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Novel management strategies/technologies investigation

Introduction

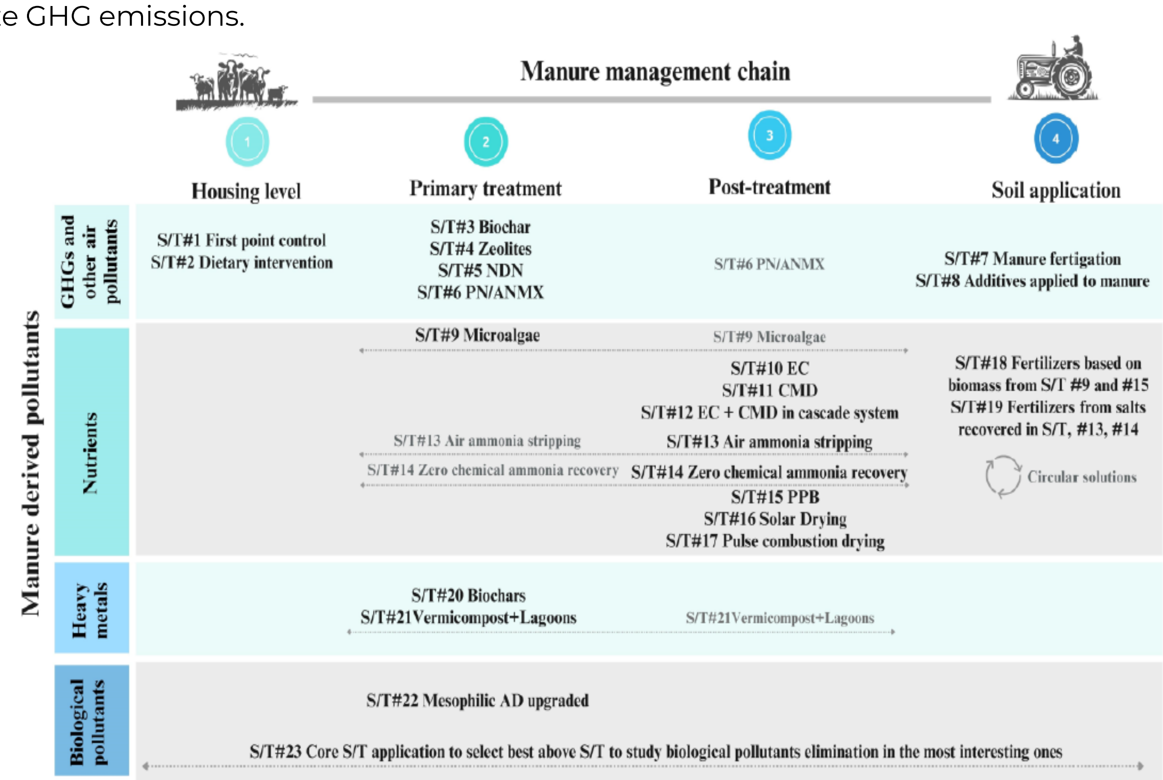
This work package (WP) will demonstrate various strategies and technologies (S/T) along the manure management chain aimed at mitigating manure-derived pollutants, improving efficiency, and reducing environmental and socioeconomic impacts at laboratory and pilot scales (TRL 3–6). The proposed solutions are grouped by the type of pollutant targeted (GHG and other air emissions, nutrients, heavy metals, and biological contaminants) and further classified according to the stage of the manure management chain where they will be applied (from housing to soil application, including primary and post-treatment systems). Although each strategy/technology focuses on specific pollutants, potential secondary effects will also be assessed in each task. Sampling, processing, and analysis will follow the protocols established in WP1 to ensure comparability. Additionally, a standardized system of efficiency indicators will be developed to enable comparison among strategies and technologies.

Housing Level

At the housing stage, essential oils and their derivatives will be tested to reduce ammonia emissions, microbial contamination, and specific pathogens as an initial on-farm control (S/T#1). Dietary interventions (S/T#2) will also be implemented to evaluate the impact of varying protein quantity (%) and quality (soy or other sources) on ammonia emissions.

Primary treatment

For primary treatment—technologies applied directly to raw manure—several approaches will be explored. Anaerobic digestion (AD), one of the most widely used technologies (also featured in WP1 case studies), will be optimized through: (i) the addition of carbonaceous materials such as biochar to enhance biomethane production and reduce CO_2 emissions (S/T#3); (ii) the use of zeolites to mitigate ammonium (NH_4^+) inhibition in digesters, improving biomethane conversion and reducing ammonia emissions from digestate (S/T#4); and (iii) strategies to maximize antibiotic, ARB, and ARG removal during AD by adjusting operational parameters or combining with activated carbon (S/T#22). Co-digestion of different manure types (cow and pig) will also be tested. Other non-AD technologies include nitrification/denitrification (S/T#5) and partial nitration/Anammox (S/T#6), where system layout (single vs. two-unit) and operational conditions (nitrogen load, oxygen requirements) will be optimized to minimize GHG emissions.



