Acta Geochim (2021) 40(3):466–471
https://doi.org/10.1007/s11631-021-00468-0

SHORT COMMUNICATION

Heavy metal: a misused term?

Olivier Pourret[1] · Jean-Claude Bollinger[2] · Andrew Hursthouse[3]

Received: 28 January 2021 / Revised: 10 March 2021 / Accepted: 10 March 2021 / Published online: 25 March 2021

Abstract The use of the term "heavy metal" is regularly questioned by the scientific community. Here, we followed the evolution (1970–2020) in the number of published papers including this term in their title. Thus, we can evidence a continuous, albeit sometimes stabilizing, increase especially in environmental journals. After several other warning opinions, we propose that it should be replaced in the scientific literature by terms like "metal", "metalloid", "trace metal elements" or "potentially toxic element".

Keywords Heavy metals · Trace metal elements · Metal · Metalloid · Potentially toxic elements

1 History

The chemical elements are now well characterized, and their classification in the so-called "Periodic System" reached its 150-year celebration in 2019 (Ghibaudi 2019). They are also allocated to various series, according to similarities in their properties or their electronic structure; among which are the so-called "heavy metals". Initially, the term "heavy metal" was based on categorization by density or molar mass (zinc or copper have relatively low density and molar mass compared to lanthanides and actinides). It is often used as a group name for metals and metalloids (i.e., arsenic) that are associated with contamination and potential toxicity in the environment. The "heavy metals" list is not clearly defined and often mixes metals and metalloids. Ultimately, the pejorative connotation of "heavy" associated with the toxicity of metal induces a kind of fear in society. From a quick perusal of the recent scientific literature, it appears that the (mis)use of the term "heavy metal(s)" seems still to be rampant: therefore we decided to follow it, as described in the present article.

In elementary science classes, one often asks the children: "Which weighs more—a pound of lead or a pound of feathers?" The seemingly naive answer to the familiar riddle is the pound of lead. The correct answer, of course, is that they weigh the same amount (Wagman et al. 2007). Unfortunately, our own experience has demonstrated that this confusion remains for a part of college students! Apart from this funny side, it seems that it is not so easy to understand what really a "heavy metal" is, and its original definition thus pertains, although several "heavy" metallic elements have somewhat low density.

In 1980, Nieboer and Richardson (1980) had already proposed the replacement of this nondescript term by biologically and chemically significant classification. Moreover, according to the International Union of Pure and Applied Chemistry (IUPAC) (Duffus 2002), the term "heavy metal" is considered imprecise at best, and meaningless and misleading at worst. The use of this term is strongly discouraged, especially as there is no standardized definition of this term. In 2004, Hodson (2004) considered it as geochemical bogeyman; In 2007, Chapman (2007) first proposed to keep this term for music not for science. In 2010, Hübner et al. (2010) proposed to move on from semantics to pragmatics, whereas Madrid (2010) recalled the long-standing and sometimes forgotten

✉ Olivier Pourret
olivier.pourret@unilasalle.fr

[1] UniLaSalle, AGHYLE, 60000 Beauvais, France

[2] Faculté Des Sciences Et Techniques, Université de Limoges, PEREINE, 87060 Limoges, France

[3] School of Computing, Engineering & Physical Sciences, University of the West of Scotland, Paisley PA1 2BE, UK

controversy. Nikinmaa and Schlenk (2010) further insisted on the ill-defined term. In 2011, Bhat and Khan (2011) defined them as an ambiguous category of inorganic contaminants, nutrients and toxins. In 2012, Chapman (2012) continued to wrote on “the cacophony not the symphony” around “heavy metals” and Batley et al. (2012) further detailed on the usefulness of this term.

However, some authors still proposed their classification. In 2010 Appenroth (2010) defined “heavy metals” in Plant Sciences, and Ali and Kahn (2018) proposed their own “comprehensive“ definition (Fig. 1). In some classical textbooks, their authors continue to use the term in their titles (Alloway 2013; Gupta 2020); however, they now discuss the misuse of the term. Some other authors have clearly changed their mind and revised the content of their textbooks (Lambers and Oliveira 2019).

