Water Quality Criteria for Wyoming Livestock and Wildlife
Final Report

M. F. Raisbeck[1], B. Wise[1], J. Zygmunt[2], M. Smith[3] and C. Tate[4]
[1]Dept Veterinary Sciences, University of Wyoming
[2]Wyoming Dept Environmental Quality
[3]Dept Renewable Resources, University of Wyoming
[4]Wyoming Dept Game and Fish
Duration: 3/1/2009 - 2/28/2011

Abstract

Water is arguably *the* most essential nutrient for terrestrial animals. Thus, it isn't surprising that water quality plays a significant role in animal health and productivity. Never in great supply, high quality water for livestock and wildlife is becoming scarcer as the result of competition by mineral development and urbanization. While animals can, and often do, subsist upon less-than-perfect drinking water such as that produced by oil and gas development ("produced water"), there are tradeoffs with health and productivity. Water quality standards, as promulgated by various educational and regulatory agencies, are often based upon science that is several decades old. It is not that the data don't exist, but rather that they haven't been compiled into any sort of useful, user-friendly summary or, in some cases, mineral production has itself created new questions (e.g. chronic toxicity of water-borne barium to ruminants) that never had to be answered before.

Our group recently completed a literature review of several water quality elements important to domestic livestock and large mammalian wildlife for the Wyoming Department of Environmental Quality (Raisbeck *et al.*, 2007), which has since been released as UW Agricultural Experiment Station Bulletin #1183. The present project expands the previous effort to include other elements, such as iron and uranium, which are of future potential interest as they occur naturally in Western waters and are extremely toxic. Our objective to provide a summary of the current knowledge base that is both simple enough for laymen to use, and comprehensive enough to permit sound decision making by experts.

Methodology

Our methodology was fairly simple, if laborious. Older (roughly pre-1990) scientific literature reviews were obtained to validate the previous state of the art re: the toxicity of a given element in our species of interest (cattle, sheep, horses, antelope, deer and elk). After these documents were digested, a search was conducted for detailed, primary sources via biological literature databases such as Medline, Biosis and CAB. These papers were reviewed, evaluated for applicability and reliability, and summarized in our database. Then, the better papers were used as a basis for reversed (e.g. citation) searches and the process repeated. As the amount of information available from conventional sources was frequently inadequate, we also contacted regional animal health agencies for unpublished data such as diagnostic case reports or game and fish studies.

As noted previously, each report was rated for applicability (i.e. route of administration, class of animal, and chemical form of the toxicant) to what is found in Wyoming and reliability (adequate controls and sufficient numbers of animals to support conclusions, etc.). Controlled experimental studies were normally given more weight than case reports; however, this rule was tempered by common sense and the professional expertise of our team. For example, an experiment concluding "no effects" based upon n=3 animals exposed is obviously less credible than a case report documenting a 5% mortality among 200 head exposed to the same substance and dose. If there was *no* quantitative data in our species of interest, we extrapolated from species for which there are data. Such extrapolations were based upon the known comparative physiology of the various species and are detailed in the final report.

Principle findings and significance

Boron - There is almost no experimental, and very little clinical, data regarding poisoning by water-borne boron (B) in ungulates. In areas where better quality (low B) water is available, most species will avoid water containing potentially toxic concentrations of B. There is insufficient data to name a safe upper limit for acute, non-toxic, exposure (an acute NOAEL), but it is probably in excess of 200 mg/L. Chronic effects, mainly decreased productivity, should not occur below 50 mg/L.

Cadmium – The biggest economic risk associated with cadmium (Cd) contamination of livestock water is illegal Cd residues in edible livestock products (e.g. meat). This is because Cd has a very long biological half-life and tends to accumulate indefinitely in edible tissues, especially kidney of exposed animals. We calculate (see full text for assumptions) that lifetime exposure to 0.03 mg Cd/L drinking water would result in violative residues and condemnation of the carcass. By contrast, the literature indicates that concentrations greater than 10 mg/L would be required to produce toxic effects in livestock species.

Chromium – The toxicity of chromium (Cr) depends upon its valence, with hexavalent Cr being much more toxic than trivalent Cr; however, hexavalent Cr is relatively rare in natural surface waters. Hexavalent Cr is also reduced to trivalent Cr by the ruminant GI tract, unless the dose is large enough to overwhelm this capacity. That said, hexavalent Cr *does* occasionally occur in natural waters, and, in the absence of any convenient way of predicting which is going to occur in a particular pond or stream, we opted to base recommendations upon the more toxic hexavalent form. Chronic health effects should not occur in our species of interest at concentrations less than 5 mg Cd/L.