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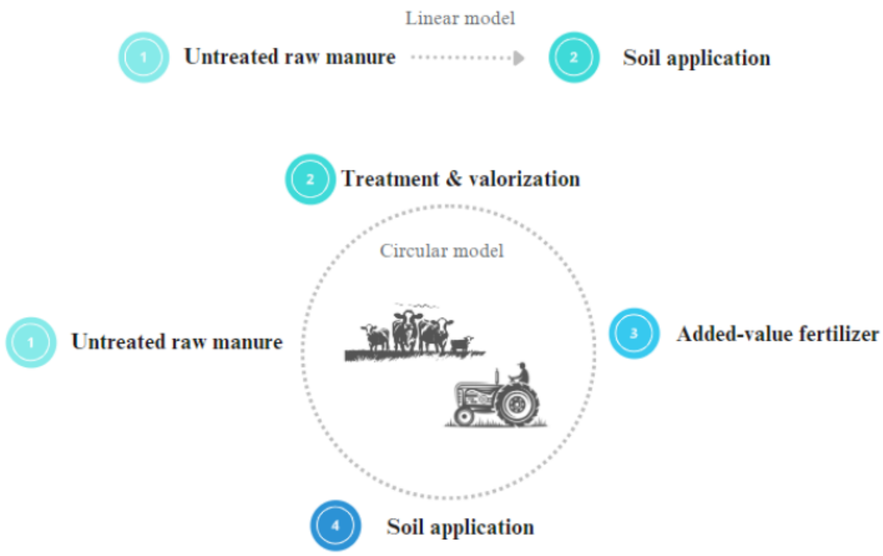
Post treatment technologies

Recent trends toward circular economy principles have shifted the focus from energy recovery alone to nutrient recovery from manure and digestate, adding value to livestock operations and maximizing resource use. In this context, microalgae (S/T#9) will be applied for nutrient recovery, with species selected to optimize nitrogen and phosphorus removal while vaporizing biomass as fertilizer. Low-cost harvesting methods will be considered to improve economic feasibility. Microalgae will be tested as both primary and post-treatment technologies. Additional post-treatment options include biochar application (S/T#20) and vermicomposting in lagoons (S/T#21) for nutrient and heavy metal removal, particularly Cu and Zn in pig manure.



Further strategies for ammonia emission reduction from digestate include: (1) electrocoagulation to lower nutrient content, COD, odors, and heavy metals, potentially combined with ceramic membrane distillation (S/T#10 and S/T#12); (2) ceramic membrane distillation for ammonia recovery using phosphoric acid (S/T#11); (3) ammonia stripping (S/T#13), which operates in closed-loop systems with minimal emissions and high recovery efficiency (50–60% without caustic dosing, 75–85% with dosing); and (4) zero-chemical ammonia recovery (S/T#14), incorporating a refining stage to eliminate scrubbing acids and improve sustainability. Drying technologies such as solar drying (S/T#16) and pulse combustion drying (S/T#17) will also be tested to reduce water content, produce fertilizer, and lower ammonia emissions, leveraging heat from AD processes. Additionally, phototrophic purple bacteria (PPB, S/T#15) will be evaluated for treating effluents from AD and nitrogen removal systems, aiming to reduce residual nitrogen while producing protein-rich biomass for use as microbial protein or fertilizer, with lower CO_2 and N_2O emissions.

Application strategies

Finally, at the soil application stage, strategies (S/T#7, S/T#8, S/T#18, S/T#19) will be assessed on at least three soil types and two crops, including fertigation under different technologies (spreading, infiltration), timing after manure collection, and the use of additives (e.g., hydrolytic bacteria) to reduce GHG emissions. The fertilizer potential of microalgae and inorganic products from technologies such as S/T#13 and S/T#14 will be validated. Emerging pollutant removal (S/T#23) will be studied during optimized steps to evaluate environmental impacts of the most promising NUTRITIVE technologies.

Conclusions

This work package will also explore various circular farm business models aimed at utilizing final products for agricultural applications. The focus is on removing nutrients from livestock manure while recovering value-added compounds to be used as crop fertilizers. To achieve this, different treatment technologies for nitrogen (N) and phosphorus (P) removal and recovery will be combined as outlined below. All recovered compounds obtained through these strategies/technologies will be analysed to ensure quality and compliance with current EU fertilizer regulations. Their performance will then be compared against conventional and commercial formulations through representative experimental trials conducted at the field level.

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INNOVATIVE DECISION-MAKING TOOL FOR DEFINING THE MOST SUITABLE MANURE MANAGEMENT STRATEGIES TO ACHIEVE A SUSTAINABLE LIVESTOCK FARMING SYSTEM DURING THE WHOLE VALUE CHAIN