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EFFECT OF MUD TURBIDITY ON FERTILIZATION, AND AN ANALYSIS OF TECHNIQUES TO MITIGATE TURBIDITY PROBLEMS

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ABSTRACT

This experiment was designed to 1) assess effects of different turbidity reduction techniques on fish growth and water quality and 2) find a suitable approach for turbidity mitigation. It was conducted in 15 earthen ponds at the Asian Institute of Technology, Thailand, during October 1997 through April 1998. The five different treatments were: (A) control; (B) covering 50 cm of the pond edges starting from the top of pond dikes with black plastic to prevent turbidity from run-off; (C) covering pond bottoms with green manure (terrestrial weeds) to alter texture; (D) covering pond bottoms with netting material to prevent turbidity from fish disturbance; and (E) liming ponds biweekly with quick lime at a rate of 200 kg ha^{-1}. All ponds were fertilized weekly with chicken manure at a rate of 225 kg ha^{-1} (dry matter basis) supplemented with urea and triple super phosphorous (TSP) to provide 28 kg N ha^{-1} wk^{-1} and 7 kg P ha^{-1} wk^{-1}. Sex-reversed male Nile tilapia (*Oreochromis niloticus*) were stocked at 2 fish m^{-2} at a size of 15.0 ± 1.0 g. The liming treatment led to the best growth performance except for survival. The lowest survival and net fish yield occurred in the weed-covered treatment. With the exception of the weed-covered treatment, the different mitigation techniques did not result in significantly increased fish yield in the experiment conducted in the dry season. The significantly higher fish mortality in the weed-covered treatment was probably attributable to the low dissolved oxygen concentration due to decomposition of terrestrial weeds during the first month of the experiment. The bottoms covered by netting material prevented turbidity from fish disturbance, resulting in reduced phosphorus regeneration from pond muds but no reduced fish production. Compared with the control, the edge-covered treatment was not significantly different in fish growth performance. This treatment is expected to be more effective during the wet season. A similar experiment should be done during the wet season to further assess the proposed techniques for mitigating turbidity problems.

INTRODUCTION

Mud turbidity is a global problem in aquaculture using ponds with heavy clay dikes and bottoms. Colloidal clay particles from the dikes and bottom (as well as from runoff and source water) become suspended in the water column and inhibit plankton growth by binding with mineral nutrients from water as well as with plankton cells (Avinimelech et al., 1981). High mud turbidity usually causes acidity, low nutrient levels, and limited light penetration for photosynthesis (Boyd, 1990) and thus results in reduced primary production (Diana et al., 1991). With only fertilizer inputs, turbidity often limits production and growth of fish (Banarjea and Ghosh, 1963; Buck, 1956). From these points of view, mitigation of mud turbidity is essential to enhance and allow normal phytoplankton growth in response to fertilization.

The purpose of this study was to evaluate several mud turbidity mitigation techniques in order to: 1) assess effects of different mitigation techniques on fish growth; and 2) find a suitable approach for turbidity mitigation.

METHODS AND MATERIALS

The experiment was conducted in fifteen 200-m^2 earthen ponds with an average depth of 1.0 m at the Asian Institute of Technology, Thailand. All ponds were fertilized weekly with chicken manure at a rate of 225 kg ha^{-1} (dry matter basis) supplemented with urea and triple superphosphate (TSP) to provide 28 kg N ha^{-1} wk^{-1} and 7 kg P ha^{-1} wk^{-1}. Sex-reversed all-male Nile tilapia (*Oreochromis niloticus*) were stocked at 2 fish m^{-2} at a size of 15.0 ± 1.0 g (mean ± SE) on 24 October 1997.

The ponds were divided randomly into five treatments, with triplicate ponds for each treatment. The five treatments were: (A) control; (B) covering 50 cm of the pond edge starting from the top of dikes with black plastic to prevent turbidity from runoff (edge-covered); (C) covering pond bottoms with green manure (terrestrial weeds) to alter texture (weed-covered); (D) covering pond bottoms with netting material to prevent turbidity from fish disturbance (bottom-covered); and (E) liming ponds biweekly with quick lime at a rate of 200 kg ha^{-1}.