Copper – Sheep are the domestic species most sensitive to copper (Cu). Cattle are less sensitive, but consume more water per unit of body weight, thus the calculated hazardous drinking water Cu concentrations are similar for these species. Dietary (feedstuffs) Cu also contributes to the total dose received by any animal, and must be factored into any estimation of potential hazard. The NOAEL calculated for sheep and cattle, assuming typical Wyoming forage concentrations of 7 ppm, were 4.5 and 4.125 mg Cu/L, respectively. The lack of reported Cu intoxication in large mammalian wildlife or horses suggests that such is relatively rare. Extrapolation from the comparative physiology between these species supports the notion that recommendations based upon cattle and sheep will provide adequate protection for elk, pronghorn, etc. and horses. Thus, we recommend a maximum concentration of no more than 4 mg Cu/L.

Lead – Lead (Pb) is also a residue concern. At present there are no *fixed* tolerance limits for Pb in human foodstuffs, such as meat, in the US, thus we used the WHO reference dose of 25 µg Pb/kg BW/week and a BTF for kidney to calculate residue-driven limits for various tissues. While it is possible that exposure to 20 mg/L would produce violative residues in kidney, the accumulation in red meat is sufficiently low that overt toxicity would likely occur in the animal before residue limits were exceeded. Calculations based upon nervous damage in the most sensitive receptor, lambs, suggest that Pb concentrations should be kept less than 3 mg/L.

Mercury – Like Cd, the biggest risk from mercury (Hg) exposure is condemnation as a result of Hg accumulation in edible tissues with potential human exposure. Unlike Cd, the chemical form of Hg determines both its short term toxicity and its accumulation in animal tissues. Ideally, we would have preferred to establish limits for each of the three major forms of Hg; however these forms are somewhat interchangeable in the aquatic environment, thus we opted to base recommendations upon the most toxic form, methyl Hg. Based upon residue considerations outlined in the thesis, concentrations greater than 0.24 mg/L are economically hazardous. Critical readers will note that this recommendation is noticeably higher than the 1972 NAS recommendation. The difference is that the latter were based upon the amounts found in useable waters at the time of the report, and not upon animal data. Given the emphasis of various regulatory agencies on Hg in the food chain, it may well be that our upper tolerance limit will need to be re-evaluated in the future.

Uranium – There is a serious paucity of data on uranium (U) in large animals of any sort. Extrapolating from rodent and human data suggests an temporary upper limit of exposure of 0.065 mg/L/day for our species of interest until better data becomes available. Given the resurgence of nuclear power, and the importance of Wyoming as a source of U, this is an area that urgently needs further study.

Zinc - Zinc (Zn) intoxication from drinking water appears to be unlikely as the concentrations required to produce poisoning are substantially higher than those which induce refusal under experimental conditions. Pregnant sheep seem to be the most sensitive receptor to Zn, and we calculated a maximum tolerance concentration of 70 mg/L for them. Non-pregnant sheep and other species should be protected by 100 mg/L.

Publications & Presentations

M. F. Raisbeck: Water quality for animals. Some theoretical considerations. Wyoming VMA meeting, Laramie, WY, 6/14/08.

M. F. Raisbeck: Water quality for animals. Wyoming Environmental Quality Council, Laramie, WY, 11/23/08.

M. F. Raisbeck: Water quality for Wyoming Livestock and Wildlife. CLE, Int'l, Wyoming Water Law, Cheyenne, WY 4/17/09.

B. Wise and M. F. Raisbeck: Water quality for livestock and wildlife. RMSETAC Denver, CO, 4/24/2009.

B. Wise and M. F. Raisbeck: Water quality for Wyoming Livestock and Wildlife. Soc Toxicol annual meeting, Salt Lake City, 3/9/10.

B. Wise and M. F. Raisbeck: Water quality for Wyoming Livestock and Wildlife. RMSETAC, Denver, CO, 4/15/10.

B. Wise: Water Quality for Wyoming Livestock and Wildlife. MS thesis, UW (attached).

M. F. Raisbeck, B. Wise, J. Zygmunt, M. Smith and C. Tate (in peer review April, 2011): Water Quality for Wyoming Livestock and Wildlife, vol II. UW AES Bulletin.

Student support & training

Undergraduate

Kaitlin McDaniel, currently a graduate student in molecular toxicology at Pennsylvania State University.

Graduate

Ben Wise, MS in ANVS and ENR, currently seeking employment in the water quality with various state and federal agencies.

Rebecca Morris, PhD (partial support), currently employed by CBM Associates.