In 2018, Pourret and Bollinger (2018) further questioned on the use of the term “heavy metals”: to use or not to use? and Pourret (Pourret 2018) proposed to ban this term from the scientific literature. Eventually, Pourret and Hursthouse (2019) and Pourret et al. (2020) proposed to replace the term with “potentially toxic elements”. Indeed, due to their persistence and indestructible nature (only changes in their chemical species can occur), most of them are unfortunately able to definitively pollute groundwater (Belkhiri et al. 2017) or soils (Antoniadis et al. 2019).

All so-called “heavy metals” and their compounds may have relatively high toxicity: human exposure to lead by the addition of tetraethyl-lead to gasoline as an antiknock agent, or to lead paint is well documented, however lead–acid battery does not pose direct threat to humans although its disposal may generate environmentally hazardous waste. Nonetheless, metals are not always toxic, and some are in fact essential: depending on the dosage and exposure levels and the receiving organism/population, it may be essential or toxic. Known for its use in the US five-cent coin (thus its nickname), nickel is one of the most versatile metals found on Earth: nickel is essential for life (functional in some proteins) and its deficiency is accompanied by histological and biochemical changes and reduced iron resorption and may lead to anemia (Chivers 2014). Physical organic chemists refer the isotope effects of any elements other than H as ”heavy isotope effects“.

2 Current status

The term is increasingly used in the scientific literature (Fig. 2a), especially in articles pertaining to multidisciplinary environmental issues (see Fig. 3 for the year 2020). Despite the repeated calls to stop using the term (including ours), and the apparent regular publication of the articles related to this controversy (Table 1), the use of the term “heavy metal” appears not to have declined in the scientific literature (Fig. 2a). Indeed, the use of the term is increasing rather than declining. It should be noted that even if the total number of publications has also simultaneously increased: the proportion of publications using this term have globally increased from 0.074% in 2000 to 0.163% in 2020 (Fig. 2b).

The term “heavy metal” is a common term used for decades in sciences, and even more in environmental sciences (Fig. 3), particularly in studies of pollution impacts (Pourret and Hursthouse 2019). If we focus on top journals from the Environmental Science category (selection from

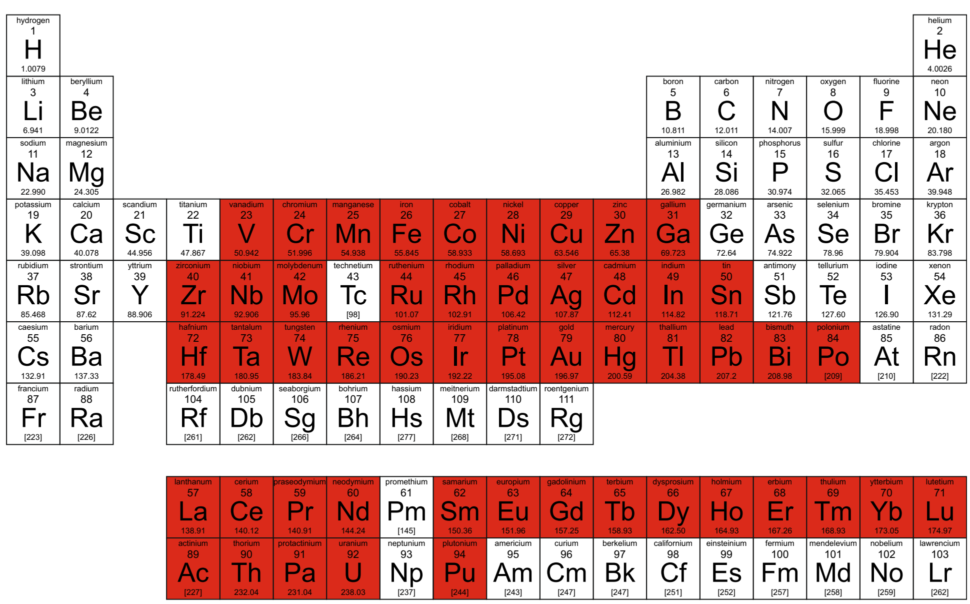

Fig. 1 Periodic table highlighting “heavy metals”, redrawn from Ali and Kahn (2018)

