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Influence of volumetric loading rate on aerobic sewage treatment for indigenous algal growth: a bio-refinery concept

INTRODUCTION

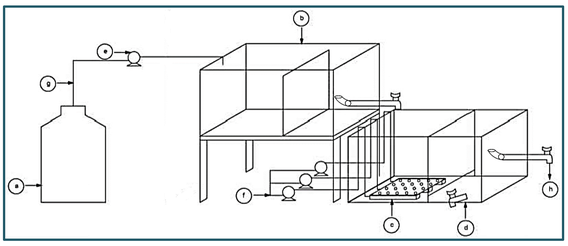
Rural areas of Latin America and the Caribbean (LAC) region have limited capacities in sewage treatment systems and suffer from a lack of opportunities to expand their economy [1]. In developing countries, up to 90% of sewage is discharged without proper treatment, affecting mainly the poor. Thus, it is worth to seek economic revenue from treated sewage of emergent nations.

Sewage treatment has been widely studied both from the process itself i.e. chemical and biological processes, and from the source i.e. urban, synthetic, separated and mixed pipelines, contaminated with agricultural runoff or industrial water, among others. Nevertheless, only a few studies reveal the behaviour of aerobic microbial population growing upon rural domestic sewage of developing countries. The organic fraction of the solid waste stream in these countries is considerably higher (to 80% of the total) compared to those from developed nations [2]. This denotes a strong analogy with the organic sewage composition mainly from kitchen food residues and preparation. The usage of non-processed organics, mainly fruits and vegetables, in developing countries, results in sewage with less oxidized organic matter, higher BOD/COD ratio, peculiar micronutrients and vitamin concentrations (folic acid being of special interest) [3]. It may eventually affect kinetics, and particularly, the biomass yield [4].

Algae become a potential raw material to produce local resources (animal feed, starch, pigments). It is of interest to couple traditional biological wastewater treatments with native algae growth. Micro-algae culture offers an interesting tertiary bio-treatment step with the production of potentially valuable biomass. Still, particular volumetric organic loading rates (Bv) applied in sewage treatment optimal for the growth of the algae have been poorly searched. The present study looks for a particular Bv promoting the best algae growth via coupling of partial biologically treated rural sewage.

METHODS

The rural sewage comes from a countryside community (100 km east from Guayaquil, Ecuador). Samples were taken during a 1.5-hour daily interval representative of the highest COD load (352±32 mg COD L-1). The experimental design included 3 aerobic systems (S1, S2 and S3) operating simultaneously at 25±2°C for 8 months in continuous-flow mode and in a kind of extended aeration.



The 500 L tank is not in scale.

Figure 1 – Schematic setup of one of the systems used in the study. a) Storage tank, b) Homogenization compartment, c) Aeration chamber, d) Secondary clarifier, e) Influent pump, f) Aeration chamber influent pumps, g) Affluent and h) Effluent.

Figure 2 – Schematic of the glass-made 3-liter cylindrical type photo-bioreactors and used in this study.

- ✓ Bv applied for S1, S2 and S3: 0.7, 1.0 and 1.4 g COD L-1d-1, respectively.
- ✓ The excess biomass (ΔX) in systems determined by measuring the entire biomass present in each system (own method).
- ✓ Treated effluents of systems used as medium to grow three algal strains native to Ecuador, genetically identified (18S rRNA sequencing) as: Chlorella sp. M2, Chlorella sp. M6 and Scenedesmus sp. R3.
- ✓ Algae cultivated using UV-light treated-filtered-undiluted effluents.
- ✓ Growth rate determined by microscopic counting
- ✓ Biomass concentrated by filtration once cultures reached the stationary phase.

RESULTS

Figure 3 – Influent and effluent COD and nutrients levels of the sewage entering S1, S2 and S3, at Bv 0.7 g COD L-1d-1, 1.0 g COD L-1d-1 and 1.4 g COD L-1d-1, respectively.

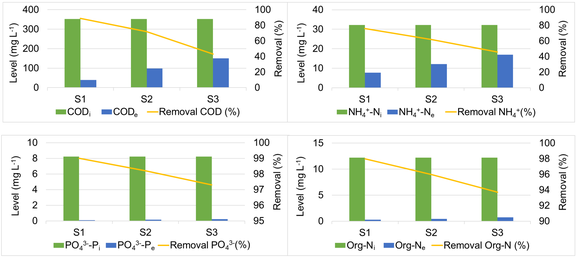
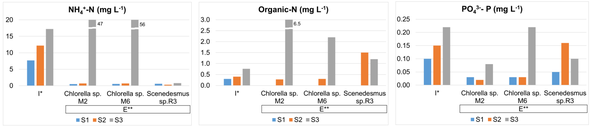


Figure 4– Influents and effluents nutrient values for microalgae cultures using cylinder type photo-bioreactors at 32±2°C.



