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7 April 2014

Danish Nature Agency
Haraldsgade 53
DK-2100
Copenhagen
DENMARK

Dear Sir/Madam,

Re: Danish Legislation on "Tungsten Gunshot to be Banned in Denmark"

The International Tungsten Industry Association (ITIA) is registered under Belgian law as a not-for-profit association with scientific purposes in support of the tungsten industry. ITIA's members are from 20 countries and include mining companies, processors, consumers, trading companies and recyclers as well as the world's leading manufacturers, importers, and users of tungsten and its compounds. One of our major tasks is to co-ordinate the extensive work programme of the Health, Safety and Environment (HSE) issues related to tungsten and its compounds including:

- regulatory and classification issues,
- monitoring proposed legislation,
- developing scientific data on the impact of tungsten on human health and the environment,
- managing the Tungsten Consortium which was established by ITIA in response to the EU's "REACH" legislation "

Hearing the news that:

"*In accordance with proposals made by the Danish Environmental Protection Agency (Miljøstyrelsen), tungsten will be phased out over the course of this year. As of 1 March 2014, it will no longer be legal to use tungsten to shoot game, but it will still be legal to purchase cartridges filled with tungsten shot and to use them for clayshooting until 31 August. After that, tungsten shot will be banned in all forms of shooting*"

ITIA wrote to the Danish Environmental Protection Agency information center for details of the legislation on 24 February 2014. Based on the information we received, it is clear that the ban proposed by the Danish Nature Agency, which prohibits the sale of any hunting shotgun ammunition made from tungsten, was based on the study by Kalinich et al (2005) reporting tumour development in rats implanted intramuscularly with tungsten-cobalt-nickel pellets.

We would like to provide details evidencing that tungsten pellets used for hunting are neither carcinogenic nor environmentally toxic:

- The scientific evidence of rodent carcinogenicity is associated exclusively with the military grade heavy alloy made of tungsten-cobalt-nickel.
- The carcinogenic effect of the tungsten-cobalt-nickel alloy can be attributed to galvanic corrosion that causes mobilisation of carcinogenic metals such as cobalt and nickel which causes the muscle tumours in rodents.
- Tungsten hunting shots do not contain tungsten-cobalt-nickel alloy as the environmentally approved tungsten shots are composed of tungsten-iron, tungsten-iron-nickel, tungsten-copper-tin-iron, tungsten-iron-copper-nickel, tungsten-polymer, tungsten-iron-tin; tungsten-tin-bismuth, tungsten-tin-iron-nickel, and tungsten-iron-polymer.

The scientific and technical information presented in this document are studies published by a variety of entities including the US Armed Forces Radiobiology Research Institute (Kalinich et al 2005; Kalinich et al 2011; Schuster et al 2012), and several US and Canadian academic institutions.

This document summarises the findings of these peer review publication studies divided in two main sections: (1) rodent carcinogenicity and (2) environmental assessment. As the tungsten shot ban relies exclusively on the carcinogenicity of military grade tungsten-cobalt-nickel alloy, this document discusses this endpoint with greater detail than the studies conducted to assess the environmental safety of tungsten based shots.

(1) Rodent Carcinogenicity Assessment Exposed to Tungsten-Based Shot

In the US Armed Forces Radiobiology Research Institute studies (Kalinich et al 2005; Kalinich 2011) tumour formation was only observed in animals implanted with tungsten-cobalt-nickel alloy (a military relevant alloy). Follow-up studies with other tungsten combinations such as tungsten-nickel-iron (a military relevant alloy), tungsten-tantalum, tungsten-nickel-tantalum, tungsten-cobalt-tantalum, and tungsten-iron-tantalum did not produce a carcinogenic effect.

a. Tungsten, Cobalt and Nickel Human Carcinogenicity

When evaluating the Kalinich et al (2005) study it is useful to review the human carcinogenicity evidence of individual components in the heavy alloy that produced tumours when is embedded in the rat muscle (Table 1).