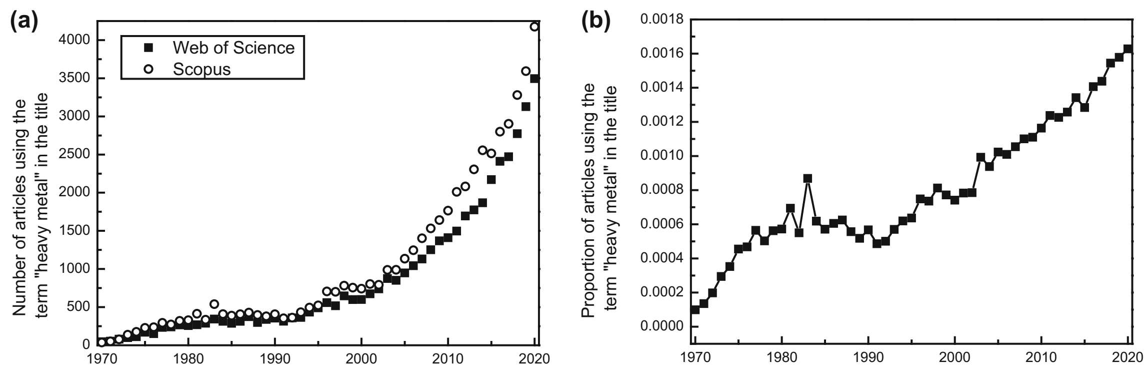

Fig. 2 **a** Evolution of the number of publications using the term "heavy metal*" in the title (sourced from Scopus and the Web of Science using the term "heavy metal*", data accessed 24 February 2021). Modified and updated from (Pourret and Bollinger 2018; Pourret and Hursthouse 2019). **b** Evolution of publications (number of articles using the term divided by the total number of all articles published that year) using the term "heavy metal" in the title (data from Scopus using "heavy metal*"search, accessed on 24 February 2021)

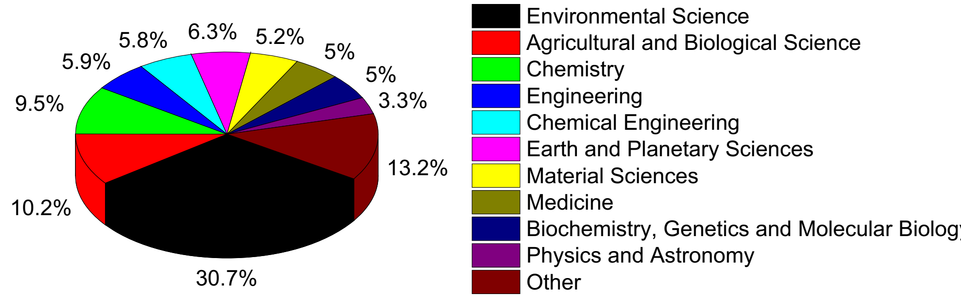

Fig. 3 Proportion of publication by research areas in 2020 using the term "heavy metal*" in the title (sourced from Scopus using the term "heavy metal*", data accessed on 24 February 2021). Modified and updated from (Pourret and Hursthouse 2019)

Table 1 Type of article and number of citations of papers related to the controversy use of the term "heavy metal", updated from Pourret and Bollinger (2018); data accessed on 24 February 2021

Reference	Type of article	Number of citations	
		Scopus	Web of Science
Nieboer and Richardson (1980)	Full paper	864	841
Duffus (2002)	Full paper	617	565
Hodson (2004)	Invited paper	49	40
Chapman (2007)	Letter	9	6
Hübner et al. (2010)	Perspective paper	28	23
Madrid (2010)	Letter	16	15
Appenroth (2010)	Review	45	41
Nikinmaa and Schlenk (2010)	Editorial	5	5
Chapman (2012)	Letter	9	9
Batley (2012)	Letter	9	9
Pourret and Bollinger (2018)	Letter	25	24
Pourret (2018)	Letter	13	11
Ali and Kahn (2018)	Full paper	44	35
Pourret and Hursthouse (2019)	Letter	16	13

Pourret and Bollinger 2018), we can notice a "plateau" or even a small decrease (Fig. 4).

