $\mu\text{g}/\text{l}$ varying from 0.33 to 0.81 $\mu\text{g}/\text{l}$.

Taking into account the concentrations of inorganic arsenic in surface and bottom water the coefficient of accumulation of arsenic in fish of the Baltic Sea, that made 300 $((\text{mg}/\text{kg})/(\text{mg}/\text{l}))$, was calculated. In the method (*EU TGD, 2003*) it is proposed to use for the calculations of a dose accumulated at fish consumption standard values used in different countries of EU (European Union), so that the consumption of fish by the population of Finland makes a value equal to 7.4 kg/yr (0.02 kg/day). This value of fish consumption was also used for calculations with the US EPA method.

Conclusions

The calculations of a mean daily dose at fish consumption were made for different periods of exposure (30 years) averaging (noncarcinogenic effects) and of 70 years (carcinogenesis). Risk estimates were calculated via an average uptake of arsenic by a man with fish containing arsenic. Mean daily doses of arsenic for the primary and secondary areas (zones) differed insignificantly. But at assessing a

noncarcinogenic risk a mean daily dose was almost twice as much as compared with the case of assessing a carcinogenic risk because the exposure periods were different.

Tables 4 and 5 give the calculation results (obtained with two different methods) of risk assessment for the population of the Bornholm Island at the consumption of fish containing arsenic compounds.

Table 4. Calculations of doses and health risk for the population of the regions around the Bornholm Deep caused by consumption of fish containing arsenic (the US EPA method)

Area	Carcinogenic risk (AT=70 yr)		Noncarcinogenic risk (AT=30 yr)	
	Mean daily dose, mg/kg	Carcinogenic risk (CR)	Mean daily dose, mg/kg	Noncarcinogenic risk (HQ)
Area (C+D)- Primary	$2.4 \cdot 10^{-5}$	$3.6 \cdot 10^{-5}$	$5.6 \cdot 10^{-5}$	0.19
Area B - Secondary	$2.0 \cdot 10^{-5}$	$3.0 \cdot 10^{-5}$	$4.5 \cdot 10^{-5}$	0.15

Table 3. Calculations of doses and health risk for the population of the regions around the Bornholm Deep caused by consumption of fish containing arsenic (the EU TGD method)

Area	Mean daily dose, mg/kg	Carcinogenic risk (CR)	Noncarcinogenic risk (HQ)
Area (C+D)- Primary	$5.7 \cdot 10^{-5}$	$8.6 \cdot 10^{-5}$	0.20
Area B - Secondary	$4.7 \cdot 10^{-5}$	$7.0 \cdot 10^{-5}$	0.16

The results obtained with the two different methods are in good agreement. According to the EPA method the level of carcinogenic risks for the population (10^{-5}) corresponds to the level of a permissible risk within the range of 10^{-6} to 10^{-4} . At the given level of risk the decision-making persons can take certain measures for its decrease. In the case considered in view of some uncertainties and conservative assumptions one should say that the risk caused by fish consumption will be somewhat lower and close to a negligible one.

According to the EPA classification, if the calculated hazard quotient (HQ) of a substance does not exceed 1, the probability of the development of hazardous effects in man at daily uptake during the life is insignificant and such an effect is characterized as a permissible one. In our case the hazard quotients do not exceed unity (0.2 and 0.15). Therefore, the risk of noncarcinogenic effects connected with consumption of fish with inorganic compounds of arsenic is permissible.

Any risk estimate is connected with several typical uncertainties. The uncertainties exist at all the stages of risk assessment. In the paper the following sources of uncertainties can be indicated:

- incomplete or inaccurate data on all the sources of marine medium contamination by arsenic compounds;
- selection or exclusion from the analysis of that or another way of impact;
- measurement errors at sampling and analysis;
- the use of standard parameters at risk assessment.

It should be mentioned that the procedure of risk assessment is rather difficult in view of a plenty of parameters used and a lot of uncertainties. In the present work the estimation of risk from consumption of contaminated fish got a concrete number with the help of widely-known by the experts in risk assessment technologies (methods). Besides, there is an ambiguity in approaches to this estimation. However, based on objective preconditions and in view of the scientific facts in hydrology of the region under investigation, the hydrochemical processes occurring in poisonous agents and the chemical weapon in the sea water, with the data on accumulation, toxicity and transitions of agents of the chemical weapon in fish of the Baltic Sea, the analysis of risk made and the numerical (not qualitative) model constructed, the estimation of risk coincides with the opinion of the majority of experts on a real danger of the chemical weapon dumped in the Baltic Sea. It can be noted that the scenario according to which the calculations are made is the following: Gradual, as a result of corrosion, hydrolysis and the subsequent degradation of products of decomposition of such toxic agents (TA) appearance of arsenic in the sea water and its accumulation by sea fish. In the present article the accent is made on contamination of the most trade kinds of fishes of the Baltic Sea by inorganic arsenic that is an end-product of degradation of such TA, as lewisite, Clark I, Clark II, Adamsite, winter yperite. These TA lie on the Bornholm Hollow bottom and in other places of chemical weapon dumping in the Baltic Sea and until (under the forecasts of some experts), a volley

(mass) emission of TA in the sea environment occurs (one of the scenarios of the development of a situation), do not present any serious danger to the environment and the human health. The estimations of risk obtained show that a regular consumption of fish containing compounds of inorganic arsenic is to some extent connected with a risk for the human health. The risk for the population is on an acceptable, but not on a negligible level. It is necessary to note also, that in the area of CW dumping near the Bornholm Hollow fishing is forbidden and the results obtained are the screening scientific estimations.