Tungsten metal is not listed or classified as human carcinogen, while cobalt and nickel are considered human carcinogens by International Agency for Research on Cancer (IARC), United States National Toxicology Program (US NTP), and the State of California; and classified as carcinogens according to European Union Classification, Labelling and Packaging (EU CLP) or United Nations Globally Harmonized System (UN GHS) guidelines. It is reasonable to assume that the carcinogenic activity on the carcinogenic pellet is conferred by cobalt and/or nickel in the presence of tungsten, but is not caused by the tungsten. This is confirmed (see below for more details) by a subsequent embedded pellet study by Kalinich (2011) that reported negative carcinogenic potential for tungsten-tantalum, tungsten-nickel-tantalum, tungsten-cobalt-tantalum and nickel-cobalt-tantalum pellets (Note: tantalum is a biologically inert metal).

Table 1. Human Carcinogenicity Classifications of W, Co & Ni

Metal	Carcinogenicity Classification			
	IARC	State of California Proposition 65	US NTP	EU CLP/ UN GHS
Tungsten (W) CAS No 7440-33-7 EC No 231-143-9	Not Listed	Not Listed	Not Listed	Not Classified
Cobalt (Co) CAS No 7440-48-4 EC No 231-158-0	Possibly carcinogenic to humans (Group 2B).	Listed	Reasonably anticipated to be a human carcinogen*	Substances presumed to have carcinogenic potential for humans (Category 1B)
Nickel (Ni) CAS No 7440-02-0 EC No 231-111-4	Possibly carcinogenic to humans (Group 2B).	Listed	Reasonably anticipated to be a human carcinogen	Suspected human carcinogens (Category 2)
** Not listed in 12th Report of Carcinogens (RoC), but it is expected to be as the US NTP 2013 rodent carcinogenicity study on cobalt metal reports a "clear evidence of carcinogenic activity".*				

b. Tungsten Alloy Embedded Carcinogenicity Rodent Studies

When contacting the Danish Nature Agency, the Agency advised that the Kalinich et al (2005) study was the main reason for banning the tungsten shot for hunting uses. Furthermore, the National Centre for Environment and Energy (DCE) report on the "Assessment of the Extent of Wounding Tungsten Shot (tungsten) mentions: "Based on a US study (Kalinich et al, 2005) showing that rats with metal implants consisting of 91.1% tungsten develop an aggressive form of cancer (rhabdomyosarcoma)" (Therkildsen & Holm 2012). The DCE report only refers to tungsten and its concentration omitting the two other metals (2.9% cobalt and 6.0% nickel) included in the embedded alloy, both of which are considered human carcinogens. This omission erroneously implies that tungsten on its own or in other alloys is the cause of the carcinogenic potential of the tungsten-cobalt-nickel alloy.

As the shot ban is supported on the peer-review publication written by Kalinich et al (2005) we will not spend a substantial amount of time discussing this publication as we are not refuting the results and it is assume that the Danish Nature Agency is well familiar with the study design and results (Table 2). We are concerned that this study is being used to improperly ban non-hazardous tungsten alloys with entirely different properties from the compound used in the study. We would like to draw your attention to the follow-up study conducted by the same investigator in 2011 and it concludes that not all the tungsten based alloys are carcinogenic, and the adverse effects are only specifically seen with the tungsten-cobalt-nickel alloy.

Kalinich (2011) follow-up study in mice focuses on two tungsten alloys of special interest to the military: tungsten 91.1% tungsten -6% nickel-2.9% cobalt and 91% tungsten-7% nickel-2% iron; and the rest of the study design included several treatment groups consisting of various controls, tungsten alloy metal tests, and a toxicity reference metal (lead) (Table 2).

The follow-up study also found rhabdomyosarcomas- type tumours in mice with embedded tungsten-nickel-cobalt and 100% nickel (positive control) pellets. No tumours were found in any other treated group.