Indeed, if we look into this with more detail, and choose four journals, like Pourret and Bollinger (2018) did, in which the term "heavy metal" is frequently used (i.e., *Journal of Hazardous Materials, Chemosphere*, *Science of the Total Environment*, and *Environmental Science and Pollution Research*), we notice an exponential increase during the last 30 years, related to the increasing number of articles; however, the proportion of articles using the term "heavy metal" remains stable at around 3% for *Environmental Science & Technology* (selected as a reference), whereas the use of the term has stabilized in *Science of the Total Environment* and *Chemosphere* (between 10% and

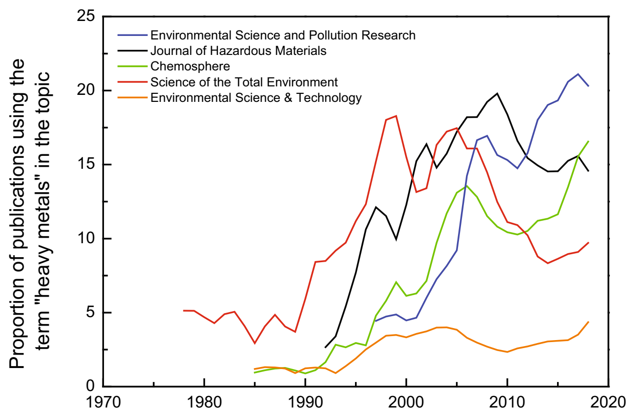

Fig. 4 Evolution of publications (number of articles using the term divided by the total number of all articles published that year) using the term "heavy metal" in the topic for journals that highly used "heavy metal" term (data from Web of Science using "heavy metal*"search, plotted using a 3 year span moving average, accessed on 24 February 2021)

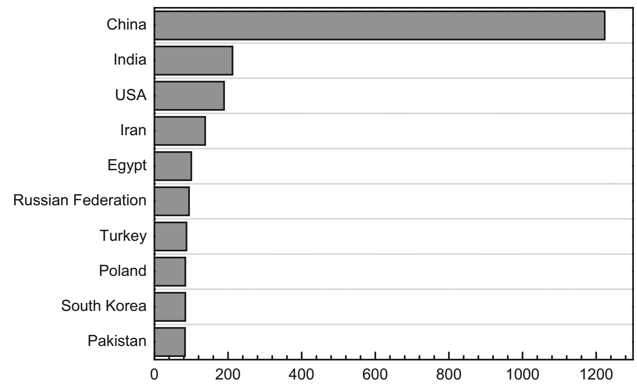

Fig. 5 Article distribution by country (top 10) of articles published in 2019 having the term heavy metal* in the title (country based on authors affiliation, several countries may count for the same article) (data accessed on 24 February 2021 from Scopus)

15%), and the *Journal of Hazardous Materials* or *Environmental Science and Pollution Research* still see high levels of use of this term (up to 20%) (Fig. 4). If we further look at the number of articles published in 2019 with the term "heavy metal" in their title (Table 2), *Environmental Science and Pollution Research* published the higher number of articles with "heavy metal" in their title (102) and up to 7% of article published in *Environmental Monitoring and Assessment* used this term. In *Acta Geochimica*, 5% of published article (3/67) used the term "heavy metal" in their title.

In 2019, 34% of those articles were co-authored by researchers from Chinese institutions, 6% from India and 5% from USA (Fig. 5), reflecting in part the emergence of intense research activity on widespread environmental issues in the region and as already outlined by Pourret and Hursthouse (2019), emerging reports in English language journals, perhaps has enhanced the growth of the term, a result of perpetuating the approach to an established and long-standing practice.

Thanks to social media, the debate is also relayed to a larger audience (e.g. sketchnote on twitter, Fig. 6).

3 Discussion

As already proposed by Hübner et al. (2010), solutions exist to deal with the long-standing problem of the imprecise usage of the term "heavy metals" in the scientific literature.

Some authors propose:

(i) Formulating one single scientific definition. This would be an ideal approach, but unlikely to be adopted. A general agreement about a single atomic mass, atomic number, density or another similar criterion will be difficult to achieve. Indeed, Ali and Khan (2018) try to but half of the periodic table is considered by this definition (Fig. 1).

(ii) Calling the ten elements most commonly considered as "heavy metals", Cr, Co, Ni, Cu, Zn, As, Cd, Sn, Hg, Pb as "heavy metals", all other

Table 2 Number of publications during 2019 using the term "heavy metal" in the title for the ten most common sources and proportion of articles (from Scopus using "heavy metal*" search, data accessed on 24 February 2021)

Journal title	Number of articles	Proportion
Environmental Science And Pollution Research	102	3%
Science Of The Total Environment	95	2%
Ecotoxicology And Environmental Safety	58	4%
Environmental Monitoring And Assessment	55	7%
Chemosphere	52	2%
Environmental Pollution	49	3%
International Journal Of Environmental Research And Public Health	45	1%
Huanjing Kexue Environmental Science	42	6%
Journal Of Hazardous Materials	41	3%
Desalination And Water Treatment	40	3%

