

# "Potentially Toxic Element"—Something that Means Everything Means Nothing

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A character in a famous William Shakespeare play commented that “a great cause of the night is lack of the sun”.<sup>1</sup> Shakespeare used the comment as a statement and a humorous device, which we refer to here as we wish to address reasons why there is perhaps more humor and less illumination in the increasing use of the phrase “potentially toxic element”. Usage of this phrase gained momentum after a 2002 International Union of Pure and Applied Chemist’s publication criticizing the use of the term “heavy metal” to describe metals/metalloids “and their compounds [that] have highly toxic or ecotoxic properties”.<sup>2</sup> The 2002 paper was a scholarly work that carefully analyzed the use of heavy metal in the context of existing definitions, intended meaning, and possible consequences of using a phrase not unequivocally defined to describe hazardous substances. Throwing the proverbial baby out with the baby’s bathwater, we now have the alternative of a less useful phrase. While “toxic element” certainly addresses the concept of toxic and that not all heavy metals are strictly speaking metals, what is not “potentially” toxic? People have died from star fruit poisoning, carrot juice addiction, and water intoxication.<sup>3–5</sup> This global descriptor admits nothing to differentiate the relatively benign iron (Fe), or even sodium (Na), from lead (Pb) and cadmium (Cd), that is, metals toxic at relatively low dosages and simultaneously most frequently referred to as “potentially toxic elements”. Under this “helpful” classifier of “potentially”, we lack a definitive basis for not counting star fruit, carrot juice, or water as potentially toxic, and we, the authors of this Viewpoint, could be said in all factual validity to be potentially intergalactic travelers. As the famous ecological economist Herman Daly pointed out “One way to render any concept innocuous is to expand its meaning to include everything... Any definition that excludes nothing is a worthless definition”; that is, a definition that means everything, means nothing.<sup>6</sup>

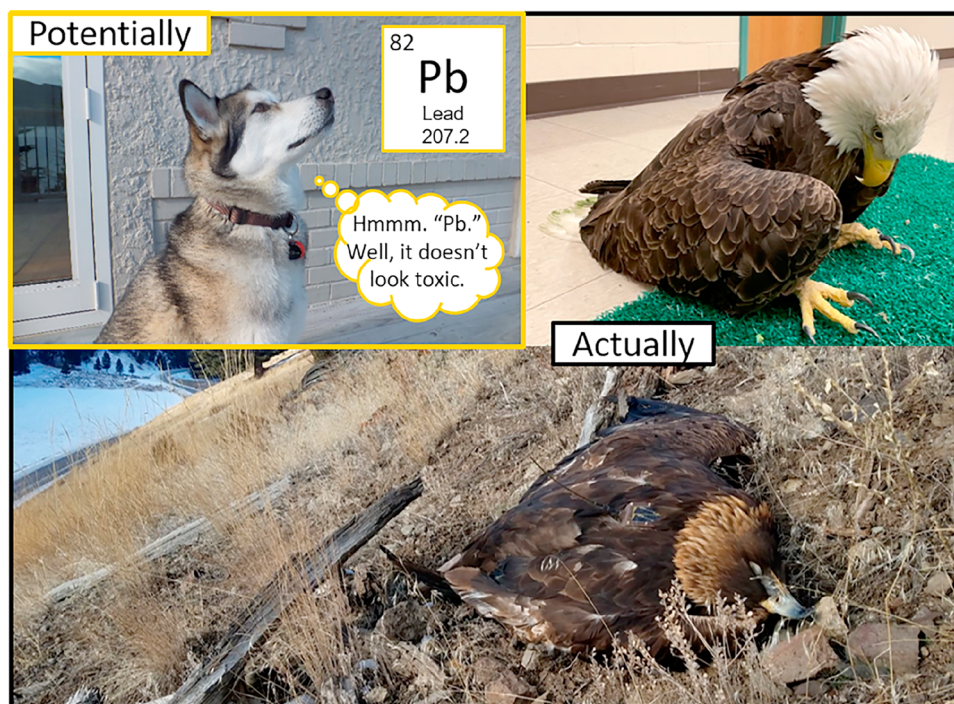
In our survey of the literature, there is no official definition of “potentially toxic element”. In a paper boldly entitled “It’s Time to Replace the term ‘Heavy Metals’ with Potentially Toxic Elements in Environmental Research”,<sup>7</sup> the majority of the text was concerned with why the term heavy metal should not be