For analyses of most water quality parameters, combined water samples encompassing the entire water column were taken from walkways extending to the center of the ponds. Pondwater analyses—including DO, temperature, pH, alkalinity, total ammonium nitrogen (TAN), nitrite nitrogen, nitrate-nitrite nitrogen, total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), and total volatile solids (TVS)—were conducted biweekly at 0900 h using standard methods

Table 1. Growth performance of Nile tilapia in the 180-day experiment.

Performance	Treatment				
	Control	*Edge-covered*	*Weed-covered*	*Bottom-covered*	*Limed*
Initial Biomass (kg pond^{-1})	6.0 ± 0.2	6.1 ± 0.1	6.1 ± 0.2	6.1 ± 0.1	6.0 ± 0.2
Initial Mean Wt. (g fish^{-1})	15.0 ± 0.5	15.3 ± 0.3	16.3 ± 0.5	15.3 ± 0.3	15.0 ± 0.5
Final Biomass (kg pond^{-1})	21.9 ± 1.6	23.6 ± 2.5	18.0 ± 0.2	21.9 ± 2.7	26.6 ± 1.0
Final Mean Wt. (g fish^{-1})	74.7 ± 2.3	71.1 ± 8.5	77.0 ± 5.4	69.1 ± 4.0	91.7 ± 1.1
Mean Wt. Gain (g fish^{-1})	59.7 ± 2.7	55.8 ± 8.6	61.6 ± 5.9	53.7 ± 4.0	76.7 ± 1.5
Mean Daily Wt. Gain (g fish^{-1} d^{-1})	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.4 ± 0.0
Net Fish Yield (kg pond^{-1})	15.9 ± 1.7	17.5 ± 2.5	11.8 ± 0.4	15.8 ± 2.7	20.6 ± 0.8
Extrapolated Fish Yield (t ha^{-1} yr^{-1})	1.6 ± 0.2	1.8 ± 0.3	1.2 ± 0.3	1.6 ± 0.3	2.1 ± 0.1
Survival (%)	73.2 ± 3.4	83.6 ± 1.8	59.3 ± 4.4	78.5 ± 5.8	72.8 ± 3.6

Table 2. Water quality variables at the end of the experiment.

Variable	Treatment				
	Control	*Edge-covered*	*Weed-covered*	*Bottom-covered*	*Limed*
DO (mg l^{-1})	2.9 ± 1.0	3.2 ± 0.3	3.3 ± 0.7	3.2 ± 0.4	2.4 ± 0.6
Temperature (°C)	30.9 ± 0.2	30.9 ± 0.1	30.7 ± 0.3	30.8 ± 0.3	30.5 ± 0.3
Alkalinity (mg $CaCO_3$ l^{-1})	174.7 ± 11.0	168.0 ± 13.9	123.3 ± 3.1	157.3 ± 15.0	179.3 ± 9.0
pH	7.7 ± 0.2	7.8 ± 0.2	7.4 ± 0.2	7.6 ± 0.1	7.7 ± 0.1
TKN (mg l^{-1})	0.51 ± 0.09	1.24 ± 0.11	0.46 ± 0.14	1.89 ± 1.57	2.13 ± 1.63
TAN (mg l^{-1})	0.44 ± 0.44	0.11 ± 0.20	0.07 ± 0.13	0.02 ± 0.03	0.04 ± 0.08
Nitrite Nitrogen (mg l^{-1})	0.023 ± 0.025	0.033 ± 0.023	0.010 ± 0.010	0.070 ± 0.035	0.030 ± 0.026
Nitrate-Nitrite Nitrogen (mg l^{-1})	0.10 ± 0.08	0.20 ± 0.17	0.10 ± 0.03	0.39 ± 0.19	0.16 ± 0.06
Total Phosphorus (mg l^{-1})	0.35 ± 0.08	0.32 ± 0.06	0.31 ± 0.07	0.27 ± 0.01	0.32 ± 0.04
SRP (mg l^{-1})	0.04 ± 0.02	0.04 ± 0.02	0.02 ± 0.02	0.04 ± 0.03	0.03 ± 0.01
Secchi Disk Depth (cm)	16.0 ± 4.6	14.7 ± 2.1	15.3 ± 1.5	18.3 ± 2.3	14.0 ± 1.0
Chlorophyll *a* (mg l^{-1})	37.6 ± 25.0	48.2 ± 14.1	37.2 ± 12.2	30.4 ± 6.7	44.4 ± 23.8
TSS (mg l^{-1})	138.3 ± 48.2	157.0 ± 27.7	135.0 ± 20.3	85.3 ± 17.0	172.3 ± 48.0
TVS (mg l^{-1})	42.0 ± 8.7	41.0 ± 18.5	32.0 ± 19.7	20.3 ± 11.7	39.0 ± 20.8