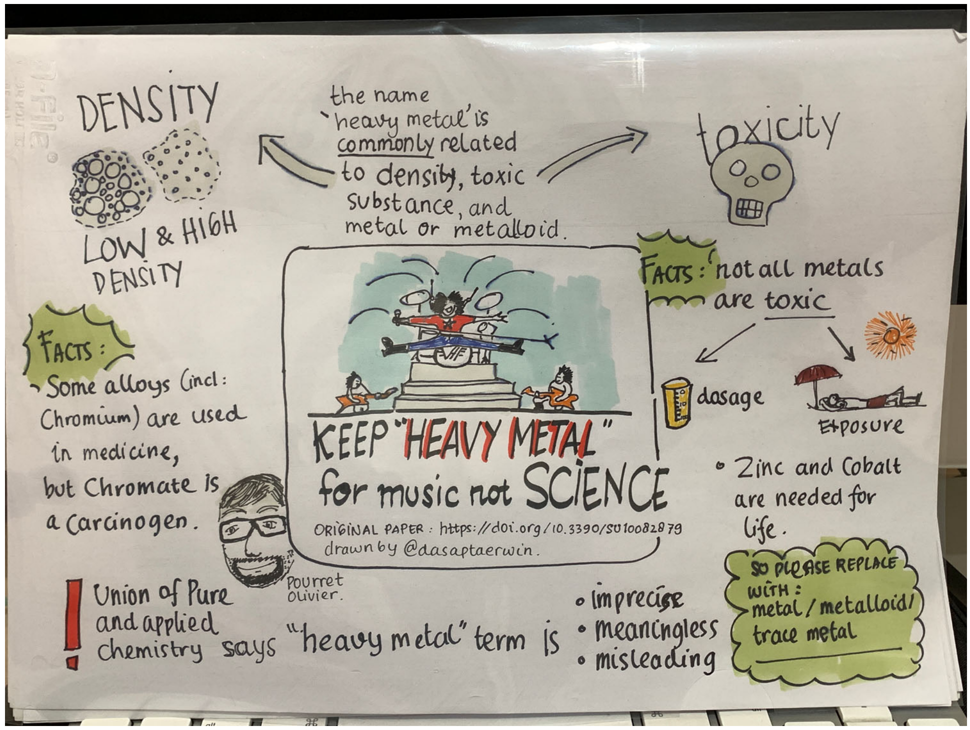

Fig. 6 Sketchnote illustrating the misused term "heavy metal" (artwork from Dr. Dasapta Erwin Irawan) (Irawan 2020)

elements not. It is basic and to a certain degree arbitrary, but at least uniform and based on a mutual understanding (Hübner et al. 2010), though metalloids are still included.

We propose:

(i) Replacement of the term "heavy metals" with a reasonable and scientifically defendable terms like "potentially toxic element", "trace metal element", "metal", "metalloid" in environmental studies (Pourret and Hursthouse 2019).

(ii) Avoiding the problem by not using this umbrella term and referring simply to metals or elements. This is a reasonable approach and is probably the only approach that ultimately might successfully suppress the term "heavy metals" (Pourret and Bollinger 2018).

4 Conclusions

To be consistent, researchers should only use well-accepted definitions. In the case of "heavy metal", this term should be replaced by "metal", "metalloid" according to the case, or by "trace metal" or "potentially toxic element" when this can be considered. The best way to describe the studied elements is to clearly name them or consider them as a group of elements (metals or metalloids).

Declaration

Conflicts of Interest The author declares no conflict of interest.

References

Ali H, Khan E (2018) What are heavy metals? Long-standing controversy over the scientific use of the term 'heavy metals'—proposal of a comprehensive definition. Toxicol Environ Chem 100(1):6–19. https://doi.org/10.1080/02772248.2017.1413652

Alloway BJ (2013) Heavy metals in soils—trace metals and metalloids in soils and their bioavailability, 3rd edn. Springer, Heidelberg, p 614.

