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Kinetic of CO_2 Reduction by Selected Aquatic Plants

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Several experiments were conducted to investigate the kinetic coefficient of photosynthesis reaction (k) by various aquatic plants. The results illustrated that the kinetic reduction of CO_2 in the PBRs can be expressed by first-order reaction with R^2 values > 0.88. The k values were varied from 0.38-0.60 depending on types of aquatic plants and initial elevated CO_2 concentrations. In addition, the relationship between photosynthesis rate coefficients (k) and initial elevated CO_2 were linearity with R^2>0.99.

Key words: CO_2 removal, aquatic plant, kinetic

1. Background

The role of carbon dioxide (CO_2) in global warming is one of the most important contemporary environmental issues and it is therefore necessary to have available technology which minimizes the discharge of CO_2 into the atmosphere. It is now generally accepted that limits will have to be placed on the atmospheric concentration of CO_2 and other greenhouse gases in the atmosphere. The UN Framework Convention on Climate Change (UNFCCC) is intended to address this issue. Through the Kyoto Protocol, world industrialized nation members agreed to reduce their emissions by 5% below 1990 levels. (IPCC, 1995). Atmospheric levels of carbon dioxide have increased over the same period from an estimated 280 ppm (Bolin et al., 1979) to present day levels of approximately 360 ppm (IPCC, 1995 and Nilsson et al., 2000). Higher concentrations of greenhouse gasses reduce the ability of the Earth to radiate planetary heat through the atmosphere. Most scientists agree that the increases in greenhouse gases are a major cause in the observed trend of global climate warming (IPCC, 1995).

Green plants in both terrestrial and aquatic ecosystems withdraw carbon dioxide from the atmosphere during photosynthesis, but also produce it during respiration. Carbon sequestered from the atmosphere is stored in plant fiber (above and below ground) for extended periods of time (Bolin et al., 1979 and IPCC, 1995). Higher atmospheric carbon dioxide levels, contribute to enhanced plant productivity generally and, consequently, the rate at which carbon dioxide is removed from the atmosphere (Hollinger et al., 1995; Schulze et al., 1995 and Burton, 1997). The net effect is an uptake of carbon dioxide from the atmosphere equivalent to around 60 billion-ton of carbon each year (GHG Online, 2003). However, the specific data for each species of plants on CO_2 removal and their kinetic rate coefficient have been limited. The purpose of this research is to study the kinetic of CO_2 removal by various plants species.

2. Methodology

2.1. Phyto-batch Reactor (PBR)

Phyto-batch reactors are made of acrylic and air-tight materials with a dimension of 230 mm × 230 mm × 600 mm (width × length × height). The reactors were replaced of Ø10-15 mm of gravel and Ø0.6-2.4 mm of sand with approximate 4 L. Various kinds of aquatic plants were planted into each reactor and filled up with 2 L of synthetic water. Top of reactors is designed to

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Table 1. List of Aquatic Plants

Phytoremediation reactor	Plant's name
Control[a]	None
R-A	Cyperus alternifolius
R-B	Dracaena F. massangeana
R-C	Iris ensata
R-D	Thalia dealbata

[a] Control is reactor without plant.

connect with CO_2 sensor for online CO_2 measurement. Table 1 shows the list of aquatic plants used in the experiment. Control reactors, the PBR without aquatic plants, are used for all experiment.

Fig. 1 shows the PBR used for the experiments. High concentrated CO_2 gas (99% v/v) is diluted with ambient air and filled to the PBR by batch operation. The CO_2 concentration of 1,000, 1,500 and 2,000 ppm are distributed to the PBRs for 8 hours per a day. The light source used for the experiment is florescence lamp OSRAM FL40 provided light intensity at top of PBR-surface by 55 ± 5 mmole/m^2/s. The temperature in the PBRs is controlled at 25 °C for all experiment.

2.2. Raw Water Characteristics

Raw water used in the experiment was synthesized by laboratory grade chemicals (source of nitrogen and potassium will be synthesized by KNO_3 and phosphorus is from mixture of Na_2HPO_4 and NaH_2PO_4 with proportion of 4:1 as for buffer solution and source of phosphorus). The nutrient solutions are maintained pH at 7.5. The water characteristics are summarized in Table 2.

Table 2. Water Characteristics

Parameters	Units	Quantity
pH	-	7.5
Temperature	°C	25.0
Total Nitrogen (TN)	mg/L	25.0
Total Phosphorus (TP)	mg/L	10.0

3. Results and discussion

The experimentation illustrated that the reduction of CO_2 by photosynthesis reaction was *first-order* reaction (Fig. 2). In such the CO_2 reduction rate CO_2 is directly proportional to the amount of initial CO_2 concentrations and may be expressed mathematically as

