How big is small? Nanotechnology's influence on global element cycles

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Humans' relatively nacent ability to manipulate matter on the atomic scale marks a new era within the Anthropocene, one in which we are able to extract novel properties via nanomaterials that could not be realized in bulk counterparts of the same elements. This has fostered a renewed interest in material exploration across the periodic table. As a result, elements that were previously rare in consumer goods may become widely distributed via the production, use, and disposal of the relevant products. In particular, material extraction of rare minerals from pristine areas and re-extraction of previously mined ores (i.e., "slag mining") may enhance contamination of surface environments. From the raw materials, some have raised concern that intentional fabrication of nano-sized particles will augment long-range transport; although, early evidence suggests this is not the case due to the rapid agglomeration of the high-surface-area materials. In the use phase, when toxic elements are employed, manufacturers encapsulate the nanoparticles to prevent release (e.g., for CdSe quantum dots), but end-of-life product reclaimation strategies are few. Implications for the influence of these activities on element cycling are poorly constrained to date. Nevertheless, many of society's grand challenges rely on such material innovation, and the production of novel chemicals always precedes a full description of the influence on the geochemical processes. In this address, the author will highlight the important role of nanotechnology in overcoming society's most pressing challenges, the current status and scale of those technologies, the potential influence on elemental global biogeochemical cycles, and finally, discuss measures taken to minimize the impact of these novel technologies on human and environmental health.