論 文 の 内 容 の 要 旨

論文題目　DEVELOPMENT OF NATURAL TREATMENT SYSTEM FOR THE RECLAMATION AND REUSE OF STRONG WASTEWATER FROM RURAL COMMUNITY
（非都市域から排出される高濃度排水再利用のための自然浄化システムの開発）

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A novel treatment system as a countermeasure for the strong wastewater problem from rural community was put forward, which consisted of two treatment stages within an elaborate greenhouse, i.e. advanced anaerobic digestion and soil-plant based Natural Treatment System. How to develop a sound Natural Treatment System as a post-treatment process for the anaerobically-digested strong wastewater to achieve its reclamation and reuse was the main focus of the entire study.

In the bench-scale study, the major materials used were two types of soils (red ball earth and black soil) and grasses (alfalfa and Kentucky bluegrass). Characterization of soils was performed, in which their basic properties, internal mass transport processes, and adsorption behaviors of ammonium were comprehensively investigated. In ammonium adsorption test, phosphate introduced into soil from applied wastewater was found to dramatically enhance the quantity of negative charges on the soil colloid surface, and hence largely increased the adsorption capacity of ammonium by soil. Besides, a preliminary pot experiment was conducted, by which the appropriate application pattern (dilution ratio and hydraulic loading rate) of the target wastewater was determined.

Based on the abovementioned results, the feasibility and basic performance study on the proposed Natural Treatment System was then carried out in the manner of long-term soil column test. Synthetic wastewaters were applied to the soil columns in the predetermined application patterns, and two pairings of soil and plant were tested in parallel, i.e. red ball earth plus alfalfa and black soil plus Kentucky bluegrass. The feasibility and sustainability of the proposed Natural Treatment System for the removal and recovery of water-borne nutrients (N, P and K) were fully identified in the tests of both pairings, according to the results of effluent quality, nutrient distribution in the soil column, plant harvest and mass balance of nutrients. In terms of N, under low influent BOD concentration the system featured remarkable nitrification performance, especially in the top 20 cm layer of soil. However, denitrification performance was unsatisfactory, which suggested that the effluent be either treated by a supplementary denitrification process before discharge or utilized for restricted irrigation. With regard to P and K, they were retained by the soil through different mechanisms, i.e. precipitation of insoluble salts and inclusion in complexes for P and electrostatic attraction for K. Their plant-available forms retained by the soil were considered indirect nutrient reuse achieved by this system. As a highlight of this test, both grasses were discovered to have stimulation effect on the soil nitrification process by altering the community structure of nitrifying microorganisms and enhancing cell-specific nitrification potential with substrate (NH_4^+) and oxygen sufficiency in the top layers of soil. This important finding verified the indispensable role of these two plants in the nutrient removal and recovery functions of this proposed Natural Treatment System. Through comparison, red ball earth showed much better permeability for both water and oxygen than black soil, and Kentucky bluegrass was evidently superior to alfalfa from the perspectives of resistance and nutrient recovery capability. They were thus selected as the expected better pairing for system establishment.

For the sake of optimizing the nutrient removal and recovery functions, pot experiment within elaborate CO_2 chambers was further conducted, in which the pairing of red ball earth plus Kentucky bluegrass was tested with wastewater application under three different CO_2 concentrations, i.e. 340 ppm (normal atmospheric level), 900 ppm and 1400 ppm (expected saturation point). After 8-week operation, the result confirmed the positive effect of elevated CO_2 concentration on the biomass production of Kentucky bluegrass, as well as the consequent nutrient recovery from wastewater. More importantly, higher CO_2 level also gave birth to a significantly improved nitrification performance of soil nitrifiers, which was considered to function in an indirect way. On one hand, the higher plant biomass production under elevated CO_2 concentration and resultant higher plant input into soil through litterfall and root turnover could accelerate the substrate (NH_4^+) turnover rate in the surface soil and boost the activity of nitrifiers. On the other hand, some positive changes in the physiological status of plant caused by higher CO_2 level may further fuel nitrifier activity through altered rhizodeposition including certain exudates and secretions generated by plant. 1400 ppm is hence recommended for the CO_2 level control within the greenhouse facility where the whole system is to be established.

In the end, soil column test was performed again for the purpose of limitation and potential study on the proposed Natural Treatment System. The major two challenges involved were higher BOD loading rate and higher hydraulic/nutrient loading rate, and the test was carried out under optimal CO_2 level of 1400 ppm. Although relatively higher BOD concentration did suppressed nitrification performance of nitrifying microorganisms in soil to a certain extent, in a short run the system managed to function well. Besides, higher hydraulic/nutrient loading rate could benefit nitrification process in red ball earth, and lead to a better land use efficiency. However, it could also cause reduction in biomass production and nutrient recovery of Kentucky bluegrass, which is a trade-off need to be paid attention to.

After successful development and improvement, the entire wastewater treatment system is expected to be further scaled up. Characterized by excellent removal and recovery functions of nutrients from wastewater, this system could be adopted by many places in the world as a route for mitigating water crisis and approaching sustainable development.