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A Dynamic Model for Circularity Assessment of Nutrient Recovery from Domestic Sewage

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Abstract : The food system depends on the availability of Phosphorus (P) and Nitrogen (N). Growing population, depleting Phosphorus reserves and energy-intensive industrial nitrogen fixation are threats to their future availability. Recovering P and N from domestic sewage water offers a solution. Recovered P and N can be applied to agricultural land, replacing virgin P and N. Thus, recovery from sewage water offers a solution befitting a circular economy. To ensure minimum waste and maximum resource efficiency a circularity assessment method is crucial to optimize nutrient flows and minimize losses. Material Circularity Indicator (MCI) is a useful method to quantify the circularity of materials. It was developed for materials that remain within the market and recently extended to include biotic materials that may be composted or used for energy recovery after end-of-use. However, MCI has not been used in the context of nutrient recovery. Besides, MCI is time-static, i.e., it cannot account for dynamic systems such as the terrestrial nutrient cycles. Nutrient application to agricultural land is a highly dynamic process wherein flows and stocks change with time. The rate of recycling of nutrients in nature can depend on numerous factors such as prevailing soil conditions, local hydrology, the presence of animals, etc. Therefore, a dynamic model of nutrient flows with indicators is needed for the circularity assessment. A simple substance flow model of P and N will be developed with the help of flow equations and transfer coefficients that incorporate the nutrient recovery step along with the agricultural application, the volatilization and leaching processes, plant uptake and subsequent animal and human uptake. The model is then used for calculating the proportions of linear and restorative flows (coming from reused/recycled sources). The model will simulate the adsorption process based on the quantity of adsorbent and nutrient concentration in the water. Thereafter, the application of the adsorbed nutrients to agricultural land will be simulated based on adsorbate release kinetics, local soil conditions, hydrology, vegetation, etc. Based on the model, the restorative nutrient flow (returning to the sewage plant following human consumption) will be calculated. The developed methodology will be applied to a case study of resource recovery from wastewater. In the aforementioned case study located in Italy, biochar or zeolite is to be used for recovery of P and N from domestic sewage through adsorption and thereafter, used as a slow-release fertilizer in agriculture. Using this model, information regarding the efficiency of nutrient recovery and application can be generated. This can help to optimize the recovery process and application of the nutrients. Consequently, this will help to optimize nutrient recovery and application and reduce the dependence of the food system on the virgin extraction of P and N.

Keywords : circular economy, dynamic substance flow, nutrient cycles, resource recovery from water
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