used rather than providing an evidentiary basis for why “potentially toxic element” should be used. Since “potentially toxic element” was not defined, we are left to rely on definitions for the phrase’s constituent words, which, as we argue here, is problematic, since they potentially encompass everything, exclude nothing, and differentiate nothing. Oxygen is a potentially toxic element, as are some forms of “organic carbon”, straying now well-afield of the point that metals/metalloids comprise the most toxic “elements”. These authors discussed in some detail that chemical speciation is an important governing factor in toxic response. They did not, however, state how an audience would link speciation to “potentially toxic element”, which is likewise inadequate to convey meaning regarding emerging and more sophisticated models of toxicity (e.g., hormesis).<sup>8</sup>

Unquestionably, toxicity is a function of exposure and bioavailability, and bioavailability in turn depends on concentration and speciation. In the last 20 years, some of the authors of this Viewpoint have published numerous papers confirming this and attesting to the value of taking bioavailability into account in risk assessment.<sup>9–11</sup> Our own research recognizing that bioavailability is a prerequisite to toxicity in no way abrogates other facts: in environmental research on contaminants with no known nutritive value, such as Cd and Pb, toxic effect is the key driver. The World Health Organization, the United States Environmental Protection Agency, the European Environment Agency, and the Ministry of Ecology and Environment of the People’s Republic of China all refer to Cd and Pb and a small number of other metals/metalloids as toxic, because they are toxic at low doses. Pb specifically has been described as “one of the most toxic elements

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**Figure 1.** Example of lead (Pb). Is it potentially or actually toxic? The dog in the upper left-hand image is not worried about “potentially toxic” Pb because potentially is not actually, the dog is not an expert on Pb, and for that matter does not speak English. American Bald Eagles do not speak English either; nonetheless, as the photos on the top right and bottom show, Pb is, actually, highly toxic to them and, according to research recently published in *Science*, a great threat to their existence as a species. The eagle in the top photo was confirmed to be Pb poisoned, some symptoms of which include, bowed head, drooped wings, and green stained tail feathers. The female eagle in the second photo was recovered dead approximately 1.5 miles from where she nested. She was necropsied at the United States Geological Survey’s National Wildlife Health Center where the cause of death was determined to be lead poisoning, with liver lead concentrations measured at 48 ppm dry weight. Top left photo created by the authors in homage to content on a Web site emphasizing the actual threat of pediatric Pb poisoning (<https://pedemmorsels.com/lead-poisoning>). Top right and bottom photos are public domain (<https://www.usgs.gov/news/national-news-release/groundbreaking-study-finds-widespread-lead-poisoning-bald-and-golden>), courtesy of The Raptor Center, Saint Paul, MN, and Connor J. Meyer, respectively.

in existence”,<sup>12</sup> presenting an impending global health crisis due to increasing levels of environmental Pb and concomitantly **no safe level of Pb exposure**.<sup>13</sup> Cd is one of a relatively elite and small number of items on the list of known carcinogens, as classified by the International Agency for Research on Cancer. Many environmental criteria limiting acceptable amounts of these and other toxic metals/metalloids are still based on total concentration,<sup>14</sup> because bioavailability is neither a simple nor an immutable quantity and because these toxic substances are highly subject to mobilization, for instance, in acidic conditions such as the human digestive tract.<sup>15</sup>

The Oxford English Dictionary defines “potentially” as something with the capacity to develop or happen in the future. An antonym of potentially is the word actually. If even the most toxic substances are now to become “potentially toxic”, this substantially complicates both language and practice surrounding things that actually are toxic. For instance, in environmental risk assessment and remediation, does it make sense for environmental practitioners to recommend that governments and/or liable entities pay eye-watering sums of money to remediate potentially, not actually, toxic elements that have potential, not actual, risks/impacts? The importance of the difference between potentially and actually, per Figure 1, is *actually* reasonably straightforward to understand.