Table 2. US Armed Forces Radiobiology Research Institute Embedded Tungsten Alloy Studies

Reference & Study Design	Pellet Compositions Tested	Results	
		Tumour Development	Comments
Kalinich et al. (2005) Male rats (n= 46 per group) were implanted intramuscularly with 4 (low dose) or 20 pellets (high dose) of weapons-grade tungsten alloy. Tantalum (20 pellets; n=46) and nickel (20 pellets; n=36) served as negative and positive controls	1) 100% Ta 2) 100% Ni 3) W 91.1%-Co 2.9%-Ni 6.0%	No Yes Yes	The tungsten-cobalt-nickel alloy high-dose-implanted rats developed aggressive tumours surrounding the pellets within 4–5 months after implantation. The tungsten-cobalt-nickel alloy low-dose-implanted rats and nickel-implanted rats also developed tumours surrounding the pellets but at a slower rate. Rats implanted with tantalum did not develop tumours. Rhabdomyosarcoma tumour yield was 100% in both the tungsten-cobalt-nickel alloy low- and high-dose groups.
Kalinich (2011) Male mice (n= 20 per group) were implanted in the quadriceps muscle with 2 (low dose) or 4 pellets (high dose) of variety alloys. Tantalum and nickel served as negative and positive controls. Serial collection of tissues was conducted at 1, 3, 6, and 12 months post-implantation aimed at identifying early changes relevant to the development of carcinogenic endpoints.	1) 100% Ta 2) 100% Pb 3) 100% Ni 4) 91.1% W-2.9% Co-6.0% Ni 5) 91.0% W-7% Ni-2%-Fe 2.0% 6) 91.1%W-8.9% Ta 7) 6% Ni-94% Ta 8) 2.9% Co-97.1% Ta 9) 2% Fe-98% Ta 10) 91.1% W-6% Ni-2.9% Ta 11) 91.1% W-2.9% Co-6%Ta 12) 91.0% W-2.0% Fe- 7.0% Ta 13) 6.0% Ni-2.0% Fe-92.0% Ta 14) 6.0% Ni-2.9% Co-91.1% Ta	No No Yes Yes No No No No No No No No No No	Mice in tungsten-nickel-cobalt and positive control (100% nickel) low- and high-dose groups developed tumours (rhabdomyosarcomas) at the pellet implantation sites. No tumours were found in any other treated group. Time to tumour development in the mouse was far slower than rat and did not metastasize to other organs. This was not unexpected considering the long latency period for implanted-metal carcinogenesis in mouse reported by others investigators. Hematological and splenic changes induced by tungsten-nickel-cobalt in the rat were not observed in the mouse.

Schuster et al (2012) conducted electron microscopy of pellets extracted from rats after being embedded for 6-months. Progressive galvanic corrosion of the matrix phase of the tungsten-cobalt-nickel was observed and was accompanied by high urinary concentrations of nickel and cobalt. The galvanic corrosion takes place because of the difference in electrode potential between the matrix phase (anode) and the W phase (cathode).

In contrast, non-carcinogenic tungsten-nickel-iron pellets were minimally corroded and urinary metals were low; but this was not progressive and decreased over time. In addition, over time these pellets developed a surface oxide layer (passivation) *in vivo* that may have restricted further anodic dissolution of the matrix phase. The formation of a "protective skin" on pellets greatly limited corrosion and mobilisation of carcinogenic nickel (Schuster et al 2012).

Overall, Kalinich's follow-up study confirms (using another rodent species) that the carcinogenic effect is associated exclusively with tungsten-cobalt-nickel alloy, and it shows that the carcinogenic activity cannot be associated with all tungsten alloys, as it depends greatly on the

mobilisation carcinogenic metals by galvanic corrosion, and this corrosion can be restricted by passivation.

(2) Environmental Assessment

Although the basis of the ban was not environmentally related, it is worth to mention that several types of tungsten based shot have been environmentally assessed in mallards, ducklings, birds, and aquatic organisms.

