



Fluoride Affects Aluminum Toxicity in Atlantic Salmon

The addition of small amounts of fluoride to test solutions reduced mortality and gill damage and improved growth of young Atlantic salmon (*Salmo salar*) exposed to aluminum in acidic water; greater amounts of fluoride either had no effect or increased the toxicity of test solutions. Recovery of Atlantic salmon in the northeastern United States depends in part on suitable water quality in streams that juveniles use. Northeastern waters have been harmed by acid precipitation, and aluminum has been identified as the primary cause of harm to fish. Aluminum forms complexes with naturally occurring organic acids and hydroxide, fluoride, and sulfate ions. Fluoride-aluminum complexes are the dominant inorganic aluminum compounds in surface waters, yet their influence on Atlantic salmon has not been assessed or considered in the management of suitable water qualities in streams that are essential to the recovery of the Atlantic salmon.

We conducted short-term acute and 30-day chronic exposure studies to determine the influence of fluoride addition on the toxicity of aluminum to young Atlantic salmon at pH levels of 5.5 and 6.5. Tests were conducted in water the quality of which simulated that of waters in the northeastern United States. In short-term tests, the endpoints of survival, growth, and histopathological changes in gill tissue were examined under a series of aluminum concentrations at the two pH levels and four fluoride concentrations (0, 50, 250, 500 ppb). In

long-term tests, the endpoints were examined at two pH levels with either 0 or 200 ppm aluminum and with either 0, 100, or 200 ppb fluoride concentrations.

Fluoride-Aluminum Complexes Reduced Survival and Growth

At low pH (5.5), high fluoride (500 ppb) increased the toxicity of aluminum (96-h LC50, 478 ppb), but at near-neutral pH (6.5), low fluoride (50 ppb) decreased aluminum toxicity (96-h LC50, 1,134 ppb). Aluminum toxicity was not affected at pH 5.5 by low fluoride additions (50 or 250 ppb) or at pH 6.5 by high fluoride additions (250 or 500 ppb). In general, young Atlantic salmon were 6 times more sensitive to aluminum than brook trout (*Salvelinus fontinalis*) tested by other investigators.

Survival of Atlantic salmon after 30 days exposure was 2 to 6 times lower in all pH 5.5 treatments—with or without fluoride—than at pH 6.5. Moreover, fish length and weight was reduced in all fluoride-aluminum treatments at pH 5.5 but only in the 0 ppb fluoride-200 ppb aluminum treatment at pH 6.5. Growth in fish length during early life stages is important to later survival because smaller fish have lesser swimming abilities (stamina, speed) than larger fish of the same age. Thus, smaller than normal Atlantic salmon have lesser survival skills for capturing food and avoiding predators.

Gill Morphology Is Altered by Fluoride-Aluminum Complexes

Gill tissue of fish was normal in the pH 5.5 and 6.5 treatments without aluminum or fluoride. However, in exposures with only aluminum at pH 6.5 and especially at pH 5.5, gill filaments and secondary lamellae were swollen and thickened and interfered with respiration and ion transport. At pH 6.5, addition of 100 ppb fluoride to aluminum treatments alleviated swelling and thickening of gill filaments and lamellae, whereas addition of 200 ppb fluoride was less effective in reducing gill damage. In both fluoride treatments, open lesions were observed on gill filaments—a condition not previously reported by other investigators. At pH 5.5, addition of low fluoride (100 ppb) to aluminum treatments reduced some of the swelling, but addition of high fluoride (200 ppb) had no effect.

Management Implications

Low fluoride concentrations (<100 ppb) may reduce gross gill morphological damage and cause mortality and growth deficiencies in fish exposed to aluminum in acidic waters. However, high fluoride concentrations (100 ppb) may not reduce but enhance aluminum-induced adverse effects on young Atlantic salmon, particularly open lesions on gill filaments. Heightening of adverse effects is due to the increase in concentrations of soluble aluminum resulting from fluoride complexation. Addition of fluoride in

streams may result in more solubilization of aluminum from various sources, including sediments. Because the soluble form of aluminum is more toxic, fluoride concentration is an important determinant of aluminum toxicity to fish in acidic waters. Management activities should discourage substantial increases of fluoride concentrations to mediate aluminum-induced toxic effects in young Atlantic salmon.

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