Antoniadis V, Shaheen SM, Levizou E, Shahid M, Niazi NK, Vithanage M, Ok YS, Bolan N, Rinklebe J (2019) A critical prospective analysis of the potential toxicity of trace element regulation limits in soils worldwide: Are they protective concerning health risk assessment?—A review. Environ Int 127:819–847. https://doi.org/10.1016/j.envint.2019.03.039

Appenroth K-J (2010) What are "heavy metals" in plant sciences? Acta Physiol Plant 32(4):615–619. https://doi.org/10.1007/s11738-009-0455-4

Batley GE (2012) "Heavy metal"—a useful term. Integr Environ Assess Manag 8(2):215–215. https://doi.org/10.1002/ieam.1290

Belkhiri L, Mouni L, Sheikhy Narany T, Tiri A (2017) Evaluation of potential health risk of heavy metals in groundwater using the integration of indicator kriging and multivariate statistical methods. Groundw Sustain Dev 4:12–22. https://doi.org/10.1016/j.gsd.2016.10.003

Bhat UN, Khan AB (2011) Heavy metals: an ambiguous category of inorganic contaminants, nutrients and toxins. Res J Environ Sci 5:682–690. https://doi.org/10.3923/rjes.2011.682.690
Chapman PM (2007) Heavy metal - Music, not science. Environ Sci Technol 41(12):6C
Chapman PM (2012) "Heavy metal"—cacophony, not symphony. Integr Environ Assess Manag 8(2):216. https://doi.org/10.1002/ieam.1289
Chivers PT (2014) Chapter 14 Cobalt and Nickel. In: Binding, Transport and Storage of Metal Ions in Biological Cells, The Royal Society of Chemistry, pp 381–428.
Duffus JH (2002) "Heavy metals" a meaningless term? (IUPAC Technical Report). Pure Appl Chem 74:793–807. https://doi.org/10.1351/pac200274050793
Ghibaudi E (2019) Levi's Periodic system vs. Mendeleev's Periodic System: two engaged views of chemistry between science and literature. Pure Appl Chem 91 (12):1941–1947. https://doi.org/10.1515/pac-2019-0604.
Gupta A (2020) Heavy metal and metalloid contamination of surface and underground water. CRC Press, Boca Raton, p 278.
Hodson ME (2004) Heavy metals—geochemical bogey men? Environ Pollut 129(3):341–343. https://doi.org/10.1016/j.envpol.2003.11.003
Hübner R, Astin KB, Herbert RJH (2010) 'Heavy metal'-time to move on from semantics to pragmatics? J Environ Monit 12(8):1511–1514. https://doi.org/10.1039/C0EM00056F
Irawan DE (2020) Keep heavy metal for music not science. Zenodo. https://doi.org/10.5281/zenodo.4134463
Lambers H, Oliveira RS (2019) Plant physiological ecology. Springer, Heidelberg, p 736.
Madrid L (2010) "Heavy metals": reminding a long-standing and sometimes forgotten controversy. Geoderma 155(1):128–129. https://doi.org/10.1016/j.geoderma.2009.11.031
Nieboer E, Richardson DHS (1980) The replacement of the nondescript term 'heavy metals' by a biologically and chemically significant classification of metal ions. Environ Pollut B Chem Phys 1(1):3–26. https://doi.org/10.1016/0143-148X(80)90017-8.
Nikinmaa M, Schlenk D (2010) Uses of phrases. Aquat Toxicol 97(1):1–2. https://doi.org/10.1016/j.aquatox.2010.02.015
Pourret O (2018) On the necessity of banning the term "heavy metal" from the scientific literature. Sustainability (Switzerland) 10 (8). https://doi.org/10.3390/su10082879.
Pourret O, Bollinger JC (2018) "Heavy metal"—What to do now: To use or not to use? Sci Total Environ 610–611:419–420. https://doi.org/10.1016/j.scitotenv.2017.08.043
Pourret O, Hursthouse A (2019) It's Time to Replace the Term "Heavy Metals" with "Potentially Toxic Elements" When Reporting Environmental Research. Int J Environ Res Public Health 16 (22). https://doi.org/10.3390/ijerph16224446.
Pourret O, Bollinger J-C, van Hullebusch ED (2020) On the difficulties of being rigorous in environmental geochemistry studies: some recommendations for designing an impactful paper. Environ Sci Pollut Res 27(2):1267–1275. https://doi.org/10.1007/s11356-019-06835-y
Wagman JB, Zimmerman C, Sorric C (2007) "Which feels heavier—a pound of lead or a pound of feathers?" A potential perceptual basis of a cognitive riddle. Perception 36(11):1709–1711. https://doi.org/10.1068/p5854