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Sustainable (De)centralised Recovery of Macro- and Micro-nutrients From Human Excreta Without Pharmaceuticals/PFAS: a Proposal for the "Green Architecture" of the Brisbane 2032 Olympics

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Abstract

Establishing the circular economy of the future requires the development of innovative solutions that allow for the continuous recovery and reuse of resources – including the nutrients currently excreted by humans around the world. Since 2017, researchers at The University of Queensland and Tampere University have collaborated to develop the 'UGOLD' concept, a hybrid between electrodialysis and microbial electrolysis cells, that allows for the recovery of macro- and micronutrients from various wastewater sources as a liquid fertiliser in one of the most energy-efficient ways demonstrated to date (Ledezma, et al., 2017). One of the most promising nutrient sources for the UGOLD system is source-separated human urine – which contains 79% of the nitrogen (N), 71% of the potassium (K) and 47% of the phosphorous (P) and many essential micro-nutrients, yet constitutes ≤ 1% of the total volume of wastewater generated in sewered urban environments (Ledezma et al., 2015). As a result, the energy consumption for N recovery as NH4+ is among the lowest ever demonstrated in the laboratory: 2.4 kWh kgN 1 and pilot scale: 4.3 kWh kgN 1 at a removal rate of 23.1 kgN m^{-3} d^{-1}, while simultaneously producing a liquid fertiliser that contains 27 gNH_4-N L^{-1}, 9 gK L^{-1}, 0.7 gPO_4-P L^{-1} and ~20 g L^{-1} of organic acids (+ all micro-nutrients e.g. S, Ca, Mg, Mn, Fe, Zn) (Ledezma et al., 2019). More recently, the UGOLD concept has also been tested on digested sewage sludge reject water, with results similarly promising (Koskue et al., 2021). Of equal importance is the fact that, since the process is driven by large biofilms of heavily active bacteria plus electrochemical oxidation and reduction processes, the absolute majority of the micropollutants found in either human urine of reject water are either degraded during the recovery process and/or excluded by the electrodialysis membranes, therefore yielding a liquid fertiliser product that is rich in nutrients but devoid of both micropollutants (21 compounds measured incl. caffeine, nicotine, ethyl-glucuronide, acesulfame, common medications such as antidepressants/anticonvulsants and antibiotics/antimycotics) and per- and polyfluoroalkyl substances (PFAS; 10 most common compounds measured) (Monetti et al., 2021; Koskue et al., 2022). Despite such encouraging results however, the up-scaling and commercialisation of UGOLD has been

hampered by the fact that transport costs (from ‘production sites’ in urban centres to ‘usage sites’ in agricultural fields outside the city) for liquid fertilisers produced in relatively small-scale (when compared to megaton y-1 synthetic production facilities) are simply prohibitive in Australia. In other words, the proposed concept can only be financially viable if the nutrients removed and recovered from human excreta can be reused in close proximity. In 2021, Brisbane was elected as the host city for the 2032 Olympics. While the city’s bid proposes a more austere celebration of global sport that its predecessors, there will still be significant infrastructural developments in the city, as part of the ‘Brisbane 2032 masterplan’. One key feature of this masterplan is the development of large ‘green corridors’ that will allow for the spectators to easily move between the different competition and social venues around the city by walking and/or zero-emission vehicles (e-bikes/scooters). These corridors will be completely surrounded/covered by green architecture i.e. green canopies, horizontal gardens and other types of vegetation arrangements that will showcase the exceptional native flora and fauna of Australia, while providing numerous environmental benefits such as urban cooling, air purification, etc. These corridors will therefore necessitate large amounts of water but also nutrients, which is an excellent opportunity for the UGOLD technology to contribute to one of the first intra-urban fully-circular nutrient loops, where both inhabitants and visitors to Brisbane will contribute to the long-term sustainability of the city’s green architecture by ‘donating’ their nutrients and simultaneously benefitting from their local and sustainable implementation.

Keywords: nutrient removal & recovery, source-separated urine, anaerobic sludge reject water, alternative fertilisers, green architecture.

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