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RETROSPECTIVE

Sediment Contaminant Bioaccumulation: With or Without Gut Contents?

Peter M. Chapman[1]

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Over 30 years ago I published a 3-page note in this journal (Chapman 1985) warning that "sediment gut contents significantly influence determinations of tissue metal levels in invertebrates", and suggesting either effective depuration prior to chemical analyses or a gut sediment correction. I noted that metal loads contributed by the gut sediments varied from 15 % to 60 % of the total metal loads in the oligochaete worms and lamprey larvae I collected and analyzed. That note was cited in a number of subsequent publications that assessed the effects of gut contents on not only whole body chemical analyses (Hare et al. 1989; Lobel et al. 1991; Robinson et al. 1993; Brooke et al. 1996; Mount et al. 1999; Neumann et al. 1999; Goodyear and McNeill 1999; Bat and Raffaelli 1999) but also on dry weight estimates of growth (Sibley et al. 1997). Overestimates of whole body contaminant concentrations due to gut sediment contents ranged as high as 438 % (Neumann et al. 1999).

The contribution of gut sediment to whole body chemical analyses increases as biota sediment accumulation factors decrease and can be contaminant- and sediment-specific (Neumann et al. 1999). For example, ingestion of sediments that contain high proportions of black carbon particles will result in overestimates; those particles tend to bind organic contaminants such as PAHs and PCBs, such that they are not readily biologically available (Koelmans et al. 2006).

Failing to depurate or correct for gut contents increases the probability of either false positives or false negatives in sediment toxicity tests measuring growth in terms of weight; false negatives will occur for sediments with high proportions of silt and sand that are likely to be ingested in large quantities (Sibley et al. 1997). All organisms used in sediment toxicity tests will ingest sediment, including water column organisms such as *Daphnia* (Gillis et al. 2004).

Gut sediment corrections can be applied in different ways depending on the study intent. To determine contaminant concentrations in living tissues either dissect out the gut sediments (time consuming) or measure contaminant concentrations in the sediment the organisms feed in, collect and weigh the sediments in their guts after chemical analyses of the whole organism, and then calculate the contaminant concentrations in the gut sediments relative to the analytical results (Eq. 1):

$$[CC]_b = W[CC]_t - W_g[CC]_s/W_t - W_g \quad (1)$$

where [CC] = contaminant concentration (mg/kg), W = weight (g), b = entire body without gut contents, t = entire body including gut contents, g = gut, and s = sediment on which the organism fed.

This latter method is reasonably equivalent to dissection when the gut contents are mainly sediment (Hare et al. 1989), but not when the guts contain other materials (Cain et al. 1995). To determine growth in terms of dry weight: oven-dry and weigh the organisms, then ash them and weigh the residue; the ash-free dry weight is the difference between the two measurements.

Whether guts are depurated or a gut sediment correction is applied will depend on the specific contaminants of concern, the specific biota, and the specific study aims. Depuration of gut sediment contents also allows for depuration of tissue-bound chemicals. This is of particular concern for contaminants with a log $K_{ow} < 5$, which

✉ Peter M. Chapman
peter@chapmanenviro.com

[1] Chapema Environmental Strategies Ltd., 1324 West 22nd St, North Vancouver, BC V7P 2G4, Canada

require adjusting depuration times relative to body depuration rate constants to "balance the diminishing bias from gut contents against the growing bias from depuration" (Mount et al. 1999). A gut sediment correction rather than depuration will be required when coprophagy occurs unless measures are taken to avoid feces ingestion such as feeding with an uncontaminated artificial food of constant quality (Neumann et al. 1999).

Depuration or gut sediment corrections may not, however, be appropriate when the goal is to assess contaminant concentrations in prey, given that ingestion of the organism plus its stomach contents will occur, and digestive juices may release sediment contaminants (Weston and Maruya 2002; Rust et al. 2004). Gut contents should be included in laboratory-field comparisons where field specimens include uncorrected gut contents; also, depuration is not appropriate for low-molecular-weight contaminants such as PAHs, which can be depurated rapidly (Van Geest et al. 2010).

As noted above, there are cases when gut sediment contents should be excluded from analyses and others where they should not be. Further, neither depuration nor gut sediment corrections are without uncertainties. These uncertainties in addition to uncertainties in chemical analyses mean that definitive single numerical values are unrealistic. Inappropriately ignoring contributions from gut sediment contents will result in even greater deviations from reality.

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