Alternatives for Lead

Chemical compositional standards for non-lead hunting ammunition and fishing weights

Vernon G. Thomas

https://link.springer.com/content/pdf/10.1007%2Fs13280-018-1124-x.pdf

Suggested compositional criteria for gunshot, rifle bullets, and fishing sinkers. These criteria could be incorporated into the regulations of any nation making the transition to use of non-lead products

Metal/metal alloy	Shotgun shot	Rifle bullets or shotgun slugs	Fishing sinkers
Iron, Fe	≥ 99% Fe	Not suited	Suitable as corrosion-resistant “stainless” steel for weights and jigs
Tungsten, W	95% W, with polymer	Any %W, when used as a densifier with other approved material	Any %W, when mixed with polymers, glass, or other approved material
Tin, Sn	While demonstrated to be non-toxic, and unconditionally approved in Canada, the low-density limits use as gunshot	Not suited when used alone, but can be used in conjunction with other approved materials	Suitable for use as split shot, weights, or jigs
Bismuth-tin alloy, Bi-Sn	Suitable and fully approved in USA and Canada	Not suitable, due to frangibility concerns at high-velocity impacts	Suitable as weights and jigs
Bronze, copper-tin alloy, Cu-Sn	Suitable, especially when used in conjunction with denser tungsten	Potentially suitable, but metal hardness may be problematic	Suitable as weights and jigs
Copper, Cu	Not suitable, see Fäth et al. (2018) for aquatic environmental concerns	Highly suitable, either as pure Cu, or as a 95% Cu—5% Zn alloy	Suitable as a 95% Cu—5% Zn alloy to resist corrosion
Lead, Pb	Less than 0.1% by mass	Less than 0.1% by mass	Less than 0.1% by mass
Zinc, Zn	Less than 1% by mass	Allowed only as an alloying metal	Allowed only as an alloying metal
Nickel, Ni	Less than 1% by mass	Allowed as a bullet jacket coat	Less than 1% by mass

Iron in stainless steel is unacceptable, ballistically, because of its greater hardness than annealed iron shot. This would increase pressures beyond safe limits, and be also more expensive to produce

A critical aspect of regulation is that it sets enforceable production standards, ensuring that unwanted contaminants do not enter production. Metals such as bismuth are obtained from other metal refining, and are readily contaminated by lead unless high-grade products are used. Kanstrup (2012) found that bismuth-tin shot contained up to 6,800 ppm (0.68%) lead by mass. Thus, bismuth used in shot making must be initially of high grade. The same comment regarding purity of the metal

used for shot making applies to tungsten, which is available as a commercial waste material containing nickel, or as a high-grade refined product. Thus, setting the maximum allowable content of lead, zinc, or nickel at less than 1% is realistic from a production point of view, while ensuring a high level of toxic threat protection to birds that might ingest these products. The permissible lead level in gunshot is 1% for the USA and Canada, but 0.1% for Denmark, consistent with Danish criteria for lead exposure.

Abstract The chemical composition of non-lead, nontoxic, gunshot used for hunting waterfowl is regulated only in Canada and the USA. No nation regulates the composition of non-lead fishing weights, rifle bullets, and gunshot used for upland game hunting. Compositional criteria for these non-lead products are proposed here, based on established experimental toxicity protocols. Because of the demonstrated acute toxicity of ingested zinc shot to birds, fishing weights and gunshot should never be made of this pure metal. Nickel should be avoided as an incidental component of gunshot because of potential carcinogenicity concerns about such embedded shot in birds and other animals. These compositional criteria could be adopted by all nations undertaking the transition to nonlead fishing weights and hunting ammunition. The listed criteria would facilitate production and international trade in non-lead products, and promote easier enforcement and user compliance with non-lead standards.

Prices for shotshells

Average prices of shot types in retail sale identified in the Internet search in 29 European countries

Type	*N* [a]	Price Euro/25 pcs	
		Average	Range[b]
Steel	36	11.90	7.50–25.25
Bismuth	8	57.81	42.25–60.00
Tungsten	2	85.00	79.25–90.00
Copper	3	37.28	21.50–41.25
Lead	25	10.45	6.50–18.25

[a]Number of web shops, [b]rounded up to nearest quarter Euro

The production price of a shotgun cartridge consists basically of three elements: costs of component materials, costs of construction of components, and costs of assembling the components into a cartridge (loading). This applies to lead as well as non-lead products. In terms of the shell, primer, wad, and powder, there are no significant differences between production costs. Nor is the loading process different, though some components of the machinery may be modified and adjusted to change from one type to another. Hence, the main driver for production price differences is the price of shot material combined with shot manufacture. We found the following current approximate prices for metals on world markets by Internet search: Lead: 2 Euro/kg; Iron: 0.07 Euro/kg; Bismuth: 20 Euro/kg; and Tungsten (powder): 40+ Euro/kg. Prices are dependent on market forces, purity, etc. and therefore only indicative of the raw material costs for shot types. However, the figure that bismuth is 10-fold more expensive than lead, but at the same time, that lead is 30-fold more expensive than iron, explains why bismuth shot cartridges are much more expensive than lead and

steel shot cartridges. It also demonstrates that prices of bismuth (and tungsten) shot will not fall to levels comparable to lead and steel. Secondly, the prices indicate a potential for steel shot to be significantly cheaper than lead shot if the costs of making steel shot can be reduced.

https://link.springer.com/article/10.1007/s13280-019-01151-8

Bismuth vs Lead

Worse product quality

Due to its physical properties - it expands during solidification - bismuth tends to be subject to mechanical stresses and thus to stress corrosion cracking in the components.

Worse recycling

Copper alloys are 100 percent recyclable, and the lead can also be easily separated from the copper in the smelter if required. This is not possible with copper materials containing bismuth.

No alternative

Where will bismuth come from if lead is not to be produced?

To obtain 1 ton of bismuth, 30 to 200 tons of lead have to be produced today. It would therefore not be possible to replace a large number of lead-containing applications with the use of bismuth on the one hand, while at the same time reducing the quantities of lead on the other.

Worse economy

Bismuth is almost 300 times less abundant in the earth's crust than lead and is even less abundant than the precious metal silver.

Points made by German Copper Industry:
https://www.kupferinstitut.de/fileadmin/user_upload/kupferinstitut.de/de/Documents/Arbeitsmittel/Factsheet_Bismut_als_Bleiersatz_final.pdf

Not suitable for bullets

Bismuth suitable for shotguns, but not for rifle and handgun bullets: Not suitable, due to frangibility concerns at high-velocity impacts (see first link)