$$-\frac{dCO_2}{dt} = kCO_2 \quad \text{(Eq.1)}$$

$$\ln\frac{[CO_2]_t}{[CO_2]_{t_0}} = -kt \quad \text{(Eq.2)}$$

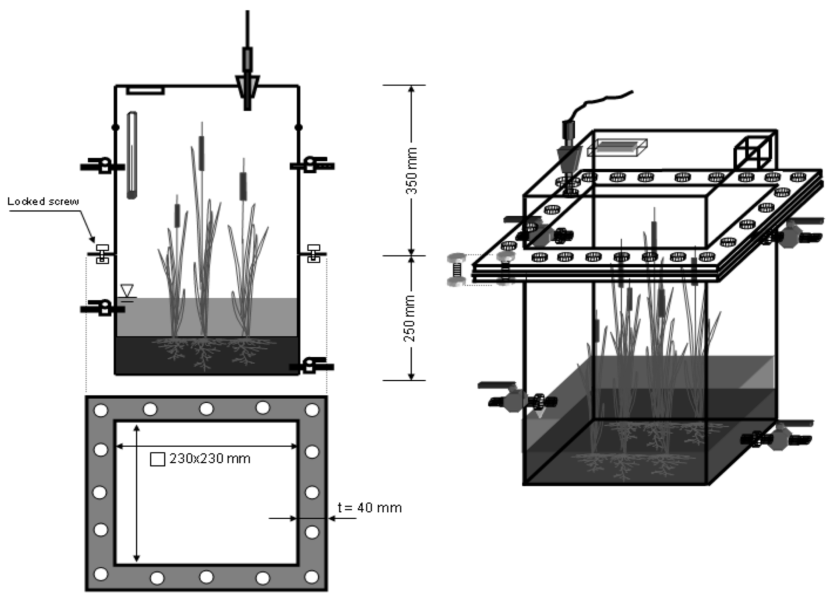

Fig. 1. Phyto-batch Reactor (PBR)

$$[CO_2]_t = [CO_2]_{t_0} e^{-kt} \quad \text{(Eq.3)}$$

where

$[CO_2]_{t_0}$ = initial elevated CO_2 concentration, ppm

$[CO_2]_t$ = residual CO_2 concentration at time t, ppm

k = photosynthesis rate coefficient, ht^{-1}

t = detention time, hr

Table 3 summarizes the photosynthesis rate coefficient k at temperature 25 °C and light intensity 55 ± 5 mmole/m^2/s. The k_{1000}, k_{1500} and k_{2000} indicate the kinetic coefficient for photosynthesis reaction in the PBRs at initial elevated CO2 of 1,000, 1,500 and 2,000 ppm.

The results shown that increase of elevated CO_2 concentration will enhance the kinetic rate of photosynthesis by aquatic plants. No significant change of CO_2 concentrations were found by control reactors.The relationship between photosynthesis rate coefficients (k) and elevated CO_2 concentrations by four species of aquatic plants is shown by Fig. 3. The points and bars in the graph indicate the average k values from four plant species and and standard deviation (n = 4).

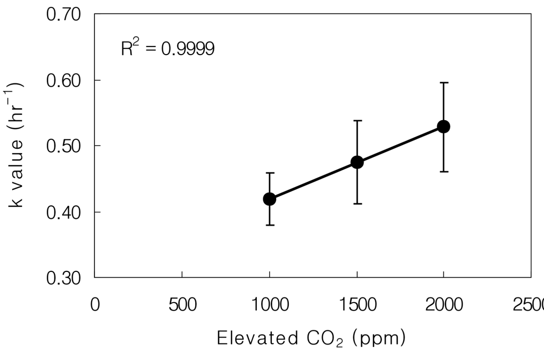

Fig. 3. Effect of elevated CO_2 concentrations on k values

4. Conclusion

Remediation of excess CO_2 in polluted atmosphere by aquatic plants was found to attractive for environment and ecological aspects. The kinetic

Table 3. Photosynthesis Rate Coefficient (k)

Aquatic plants	k_{1000}	k_{1500}	k_{2000}
Cyperus alternifolius	0.4149 (0.9865)	0.4913 (0.9819)	0.5656 (0.9544)
Dracaena F. massangeana	0.4735 (0.9813)	0.5588 (0.9602)	0.6049 (0.9447)
Iris ensata	0.3776 (0.8907)	0.4198 (0.8883)	0.4830 (0.9627)
Thalia dealbata	0.4144 (0.8883)	0.4330 (0.9297)	0.4632(0.9484)

( ) indicates R^2 values.

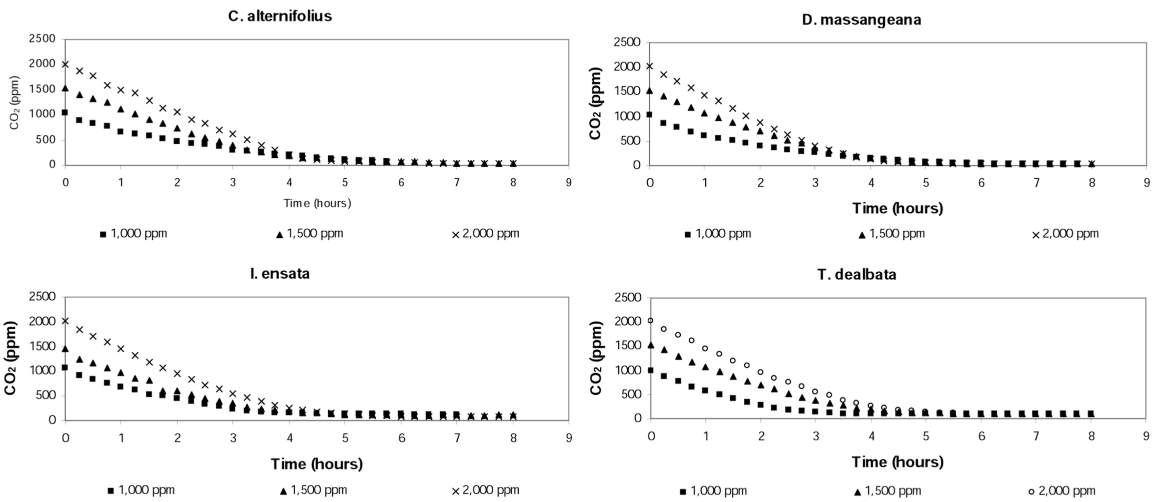

Fig. 2. Effect of initial CO_2 concentrations and plant species on the CO_2 reduction

coefficients can be determined by first-order reaction. Increase of elevated CO_2 concentration 2-4 times higher than atmospheric CO_2 levels will increase the k values and CO_2 removal efficiency by the PBRs. No significant change of CO_2 concentration was observed by the PBRs without plantation.

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