

reduced growth (Weber and Reid 1968). A diet containing 200 ppm nickel as nickel sulfate had no observed effects on mallard ducklings from 1 to 90 days of age. Diets of 800 ppm or more caused significant changes in physical condition of the ducklings (Cain and Pafford 1981). Eastin and O'Shea (1981) observed no apparent significant changes in pairs of breeding mallards fed diets containing up to 800 ppm nickel as nickel sulfate for 90 days. We have no basis for concern about the toxicity of nickel in TINT shot to fish, mammals, or birds.

Iron is an essential nutrient, so reported iron toxicosis in mammals, such as livestock, is primarily a phenomenon of overdosing. Maximum recommended dietary levels of iron range from 500 ppm for sheep to 3,000 ppm for pigs (National Research Council [NRC] 1980). Chickens require at least 55 ppm iron in the diet (Morck and Austic 1981). Chickens fed 1,600 ppm iron in an adequate diet displayed no ill effects (McGhee *et al.* 1965), and turkey poulters fed 440 ppm in the diet also suffered no ill effects. The tests in which eight No. 4 tungsten-iron shot were administered to each mallard in a toxicity study indicated that the 45% iron content of the shot had no adverse effects on the test animals (Kelly *et al.* 1998). We have no basis for concern about the toxicity of iron in TINT shot to fish, mammals, or birds.

Elemental and inorganic tins have low toxicity, due largely to low absorption rate, low tissue accumulation, and rapid excretion rates. Inorganic tin is only slightly to moderately toxic to mammals. The oral LD₅₀ values for tin (II) chloride for mice and rats are 250 and 700 mg/kg of body weight, respectively (WHO 1980).

A 150-day chronic toxicity/reproductive study conducted for tin shot revealed no adverse effects in mallards dosed with eight No. 4 sized shot. There were no significant changes in egg production, fertility, or hatchability of birds dosed with tin when compared to steel-dosed birds (Gallagher *et al.* 2000).

Environmental Fate

Elemental tungsten and iron are virtually insoluble in water and do not weather or degrade in the environment. Tungsten is stable in acids and does not easily form compounds with other substances. Preferential uptake by plants in acidic soil suggests uptake of tungsten when it has formed compounds with other substances rather than when it is in its elemental form (Kabata-Pendias and Pendias 1984).

Nickel is common in fresh waters, though usually at concentrations of less than 1 part per billion in locations unaffected by human activities. Pure nickel is not soluble in water. Free nickel may be part of chemical reactions, such as sorption, precipitation, and complexation. Reactions of nickel with anions are unlikely. Complexation with organic agents is poorly understood (U.S. Environmental Protection Agency [EPA] 1980). Water hardness is the dominant factor governing nickel effects on living things (Stokes 1988).

Tin occurs naturally in soils at 2 to 200 mg/g with areas of enrichment at much higher concentrations (up to 1,000 mg/g) (WHO 1980). However, in the United States, soil concentrations are between 1 and 5 ppm (Kabata-Pendias and Pendias 2001).

Environmental Concentrations

Calculation of the estimated environmental concentration (EEC) of a candidate shot in a terrestrial ecosystem is based on 69,000 shot per hectare (2.47 acre) (Bellrose 1959, 50 CFR 20.134). Assuming complete dissolution of the shot, the EEC for tungsten in soil is 15.09 mg/kg. The EECs for nickel and iron would be 0.65 and 2.41 mg/kg, respectively. The EEC for nickel (the only one of the four elements with an application limit) is substantially below the U.S. Environmental Protection Agency (EPA) biosolid application limit. The 0.65 mg/kg EEC for nickel also is far below the 16 to 35 mg/kg concentrations suggested as minimum sediment concentrations at which effects of the metal are likely to occur (EPA 1997, Ingersoll *et al.* 1996, Long and Morgan 1991, MacDonald *et al.* 2000, Smith *et al.* 1996). The EEC for tungsten from TINT shot is below that for the already-approved TNI shot. The EEC for iron is less than 0.01% of the typical background concentration, and the iron is in an insoluble form. The EEC for tin in soil is 5.06 mg/kg, one order of magnitude smaller than the 50 mg/kg suggested maximum concentration in surface soil tolerated by plants (Kabata-Pendias and Pendias 2001).

Calculation of the EEC in an aquatic ecosystem assumes complete erosion of 69,000 shot in one hectare (2.47 acre) of water 1 foot deep. The EECs for the elements in TINT shot in water are 3,218 µg/L for tungsten, 515 µg/L for iron, 139 µg/L for nickel, and 1,079 µg/L for tin. We concluded that a tungsten concentration of 10,500 µg/L posed no threat to aquatic life (62 FR 4877). The EEC for nickel from TINT shot is below the EPA acute water quality criterion of 1,400 µg/L in fresh water, but would

exceed the 75 µg/L criterion for salt water. However, tests showed that corrosion of TINT shot occurs at very low rates. The amount of nickel liberated into seawater by eight No. 4 TINT shot for a 30-day exposure was 23% of the amount liberated by TNI. TINT shot is predicted to release 1.8 µg/L of nickel into 1 ha-ft of seawater over 1 year. This value is 2.4% of the acute criterion and less than 23% of the chronic criterion.

The EEC for iron is below the chronic criterion for protection of aquatic life and for tin; it is four times less than the Minnesota Water Quality Standard. Previous assessments of tungsten demonstrated dissolution at a rate of 10.5 mg/L (equal to 10,500 µg/L) and concluded no risk to aquatic life (62 FR 4877). The EEC of tungsten from TINT shot is 3,218 µg/L. This level is three times less than the 10,500 µg/L level previously mentioned.

Effects on Birds

Kraabel *et al.* (1996) surgically embedded tungsten-bismuth-tin shot in the pectoralis muscles of ducks to simulate wounding by gunfire and to test for toxic effects of the shot. The shot neither produced toxic effects nor induced adverse systemic effects in the ducks during the 8-week period of their study.

Nell *et al.* (1981a) fed laying hens (*Gallus domesticus*) 0.4 or 1.0 g/kg tungsten in a commercial mash for 5 months to assess reproductive performance. Weekly egg production was normal, and hatchability of fertile eggs was not affected. Exposure of chickens to large doses of tungsten either through injection or by feeding resulted in an increased tissue concentration of tungsten and a decreased concentration of molybdenum (Nell *et al.* 1981b). The loss of tungsten from the liver occurred in an exponential manner, with a half-life of 27 hours. The alterations in molybdenum metabolism seemed to be associated with tungsten intake rather than molybdenum deficiency. Death due to tungsten occurred when tissue concentrations increased to 25 ppm in the liver.

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