Several environmental safety studies have been published in the peer-review literature and have assessed different tungsten based shots such as tungsten-bismuth-tin (Kraabel et al 1996), tungsten-iron-nickel (Brewer et al 2003), tungsten-iron and tungsten-polymer (Kelly et al 1998; Mitchell et al. 2001a; Mitchell et al 2001b; Mitchell et al. 2001c); and tungsten-copper-tin-iron (tungsten bronze) (Thomas et al 2007; Thomas & McGill 2008; Thomas et al 2009).

Based on these studies the US Fish Wildlife Service (as 2 April 2014) has approved ten non-toxic tungsten based shots (Table 3). In this approved list the non-carcinogenic tungsten-nickel-iron alloy tested by Kalinich (2011) is included. From the tungsten-shot list presented in Table 3, it is important to note that none of them contain the carcinogenic tungsten-cobalt-nickel alloy.

Table 3. US Fish & Wildlife Service Approved Tungsten-Based Shot (as 2 April 2014)

Approved shot type*	Percent Composition by Weight
Iron-tungsten	any proportion of W, and ≥1% Fe
Tungsten-nickel-iron	≥1% Fe, any proportion of W, and up to 40% Ni
Tungsten-bronze	51.1% W, 44.4% Cu, 3.9% Sn, and 0.6% Fe, or 60% W, 35.1% Cu, 3.9% Sn, and 1% Fe
Tungsten-iron-copper-nickel	40–76 % W, 10–37% Fe, 9–16% Cu, and 5–7% Ni
Tungsten-matrix	95.9% W, 4.1% polymer
Tungsten-polymer	95.5% W, 4.5% Nylon 6 or 11
Tungsten-tin-iron	any proportions of W and Sn, and ≥1% Fe
Tungsten-tin-bismuth	any proportions of W, Sn, and Bi
Tungsten-tin-iron-nickel	65% W, 21.8% Sn, 10.4% Fe, and 2.8% Ni
Tungsten-iron-polymer	41.5–95.2% W, 1.5–52.0% Fe, and 3.5–8.0% fluoropolymer

Source: US Fish & Wildlife Service: http://www.fws.gov/migratorybirds/currentbirdissues/nontoxic.htm

Closing

Based on the Kalinich et al (2005) study reporting tumour development in rats implanted intramuscularly with tungsten-cobalt-nickel pellets, the Danish Nature Agency proposed the ban, we believe that it is prudent to also consider the follow-up study in 2011 conducted in mice which elucidated the carcinogenic mode of action for this specific alloy.

Only the tungsten-cobalt-nickel alloy undergoes galvanic corrosion that causes mobilisation of carcinogenic metals such as cobalt and nickel which causes the muscle tumours in rodents. The non-carcinogenic tungsten alloys experience passivation that limits corrosion and mobilisation of carcinogenic metals.

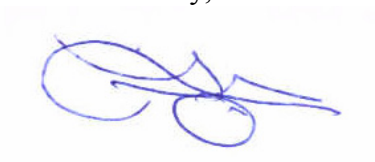
Based on Kalinich's embedded pellet studies the US Military is designing new alloys to reduce the carcinogenic risk of embedded shrapnel in military personnel without banning tungsten, but avoiding tungsten-cobalt-nickel alloy.

Overall, the comprehensive ban of tungsten shot is mainly based on the Kalinich et al (2005) study conducted exclusively on the military grade heavy alloy made of tungsten-cobalt-nickel, however, this alloy is not used in tungsten hunting shots.

With the scientific information listed in this letter, we hope the Authority will reconsider and/or amend the legislation to ban only tungsten alloys that contain cobalt-nickel. A ban of all tungsten-contained gunshot is not scientifically warranted indeed and is not justified under the precautionary principle in that it prohibits use of tungsten alloys where there is no indication of carcinogenic effect. This has an adverse impact on industry and the economy with no offsetting benefit for human health or the environment.

I, the HSE Director of the Association, or Dr Burghard Zeiler, the ITIA Secretary-General, will be available to provide information, answer questions either to in person or through email.

Yours faithfully,



Ranulfo Lemus-Olalde, ScD, DABT
ITIA HSE Director

CC: Dr Burghard Zeiler, Secretary-General

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