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References

- Hoening S.L., 2007:** *Compendium of Chemical Warfare Agents*. Springer, 2007.
- Cullen W.R., 1998:** *Arsenic in the environment*. In: *Bunnett J.F, Mikolajczyk M., Eds.. Arsenic and old mustard: Chemical problems in the destruction of old arsenical and mustard munitions*. Netherlands: Kluwer Academic Publishers, 1998;123-134.
- Dabeka R.W, McKenzie A.D, Lacroix G.M., 1993:** *Survey of arsenic in total diet food composites and estimation of the dietary intake of arsenic by Canadian adults and children*. J. AOAC Int, 1993;76(1):14-25.
- Eisler R., 1994:** *A review of arsenic hazards to plants and animals with emphasis on fishery and wildlife*. In: *Nriagu JO, editor. Arsenic in the environment. Part II: Human health and ecosystem effects*. New York: John Wiley & Sons, Inc, 1994;185-259.
- U.S.EPA, 1979:** *EPA -Environmental Protection Agency. Water-related environmental fate of 129 priority pollutants, vol. 1. Introduction and technical background, metals and inorganics, pesticides and PCBs*. Washington DC: EPA440479029a, 1979.
- Gebel T.W, Suchenwirth RHR, Bolten C.,1998:** *Human biomonitoring of arsenic and antimony. in case of an elevated geogenic exposure*. *Environ Health Perspect*, 1998; 106(1):33-39.
- IARC,1997:** *International Agency for Research on Cancer. Overall Evolutions of Carcinogenicity to Human*, 1997.
- Kaise T, Fukui S.,1992:** *The chemical form and acute toxicity of arsenic compounds in marine organisms*. *Appl. Organomet. Chem.*, 1992; 6:155-160.
- Nriagu J.O, Simmons M.S.,1990:** *Food Contamination from Environmental Sources*. New York: John Wiley & Sons, Inc, 1990;59-84.
- Pongratz R.,1998:** *Arsenic speciation in environmental samples of contaminated soil*. *Sci Total Environ*, 1998; 224:133-141.
- Redman A.D, Macalady D.L, Ahmann D.,2002:** *Natural organic matter affects arsenic speciation and sorption onto hematite*. *Environ Sci Technol*, 2002; 36:2889-2896.
- Rosenblatt D.H, Miller T.A, Dacre J.C, et al.,1975:** *Problem definition studies on potential environmental pollutants. Part II: Physical, chemical, toxicological, and biological properties of 16 substances*. Fort Detrick, MD: U.S. Army Medical Bioengineering Research Development Laboratory, 1975;7509.
- Sanders J.G, Riedel G.F, Osmann R.W.,1994:** *Arsenic cycling and its impact in estuarine and coastal marine ecosystems*. In: *Nriagu JO, editor. Arsenic in the environment. Part I: Cycling and characterization*. New York: John Wiley & Sons, Inc., 1994; 289-308.
- EU TGD,2003:** *Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market, 2003*, <http://ecb.jrc.it/home.php> (accessed sep 22, 2006).
- U.S.EPA,1996:** *Environmental Protection Agency. Guidelines for Carcinogen Risk Assessment*. Draft. Washington, 1996; 12-190.
- IRIS,2002:** *Integrated Risk Information System*. Cincinnati, 2002, <http://www.epa.gov/ncea/iris/subst/0278.htm>
- U.S.EPA,2004:** *Environmental Protection Agency. Risk Assessment Guidance for Superfund, vol.I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*. EPA/540/R99/005. Washington, DC, 2004.

U.S.EPA,1986: Environmental Protection Agency. Guidelines for Carcinogen Risk Assessment. Fed.Reg, 1986; 85; 33992-34003.

Vahter M.,1994: Species differences in the metabolism of arsenic compounds. Appl. Organomet. Chem., 1994; 8:175-182.

Welch A.H, Lico M.S, Hughes J.L.,1988:Arsenic in groundwater of the western United States. Ground Water, 1988; 26(3):333-347.

HELCOM, 1993a: Update of a report dated 7 May 1985 concerning environmental, health and safety aspects connected with the dumping of war gas ammunition in the waters around Denmark. HELCOM 14/10/1. <http://www.helcom.fi>

HELCOM,1993b:Chemical munitions in the southern and western Baltic Sea - compilation, assessment and recommendations. Federal Maritime and Hydrographic Agency, Hamburg, Germany, May 1993.

HELCOM,1993c:Complex analysis of the hazard related to the captured German chemical weapon dumped in the Baltic Sea. HELCOM CHEMU2/2/1/Rev.I.

Paka V.T.,2004: The flooded chemical weapon: a condition of a problem. Rossiyskiy Khimicheskiy Zhurnal, 2004; 48(2): 99-109 (in Russian).

Sanderson H, Fauser P, Thomsen M, Sorensen P.B.,2008:Screening level fish community risk assessment of chemical warfare agents in the Baltic Sea. - Jour.of Hazardous Materials, 2008;154:846-857.