Advocates of “potentially toxic element” have raised issues of perception of hazard, for instance, “Eventually, the pejorative connotation of “heavy” associated with the toxicity of metal induces

a kind of fear in society”, a consequence of which is “Eventually, one should continue to educate people to avoid the term “heavy metals”, especially in non-peer-reviewed regulations or governments’ research reports”.<sup>7</sup> No evidence was given to demonstrate that heavy metal does have a pejorative, that is, disparaging, connotation that induces “a kind of fear” in the public or why “potentially toxic element” will assist members of government or the public to understand that “potentially toxic”, for example, for Pb, instead means “one of the most toxic elements in existence”.<sup>12</sup> In effect, the implication is that scientists should be mindful to not scare anyone about the very serious global problem of contamination of air, water, soils/sediments, and biota with highly toxic metals such as Cd and Pb. Issues with such mitigatory language include risk compensation, whereby the perception of safety may result in riskier behavior and/or co-opting of message<sup>16</sup> by polluters, much as messages around climate change have been muddled. While our understanding of how scientists should convey messages concerning risk to legislators, policymakers, laypeople, and the general public is as yet incomplete, much research suggests that more knowledge is better than the type of dumbing down<sup>17</sup> that George Orwell foresaw and referred to as a vastly oversimplified and highly misleading version of English called “Newspeak”.

There are various alternative terms that may be used instead of heavy metal,<sup>a</sup> thus there is no reason why the question should be framed as heavy metal *or* the Newspeak of “potentially toxic element”. It seems only reasonable that



experts should clarify what they mean by terms used, while also considering the merits of the environmental precautionary principle, that is, being careful not to diminish or downplay risks of pernicious environmental toxins. After all, this is not a purely academic discussion. Pb tops the list earning the moniker “potentially toxic element”,<sup>7</sup> this in a world where an estimated one-third of children globally are actually, not potentially, lead-poisoned,<sup>19</sup> resulting in a loss of intelligence recently estimated to actually, not potentially, value 1,154 billion U.S. dollars.<sup>20</sup> According to the Pure Earth Institute, there is widespread exposure to dangerous forms of Pb, and the World Health Organization ranks it as one of two contaminants posing an actual, not potential, risk that exceeds the sum of all other Top Ten Chemicals of Concern. Those affected are predominantly living in lower-income countries.<sup>19</sup> Humor aside, on behalf of millions of people and large swaths of ecosystems actually affected, in an effort to be more illuminating, we might all reflect a bit longer before rushing to take refuge in the imprecise and flawed descriptor “potentially toxic element” over long-standing and commonly understood terms already in use. If everything toxic becomes potentially toxic, then nothing remains that is toxic.

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## Notes

The authors declare no competing financial interest.

## Biography



Mona Wells is an interdisciplinary environmental scientist specialized in Environmental Impact Assessment, Environmental Risk Assessment, and Environmental Management. Her roles have included posts in different locales internationally as an academic and as an environmental practitioner, on projects spanning a broad portfolio including technical project work, research, commercialization, program development, policy advisement, science communication, public consultation, pedagogical development, and continuous improvement. She is grateful to have been a collaborator with the other coauthors in developing this Viewpoint.

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## ADDITIONAL NOTE

<sup>a</sup>Heavy metal, metal/metalloid contaminant, metal element, metal/metalloid pollutant, metals with no known beneficial effect, toxic metal/metalloid, toxic metal/metalloid pollutant, see Gustin et al.<sup>18</sup> for a further discussion on heavy metal.

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