* I: Influent **E: Effluent

Table 1 – Kinetics of rural sewage.

q_{max}	0.69	K_d	0.136
K_s	0.021	Y	0.32

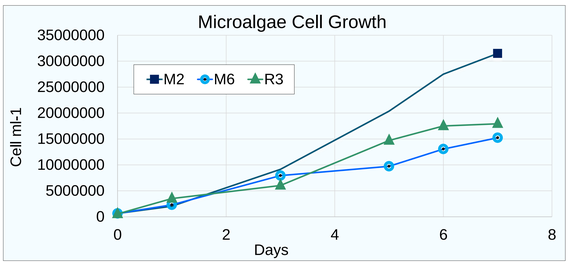
The growth yield (Y) of rural sewage (table 1) was lower than the usual values from urban sewage (0.4–0.6) commonly reported [5].

DISCUSSION

Rural sewage presents genuine characteristics. It is different from urban sewage of developing countries [6]. Sewage remains longer in collectors of urbanizations. Total solids are lower than urban. Most are soluble and organic; total dissolved solids (81%) much higher than urban. The usage of non-processed organics, mainly fruits and vegetables, in developing countries, results in sewage with less oxidized organic matter. Thus, more available energy for aerobic microorganisms.

In treated effluents, ammonia levels (Fig. 3) were not extremely removed to lower values, as expected in extended aeration, perhaps due to high temperatures in tropical countries. On the contrary, all systems showed significant organic-N and P removal.

Fig. 4 shows an increment on NH4+-N and organic-N in the effluents of the photo-bioreactors. These increased values were noticeable after using S3 (highest Bv) as growth media, probably due to the excretion of small organic molecules by the algae [7]. The observed N:P ratio of influents to algal cultures (70–80) did not affect algal growth as freshwater microalgae showed the ability to adjust its N and P levels [8]. The growth rate of the three algal species used (Fig. 5). was consistent among species.



The partial stream recovery concept concept would allow taking the highest organic portion of daily sewage (advantageously present in low volume) for algae growth while leaving the bulk contamination for less energy demanding treatments. The bulk water with lower organic load could be treated with any other less energy demanding technique.

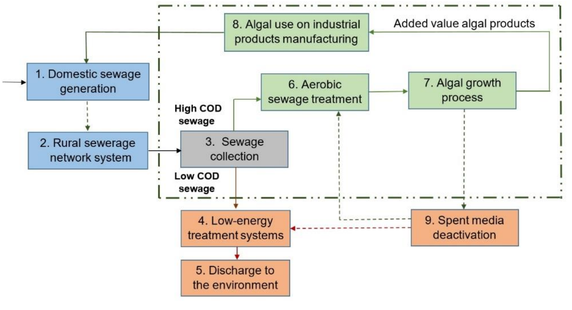


Figure 6 – Proposed stages in the partial stream recovery concept for rural sewage in developing countries.

CONCLUSIONES

- ➢Chlorella sp. M2, cultured in cylindrical-type photo-bioreactors, showed the highest growth rate (μ= 0.56 ± 0.02) at an optimal Bv of 1 g COD L-1 d-1 in S2.
- ➢Overall, the optimal Bv applied (1 g COD L-1 d-1, 72% COD removal) promoted in the photo-bioreactors 30% removal of organic-N, 87% PO43—P, and 95% NH4+-N
- ➢When rural sewage is focused to bio-refinery concerns, it seems there is no need to strictly meet sewage discharge standards, thus, saving energy in aerobic treatments
- ➢Interestingly, the proposed system resulted in a low biomass yield coefficient of 0.3, possibly due to the peculiar characteristics of the substrate. This would size smaller decantation units
- ➢The partial stream recovery concept proposed in this study, seems to be an attractive strategy for nutrients capture and reduction of organic load peaks in developing countries

Acknowledgement: The authors thank the authorities of the Marcelino Maridueña rural municipality for opening their facilities for the culmination of the present work.