(APHA, 1980; Egna et al. 1987). Secchi disk depth was measured at 0900 h daily in all the ponds throughout the experimental period. Monthly diel measurements for temperature, DO, and pH were determined in each pond at 0600, 0900, 1400, 1600, 1800, 2300, and 0600 h, and those for alkalinity and TAN were determined at 0900, 1600, and 0600 h.

Prior to stocking, dissolved oxygen (DO) at 0600 h in ponds receiving the weed-covered treatment was monitored for two weeks to check the changes in dissolved oxygen concentration. Major species of terrestrial weeds grown in pond bottoms of the weed-covered treatment were identified. The emergent macrophyte (*Typha* sp.) was uprooted, and all other weeds were trimmed to 10 to 20 cm high. The total biomass of terrestrial weeds except *Typha* sp. was determined by random sampling. Nutrient composition (nitrogen, phosphorus, and organic matter) of the weeds was determined to estimate nutrient content in the terrestrial weeds.

Bottom soil samples from nine different locations were collected in each pond, air-dried, and thoroughly mixed. A representative subsample was taken from the homogenized sample for each pond. Nitrogen, phosphorus, and organic matter of the bottom soil were measured at the beginning and end of the experiment.

Fish were not sampled during the experimental period. Ponds were harvested on 22 April 1998, after 180 days of culture. Final biomass and numbers were determined. Daily weight gain (g fish^{-1} d^{-1}), net yield (kg pond^{-1}), and extrapolated yield (t ha^{-1} yr^{-1}) were calculated.

Data were analyzed statistically by analysis of variance (ANOVA) using the SPSS 7.0 statistical software package. Differences were considered significant at an alpha level of 0.05. All means are reported with ± 1 standard error (SE).

RESULTS

Growth performance of Nile tilapia indicates that all parameters except survival were highest in the liming treatment (Table 1). Final mean weight and net fish yield in the liming treatment were significantly ($P < 0.05$) higher than those in the edge- and bottom-covered treatments, but not significantly ($P > 0.05$) different from those in the weed-covered treatment or control. However, highest survival was achieved in the edge- and bottom-covered treatments, which had significantly ($P < 0.05$) higher survival than the weed-covered treatment, but not significantly higher survival than the liming treatment and control. Net fish yield in the weed-covered treatment was significantly ($P < 0.05$) lower than the net fish yield of the liming treatment, which was not significantly higher than the net fish yield of the other three treatments.

The final and overall mean water quality parameters are listed in Tables 2 and 3. Water temperature ranged from 26.9 to

39.4°C and pH from 6.0 to 9.6. The final mean and overall mean pH was significantly ($P < 0.05$) lower in the weed-covered treatment. The measured DO concentrations at dawn fluctuated between 1.0 and 4.0 mg l^{-1} over the entire culture period (Figure 1), with the liming treatment having the lowest final value. The weed-covered treatment had the lowest overall mean DO at dawn, but there were not significant differences among treatments in DO at dawn. Low DO at dawn was initially observed in the weed-covered treatment, but this treatment reached levels similar to other treatments after two months (Figure 1). Un-ionized ammonia nitrogen concentrations in all treatments were generally low with the control having the highest value (Figure 1) and with no significant differences among treatments. Overall alkalinity concentration in the liming treatment and control was significantly higher than the alkalinity concentrations in the edge- and bottom-covered treatments, which was also significantly ($P < 0.05$) higher than the alkalinity concentration in the weed-covered treatment (Table 3). No significant differences in SRP were found among treatments. Final nitrite nitrogen concentration was significantly ($P < 0.05$) higher in the bottom-covered treatment, while overall nitrite nitrogen concentration was significantly lower in the control. Chlorophyll *a* concentrations were very low throughout the experimental period (Figure 1), but did not differ significantly among treatments. However, overall TSS and TVS concentration in the weed- and bottom-covered treatments was significantly ($P < 0.05$) lower than the overall TSS and TVS concentrations in other treatments (Table 3). The bottom-covered treatment had the lowest final TSS level, which was significantly ($P < 0.05$) lower than the final TSS level of the liming and edge-covered treatments but not significantly different from the final TSS level of the weed-covered treatment and control (Figure 2). Secchi disk depth declined over the experimental period (Figure 3). Secchi disk depth in the weed-covered treatment was significantly ($P < 0.05$) higher than the Secchi disk depth of the other treatments, among which there were no significant differences.

