The Circular Geoenvironment - Maximising geoenvironmental services to minimize environmental harm

Michael Harbottle[1*]
[1]Cardiff School of Engineering, Cardiff University, Queen's Buildings, The Parade, Cardiff CF24 3AA, UK
*HarbottleM@cardiff.ac.uk

Keywords: circular economy; geoenvironmental services; resource recovery.

1. INTRODUCTION

The environment provides services that can be harnessed or engineered to achieve the needs of society in a manner that can reduce or eliminate the need for intensive interventions, for example bio/phytoremediation and passive mine-water treatment. The geoenvironment contains the resources, the energy and the genetic capability necessary to provide a much wider range of services than is currently the case. It is the aim here to draw on recent research to demonstrate the potential for geoenvironmental services to contribute to society in ways which extend and go beyond the traditional view of the geoenvironment as a source of raw material and a sink for waste, but little in between, including in resource supply and infrastructure provision.

2. THE GEOENVIRONMENT'S ROLE IN THE CIRCULAR ECONOMY

Traditional linear economies extract materials, usually from the geoenvironment, and process them for consumption. Ultimately, these are returned to the (geo)environment, as waste or pollution. The transition to circular economies aims to amend product design to facilitate reuse, repair or recycling and eliminate waste, minimizing resource extraction in the process. It is questionable to what extent this is practically achievable as there will always be wastes that are challenging to reuse or manage, particularly large-volume wastes from processes such as in extractive industries.

Recovery of resource from geological waste storage has long been practiced to a degree, but the concept has been extended to more recent, engineered waste deposits as well as those where the resource quality is low making recovery financially and technically challenging (Sapsford *et al.*, 2017). It is a challenge to make a case for recovery purely on financial grounds with currently available techniques. Individual sites can contain significant value, but extraction would likely be unviable using traditional, intensive mining or contaminated land remedial methods, particularly on the basis of achieving a financial return, and so they remain untouched.

Geoenvironmental processes *in situ* offer an opportunity to tackle such problem wastes if their long-term nature is considered as a benefit (Sapsford *et al.*, 2017). Like other, natural, cycles (e.g. water, nitrogen), the 'resource cycle' can be driven in part by processes in the ground which alter, transport or concentrate the resource in a manner which maximizes its subsequent utility. Slow, 'passive' recovery allows harvesting of energy from natural processes and flows (e.g. groundwater) to bring about the desired change with minimal input and costs offset by resource recovery. Mobilization is achievable in the very long term by leaching and natural degradation but can be accelerated through biological activity. For example, bioleaching (from microorganisms and plants) can enhance mobility of metal resource. Once mobilized, groundwater flow channeling through properly engineered wastes or flow control can deliver the resource to zones where a range of biogeochemical processes can be employed to concentrate the resource for recovery.

3. GEOENVIRONMENTAL SERVICES FOR GROUND ENGINEERING

Much ground engineering is additive – materials and energy are used to shape, direct and restrain soil, rock and groundwater to achieve the desired outcome. To what extent can geoenvironmental services contribute to the aims of this industry in a way that works with rather than contests natural processes? The field of bio-geoengineering is looking to use these services to develop tools that are starting to find application. Biomineralisation (e.g. microbially induced carbonate precipitation, MICP) offers an alternative to cementitious materials such as grouts or even concrete for ground improvement (DeJong *et al.*, 2013) and contaminant encapsulation (Mugwar & Harbottle, 2017). Vegetation contributes to soil stability through the physical presence of roots, through moisture uptake and through plant-soil interactions via biopolymers (Chen & Harbottle, 2019). These processes, managed by biological systems, are responsive to changes and adapt to their environment. Can we harness this to develop smart engineering which is not only congruent with but can enhance its environment through ecosystem as well as geoenvironmental services?

As an example, ground structures deteriorate with time as damage accumulates. Because of their scale and/or inaccessibility they can be challenging and costly to maintain. The concept of self-healing materials is the first step towards autonomous structures that can sense, respond to and mitigate against damage to or change in the material or its environment, reducing deterioration and reducing the need for significant maintenance or replacement. The concept is advanced with construction materials such as concrete (De Belie *et al.*, 2018) but similar concepts are applicable to geo-materials. We have demonstrated that soil bacteria have the potential to offer self-healing MICP whereby spores embedded in the carbonate matrix are activated by damage to the matrix and exposure to nutrients (Botusharova *et al.*, 2020) with subsequent recovery of compressive strength. This response to damage allows self-healing MICP systems to prevent and overcome damage to earth structures from chemical and physical processes in the ground.

4. CONCLUSION

Geoenvironmental services provide an opportunity to harness energy and materials provided by the natural environment to achieve the requirements of environmental and infrastructure management and mitigate the environmental impacts of the current state of the art.

REFERENCES

Botusharova, S., Gardner, D. and Harbottle, M. (2020) Augmenting microbially induced carbonate precipitation of soil with the capability to self-heal, J. Geotech. Geoenviron., ASCE, in press.

Chen, C. and Harbottle, M. (2019) Influence of biopolymer gel-coated fibres on sand reinforcement as a model of plant root behaviour, Plant Soil, Springer, 438, pp. 361-375.

De Belie, N., Gruyaert, E., Al-Tabbaa, A. *et al.* (2018) A Review of Self-Healing Concrete for Damage Management of Structures, Adv. Mater. Inter., Wiley, 5(17).

DeJong, J.T., Soga, K.S., Kavazanjian, E. *et al.* (2013) Biogeochemical Processes and Geotechnical Applications: Progress, Opportunities, and Challenges, Geotechnique, Thomas Telford, 63(4), pp. 287-301.

Mugwar, A.J. and Harbottle, M.J. (2016) Toxicity effects on metal sequestration by microbially induced carbonate precipitation, J. Hazard. Mater., Elsevier, 314, pp. 237-248.

Sapsford, D., Cleall, P. and Harbottle, M. (2017) In situ resource recovery from waste repositories: exploring the potential for mobilization and capture of metals from anthropogenic ores, J. Sustain. Metall., Springer, 3(2), pp. 375-392.