METAL MIXTURES MODELLING
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METAL MIXTURES AND AQUATIC TOXICITY: AN INTRODUCTION

Fact Sheet One

Introduction

Mixtures of different chemicals can be extremely complex, and some of the possible mixtures may not be all that relevant environmentally. However, mixtures of metals are potentially important because they are often found together as impurities in ores and metal products.

Metals can be toxic to plants and animals in lakes and rivers, although how toxic they are depends on the conditions in the water. When metals are dissolved in water a portion of them can become associated with other ions and with dissolved organic matter, whilst another portion can become associated with the plants and animals. It is only the portion of the metal which becomes associated with the plants and animals which can cause toxicity. This is the "bioavailable" portion of the metal, the portion of the total amount of metal in the water that the organism actually experiences.

How has the "bioavailable" portion of a metal been assessed in the past?

Water quality standards for metals have sometimes been based on the hardness of the water, and this is one factor which affects metal toxicity and bioavailability. There are other factors which have a more important effect on metal toxicity and bioavailability, such as water pH and the portion of the metal which becomes associated with organic matter.

The toxicity of a single metal can be predicted using models, such as biotic ligand models (BLMs), which calculate how much of a metal will be associated with either organic matter (not bioavailable), or plants and animals (bioavailable).

How are effects of metal mixtures currently evaluated?

When a number of different metals are present together they can interact with each other, affecting the portions which become associated with either the organic matter or the plants and animals. This means that when there are several metals present together understanding the toxicity is more complicated than it is for only one metal, because the metals affect each other, and this can change how they affect the plants and animals.

Depending on the specific combination of metals, the water conditions, and the organisms present, metal mixtures may have three potential ecotoxicological influences on organisms:

- The same effect as their individual components added together - "additive effect";
- An effect which is more than their individual components added together – "more than additive";
- An effect which is less than their individual components added together - "less than additive".

A review of 191 aquatic toxicity studies on metal mixtures in 2003 noted considerable variability in the toxicological responses, even for tests with the same two metal mixtures. Figure 1 shows the categorisation of the studies and highlights that in less than a third of cases the more than additive effect is identified. Importantly, the types of interactions in these studies were all determined based upon the measured dissolved metal mixture concentrations in the tests and not on a bioavailable basis.

Some of the challenges associated with interpreting metal mixture effects from existing literature include: 1) inconsistent responses for similar metal mixture combinations, 2) inconsistent responses among testing media (aquatic or terrestrial), endpoints (i.e., survival, growth, or reproduction), and exposure duration (acute or chronic), and 3) differences attributed to the statistical analyses applied to the results. In addition, very few metal mixture studies from the literature attempt to incorporate bioavailability corrections using measured water quality.

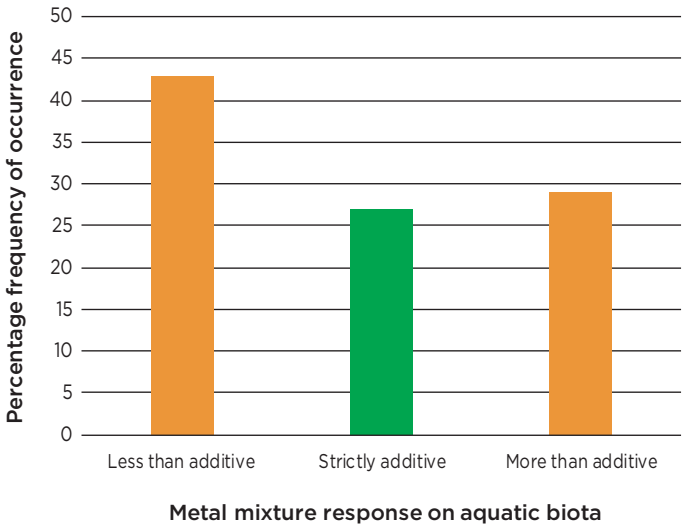

Figure 1. The interactions of metal mixtures from 191 chronic and acute toxicity tests (data from Norwood et al. 2003[1]).

How can metal mixture effects be predicted?

A recent research programme, called the Metal Mixtures Modelling Evaluation, has attempted to review existing modelling approaches that could be used to predict the overall toxicity of metal mixtures. All of the approaches are based on an approach known as "equilibrium speciation modelling" and assume that the metals, which cause toxicity, become attached to the plants and animals that they affect. These are the same basic principles as the Biotic Ligand Models or variations of BLMs. Biotic Ligand Models, and other models like them, appear to provide the best approach for interpreting the toxicity of metal mixtures and relating it to the toxicity of the individual component metals.

Further information for all levels of interest in this area are available at metalsintheenvironment.com. Here you will find more factsheets that address:

- Metal bioavailability, looking at the influence of water chemistry on toxicity and biotic ligand model development;
- Metal mixture toxicity and the challenges mixture toxicity presents to regulators and the regulated community;
- Metal mixture modelling principles;
- Future look and on-going metal mixture initiatives and regulations.

Other information sources include simple infographics, links to open scientific literature, available single metal BLMs, and also an opportunity to register to access the mixture BLM (mBLM).

[1] Norwood WP, Borgmann U, Dixon DG, Wallace A. 2003. Effects of metal mixtures on aquatic biota: A review of observations and methods. Hum. Ecol. Risk Assess., 9:795–811.