Effect of cold plasma pre-treatment on Waste Activated Sludge (WAS) for Biochemical Methane Potential (BMP) enhancement

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INTRODUCTION

Among the major disposal issues in wastewater treatment plants (WWTP) is the large amount of primary sludge and waste activated sludge (WAS) produced daily. The usage of anaerobic digestion (AD) for WAS has been applied to biodegrade the organic components convertible to bioenergy, however, it has shown a low efficiency due to the decomposition of macromolecules and slowly biodegradable materials. The application of common pre-treatment technologies such as ultraviolet (UV), ultrasonication, ozone and chemical treatments; have been researched for WAS pretreatment, resulting in high operation costs and low bioenergy yields, converting them in low cost-effective. To mitigate pretreatment cost, cold-plasma (CP) technologies have been investigated regarding: microbes inactivation, high turbidity removal, livestock excrements treatment. However, little CP application has not been investigated as a WAS with advanced oxidation process (AOP). To study the effect of CP in WAS, contact time (CT) and temperature (T) variables were modeled using a central composite design and multi-response surface model (CCD-RSM). The results were analyzed by using analysis of variance (ANOVA) with a significance level of 0.05. In addition, a biochemical methane potential (BMP) test was performed to study the methane yield and organic matter reduction.

MATERIALS AND METHODS

WAS pre-treatment CCD-RSM model

The model for this research was based in second-order CCD-RSM with independent variables assigned to: CT (hours) and T (°C) of CP pre-treatment for WAS performed in a closed hermetic incubator. The definition of these variables was done by setting the minimum and maximum values for time of contact and temperature of the experiment as established in Table 1. A significance level of 0.05, 4 axial runs, 4 factorial runs and 5 replicates-centered runs were operated.

Table 1 – WAS CP pre-treatment analysis model

CCD-RSM model - Natural variables						
Independent variables	Unit	Lowest value	Low value	Mid value	High value	Highest value
Time	h	0.78	1.50	3.25	5.00	5.72
Temperature	°C	20.86	25.00	35.00	45.00	49.14

Cold-plasma pre-treatment

This super-oxidant technology for wastewater treatment was developed in a laboratory scale bench unit by Groon Co., Ltd. Jeonju, Korea. The glow-discharge was applied to WAS through a constant flow of 5 L/min through and an aeration pump.

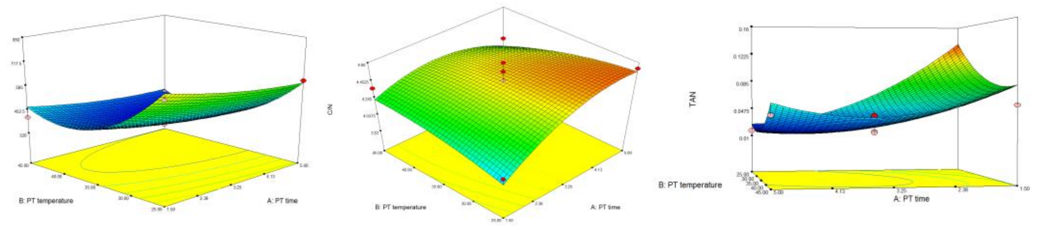
Biochemical Methane Potential (Test)

Methane enhancement and characterization tests were done to WAS samples treated with CP treatment after being co-digested by using 0.1, 0.3 and 0.5 substrate to inoculum (SIR) ratios during 30 days of testing.

RESULTS AND DISCUSSION

Effect of cold-plasma in WAS pre-treatment: CCD-RMS model results

The final model was generated by using Design-Expert software. The levels of TOC, C/N ratio, and total ammonia nitrogen (TAN) were compared finding the optimum solution model for WAS CP pre-treatment.



(a) (b) (c)

Figure 1 – 3D surface responses of (a) TOC, (b) C/N and (c)TAN 3D surface response graphs

Evaluation on the organic properties of CP pre-treated WAS revealed, significant relationships between the TOC, C/N ratio, and TAN. Results demonstrated the reduction of volatile solids (VS) up to 8%, COD up to 53%, Total Nitrogen (T-N) 66% and TAN up to 93% as maximum values, providing an increase of carbon to nitrogen ratio (C/N) of 15%. The effects of these were showed a methane enhancement (59%) compared to the control based on the BMP values.

CONCLUSION

CP pre-treatment has demonstrated to be a cost-effective AOP for WAS which can provide a faster TOC and TAN biodegradation, increasing the C/N ratio. The optimum pre-treatment parameters were found being CT= 4.63 hours, T= 45.00 °C, increasing the methane yield up to 0.27 m^3 CH_4/kg COD on AD co-digestion.

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