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Agronomic Potential of Anaerobically Digested Sewage Sludge from Croatian Capital WWTP

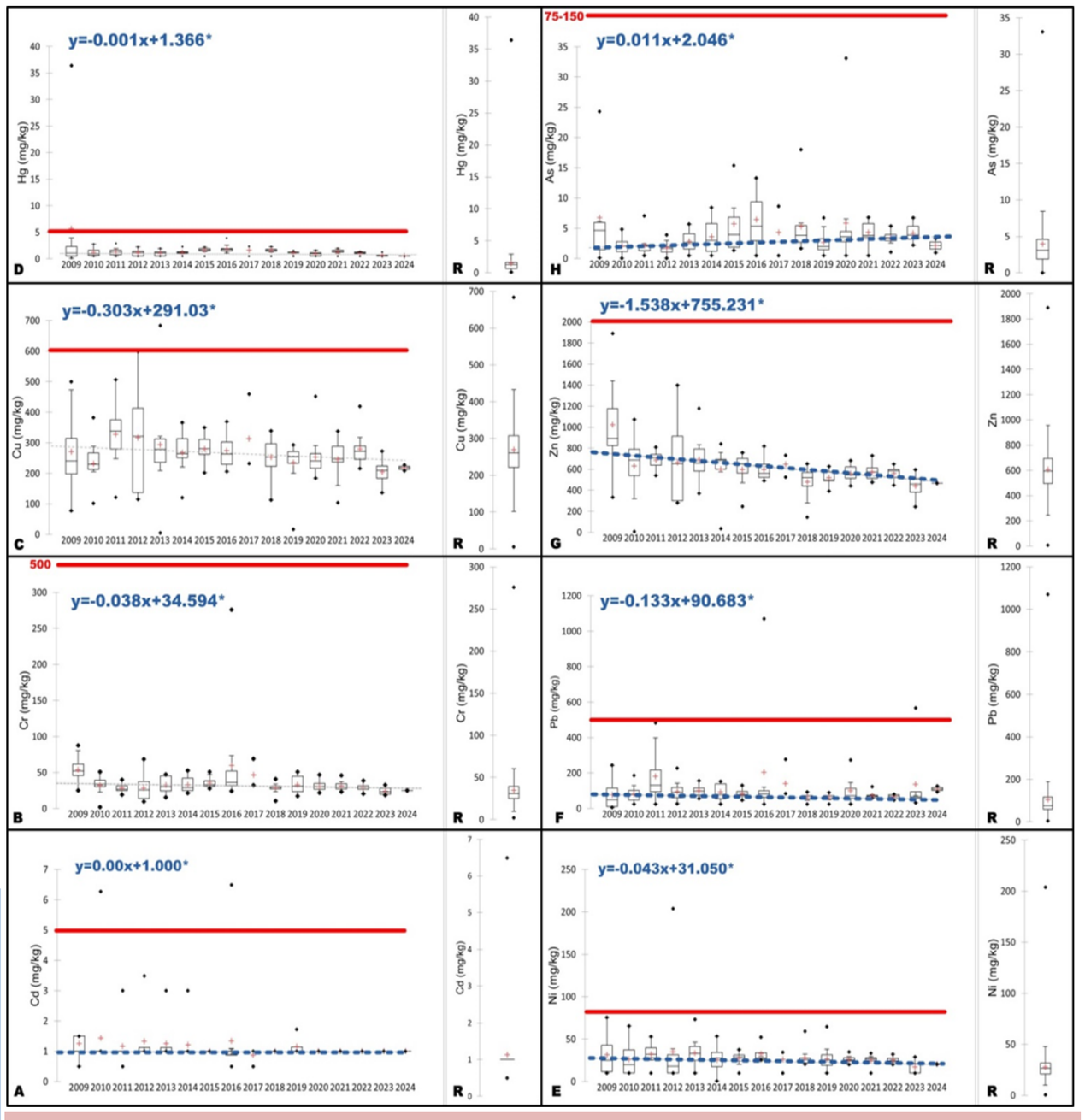
Gabrijel Ondrasek[1]*, Marina Bubalo Kovačić[1], Marko Reljić[1], Sanja Stipičević[2], René Matthies[3], Predrag Samardžija[3], Jelena Horvatinec[1]

[1] University of Zagreb Faculty of Agriculture, Department of Soil Amelioration, *gondrasek@agr.hr
[2] Institute for Medical Research and Occupational Health, Ksaverska cesta 2, Zagreb, Croatia
[3] Zagrebačke otpadne vode d.o.o., Zagreb

Abstract

Sewage sludge (SS), a by-product of wastewater treatment plant (WWTP), requires diligent management to minimize environmental risks and protect public health; however, properly treated SS becomes a renewable resource, providing: i) a high-calorific fuel for energy, ii) essential nutrients for crops, and iii) rare metal(oid)s for various industries; thus contributing to a circular economy. In this study we assessed long-term monitoring data on the physicochemical properties of anaerobically digested SS from Croatia's largest national WWTP in Zagreb. The key characteristics (heating value, dry matter, N, P, K, C content) of the examined SS meet the criteria for energy recovery and reuse in agriculture. Moreover, the most critical parameters; organic micro-pollutants (polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and organochlorine pesticides) and heavy metal(oid)s (Cd, Cr, Cu, Hg, Ni, Pb, Zn, Mo, As, and Co) were found to be within acceptable limits and compliant with the most stringent inter/national standards for the use of SS in agriculture, composting, organic fertilizers or soil amendments. Most of these indicators demonstrated stable or decreasing trends over time. However, the practical reuse of SS for agricultural application or energy recovery remains negligible at regional/national levels. This underutilization is largely driven by stringent regulatory requirements, limited infrastructure for thermal conversion, the scarcity of suitable agricultural land near WWTPs, and the prevalence of land-use restrictions. Our findings provide critical insights into SS quality trends, supporting evidence-based, region-specific strategies for its safe and sustainable reuse aligned with circular economy objectives.

The central wastewater treatment plant of the City of Zagreb, Croatia, showing: (A) inlet channel and pumping station, (B) screening facility for removal of primary impurities, (C) sand and grease trap, (D) aeration basin for biological wastewater treatment, (E) facility for mesophilic anaerobic digestion of sludge and cogeneration plant, (F) secondary sedimentation basin, (G) facility for dehydration and conditioning of digested sludge, and (H) disposal site for treated sludge.



Dynamics of annual average values (all in mg/kg) of metalloids in sewage sludge samples, including significant (*) Sen's slope estimations (dashed line) over the observation period, with corresponding overall average values shown on the right (R). Red lines represent the maximum permissible concentrations (MPCs) of metal(oid)s in Croatia for sewage sludge used in agriculture [104], except for As, which MPC is referred for organic fertilizers and soil amendments depending on soil pHKCl reaction [27].