

# Ammonia Management

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Ammonia is the primary waste byproduct of protein metabolism in fish and it rapidly attains toxic concentrations in the confines of an aquarium. It exists as a mixture of free ammonia ( $\text{NH}_3$ ) and ionized ammonia ( $\text{NH}_4^+$ ) in equilibrium. This does not mean that they are present in equal proportion, but that they are converted from one to the other at an equal rate.

The concept of equilibrium is fundamental to understanding ammonia. The siphon is a familiar and useful metaphor. If two containers of equal size and at equal level are connected by a siphon, the level and amount of water in each will be the same. If one container is lowered or made larger, then the water level in that container will begin to fall, but the siphon will compensate and the levels will become the same again, but now the amount of water will be less in the higher or smaller container than in the lower or larger container. The total amount of water does not change, but its distribution between compartments is altered. Ammonia in equilibrium behaves the same way: as the pH falls, the ammonia equilibrium shifts in the direction of ionized ammonia. As with our container metaphor, total ammonia does not change, but the amount in each compartment shifts. At pH of 8.3, free ammonia makes up about 10% of the total. At a pH of 7.0, free ammonia makes up less than 0.5% of the total.

Free ammonia is uncharged and is a gas dissolved in water. It can pass unimpeded through membranes such as fish gills. This allows it to interfere with the normal excretion of ammonia and is believed to account for its toxicity. Ionized ammonia is a charged particle and does not exist as a gas. It cannot pass through membranes and is, therefore, relatively nontoxic. It does, however, function as a proton donor, like the hydrogen ion, and, in high concentrations, produces external burns that are

identical to acid burns. This is often seen in crowded gold fish ponds and shipping containers. The external “burning” properties of ammonia in high concentration at low pH should not be confused with the respiratory toxicity of free ammonia.

Ammonia can be removed from an aquarium by depleting either free or ionized ammonia. Since it is in equilibrium, removing either component will ultimately remove both components. Picture this as adding another siphon to either of our containers. This second siphon will drain one of the compartments. As we drain one compartment, the water level falls, but this will be compensated by the first siphon. This is fundamental to what a siphon does and fundamental to what equilibrium does. If we continue to drain from one compartment, we will ultimately drain both compartments.

The biological filter removes ionized ammonia, and, provided it works efficiently, does so to the extent that free ammonia is virtually undetectable. It is often overlooked that free ammonia is toxic to nitrifying bacteria and that high ammonia concentration is a major cause of difficulty in establishing a biological filter.

Ion exchangers remove ionized ammonia, but only in freshwater. The presence of even low concentrations of salts in freshwater interferes significantly with ammonia removal by ion exchange. The most prevalent material used for this is zeolite, a natural mineral, more commonly recognized as cat litter.

The classical reaction of ammonia with formaldehyde to form methenamine is the principal of most ammonia removing conditioners. It may be used either directly or as a bisulfite complex. The bisulfite formaldehyde complex has the advantage of odor control, enhanced reaction time, and improved methenamine stability.