DISCUSSION

With the exception of the weed-covered treatment, the different mitigation techniques did not result in significantly

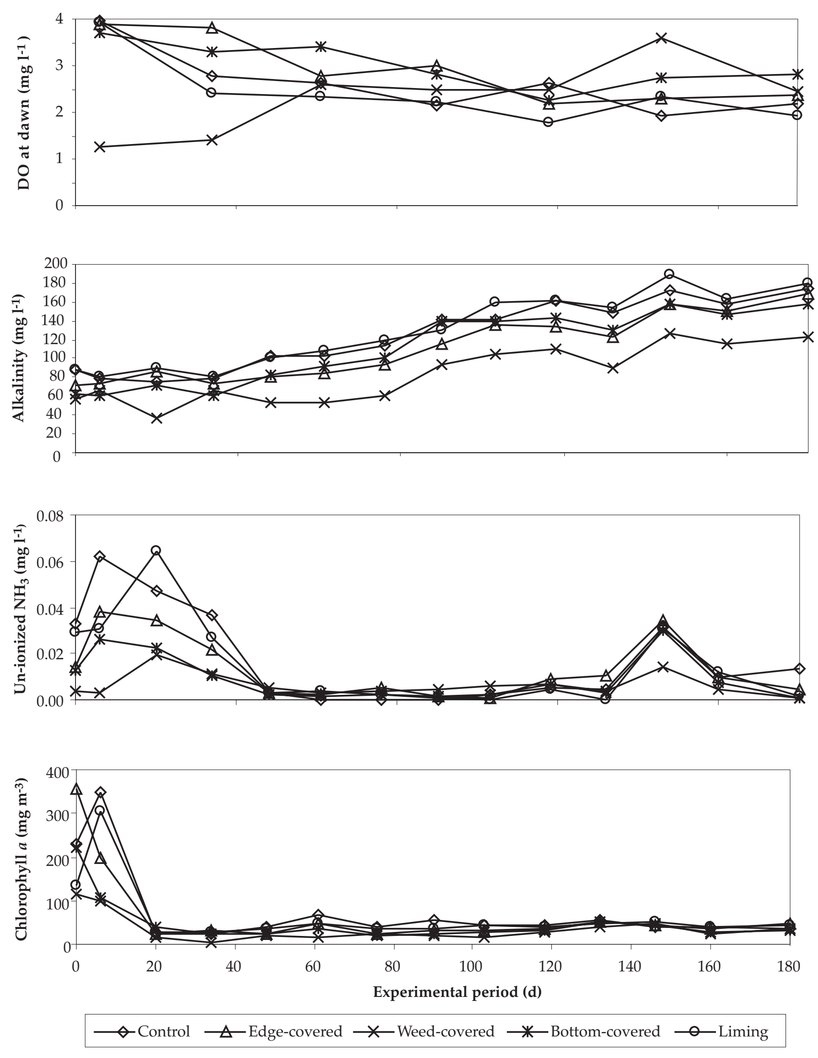

Figure 1. Changes in concentrations of dissolved oxygen at dawn, un-ionized ammonia nitrogen, alkalinity, and chlorophyll *a* in pond water during the 180-day experiment.

Table 3. Mean water quality variables throughout the experiment.

Variable	Treatment				
	Control	*Edge-covered*	*Weed-covered*	*Bottom-covered*	*Limed*
DO at Dawn (mg l^{-1})	2.6 ± 0.2	2.9 ± 0.3	2.3 ± 0.2	3.0 ± 0.6	2.4 ± 0.1
Temperature (°C)	29.1 ± 0.1	29.2 ± 0.2	29.2 ± 0.1	29.2 ± 0.1	28.9 ± 0.2
Alkalinity (mg $CaCO_3$ l^{-1})	124.4 ± 4.9	110.60 ± 6.4	82.5 ± 10.7	110.5 ± 3.8	128.9 ± 3.8
pH	7.8 ± 0.1	7.6 ± 0.0	7.3 ± 0.2	7.6 ± 0.0	7.7 ± 0.1
TKN (mg l^{-1})	2.43 ± 0.39	2.00 ± 0.10	2.17 ± 0.12	2.42 ± 0.19	2.38 ± 0.24
TAN (mg l^{-1})	0.32 ± 0.07	0.32 ± 0.06	0.44 ± 0.15	0.22 ± 0.04	0.25 ± 0.05
Nitrite Nitrogen (mg l^{-1})	0.04 ± 0.01	0.06 ± 0.02	0.07 ± 0.01	0.05 ± 0.01	0.04 ± 0.01
Nitrate-Nitrite Nitrogen (mg l^{-1})	0.16 ± 0.03	0.28 ± 0.08	0.54 ± 0.51	0.21 ± 0.02	0.20 ± 0.04
Total Phosphorus (mg l^{-1})	0.25 ± 0.04	0.20 ± 0.04	0.15 ± 0.02	0.19 ± 0.05	0.26 ± 0.01
SRP (mg l^{-1})	0.04 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.04 ± 0.02	0.04 ± 0.01
Secchi Disk Depth (cm)	21.5 ± 0.9	24.6 ± 1.9	34.4 ± 5.2	25.4 ± 1.0	20.2 ± 1.4
Chlorophyll *a* (mg l^{-1})	77.9 ± 3.4	70.4 ± 32.5	36.1 ± 1.5	50.6 ± 20.8	65.2 ± 4.6
TSS (mg l^{-1})	102.0 ± 13.6	90.0 ± 18.0	64.3 ± 7.1	65.1 ± 9.4	102.6 ± 6.6
TVS (mg l^{-1})	27.8 ± 1.1	26.6 ± 1.0	22.4 ± 2.2	20.3 ± 2.7	26.0 ± 0.5

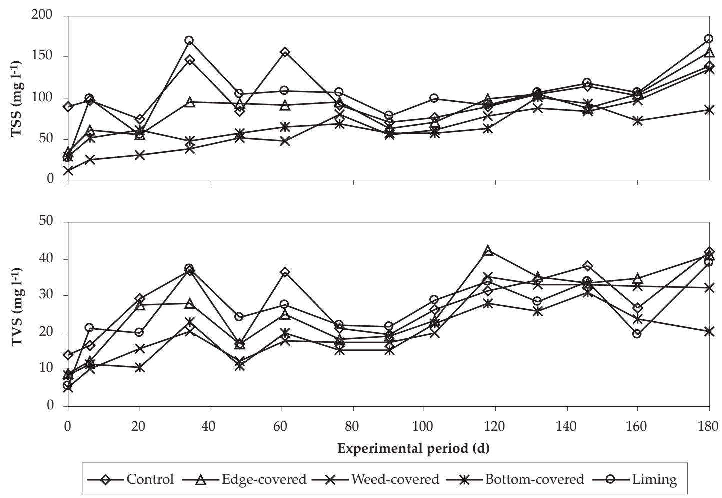

Figure 2. Changes in total suspended solids and total volatile solids in pond water during the 180-day experiment.

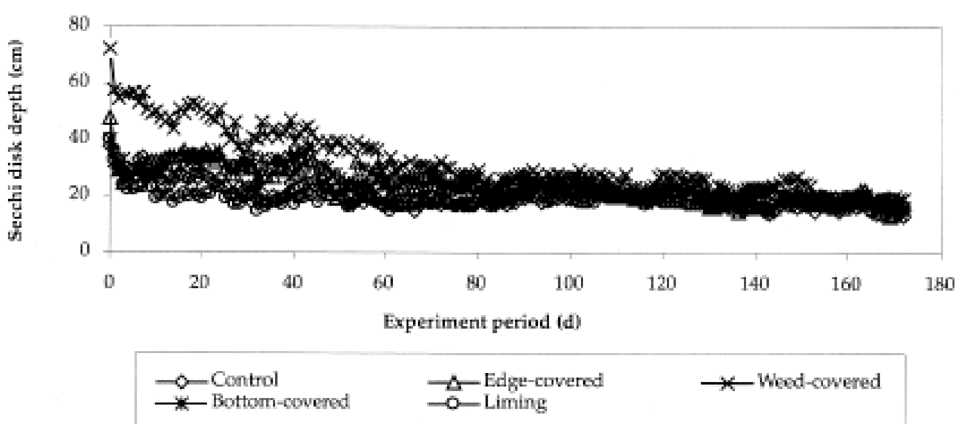

Figure 3. Daily changes in Secchi disk depth during the 180-day experiment

increased fish yield compared to the control ponds. The weed-covered treatment showed a significant reduction in fish yield.

In the weed-covered treatment, the decomposition of the terrestrial weeds in ponds consumed oxygen, causing the significantly low concentration of dissolved oxygen during the first month of the experiment. The highest fish mortality in the weed-covered treatment was probably due to the low dissolved oxygen. Significantly higher Secchi disk visibility and low total suspended solids concentration were observed in the weed-covered treatment during the first month. Ponds containing macrophytes usually had clearer water, and upon decay, dead vegetation increased the concentration of carbon dioxide, decreased pH, and resulted in the precipitation of colloidal clay (Irwin and Stevenson, 1951). However, better timing of stocking fish in the weed-covered ponds is needed to prevent mortality due to depletion of dissolved oxygen.

In the bottom-covered treatment, pond bottoms were covered with netting material to prevent turbidity from fish disturbance on pond bottoms. However, this may also reduce the nutrient regeneration from pond mud. A low level of total phosphorus and chlorophyll *a* was observed in the bottom-covered treatment, which was probably due mainly to the low rate of phosphorus release from pond mud. According to Boyd (1990), plankton growth is regulated to some extent by concentration of phosphorus in the mud of natural waters. However, compared with the control, the covered bottom did not result in significant reduction in fish growth, implying that Nile tilapia feed mainly on phytoplankton in the water column rather than graze on the pond bottom.

There were no significant differences in most water quality parameters and fish growth performance between the control and the edge-covered treatment, indicating that this treatment was not effective in mitigating turbidity problems. However, the edge-covered treatment was designed to prevent turbidity from runoff. It is not surprising that this treatment was not effective during our experiment in the dry season. It might be the most effective technique to mitigate turbidity problems during the wet season. The results also indicated that grazing on pond edges by Nile tilapia was less important than feeding on phytoplankton in the water column.

Lowest Secchi disk visibility and highest concentrations of chlorophyll *a*, resulting in the best growth performance of Nile tilapia, were observed in the liming treatment. The laboratory experiment by Vuthana (1995) indicates that quick lime is the best material to remove turbidity in fish ponds, which is consistent with results of the present experiment. However, fish growth even in this treatment was considerably below normal growth rates for well-fertilized ponds in Thailand (1 g d^{-1}; Diana, 1997), indicating that the technique was not very successful. Biswal and Roy (1991, cited by Vuthana, 1995) reported that the application of lime to remove turbidity in fish ponds turned water alkaline and was unsuitable for fish culture. However, the alkalinity concentration of the liming treatment in the present experiment conducted in earthen ponds was similar to that of the control, confirming the results of Vuthana's (1995) laboratory experiment. This experiment should be repeated in a wet season to compare the dry season results of the present experiment.

ANTICIPATED BENEFITS

The results generated in this study, in addition to similar studies in turbidity control at the other CRSP sites, will link bottom soil characteristics and water quality management for semi-intensive fish ponds. Turbidity problems prevail in many rain-fed ponds in Thailand, Cambodia, and Laos, where the effectiveness of available fertilizer input is reduced by turbidity, resulting in poor fish yields and lack of interest in managing such ponds. The topic of turbidity control has been considered a priority by the Royal Thai Government Department of Fisheries and by the Asian Institute of Technology outreach project.

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