

Study for Improving an Duong Lake Water Quality for Chi Lang Nam Stork Island Conservation and Ecotourism Development

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ABSTRACT

An Duong Lake has been selected for the study to its important role in storks' and cauldrons' habitat protection, fishery and ecotourism of Hai Duong Province and particularly Thanh Mien District. Qualitative and quantitative methods were used throughout the research. The overall purpose of this study is to find out some mitigating measures for improving water quality of An Duong Lake in order to conserve herein stork islands and ecotourism development. Specifically, the objectives of the study are included: (i) To identify An Duong Lake pollution sources; (ii) To assess An Duong Lake water quality; (iii) To suggest water pollution mitigating measures. The main sources of water pollution of An Duong Lake are: storks' and cauldrons' feces, domestic and livestock waste and run-off. Wastes of all these sources are discharged directly into the lake without any treatment. In dry and wet season, concentration of SS, BOD and COD of almost samples is higher than regulatory levels (Vietnam National Technical Regulation 08:2008/BTNMT, Class A2 and B1). pH of all water samples in the range of permissible level. Concentration of $N-NH_4^+$ and $N-NO_3^-$ is lower than permissible level. The pollution of An Duong Lake water is heavier in dry season than in wet season. Lakeshore water is more contaminated than the central part of lake. Several comprehensive methods for improving An Duong Lake water quality should be conducted such as Water hyacinth (*Eichhornia crassipes*) and Reed (*Phragmites communis*) growing for water pollutant mitigation, Septic tank toilet for treatment of domestic waste water; Treatment of livestock wastes; Combination of filtration with EM for mitigating pollutant in run-off; Fish farming; Pollution sources control and An Duong Lake water monitoring. Water hyacinth and reed growing is found out to be the most effective and practical method for mitigating An Duong Lake water contaminants.

Keywords: An Duong Lake, Water Pollution, Water Quality, Stork, Cauldron, Mitigation Measure

1. INTRODUCTION

An Duong Lake with the area of 90 hectares and the average depth of 8 m is located in Chi Lang Nam Commune, Thanh Mien District, Hai Duong Province. It connects with Cuan River and Trieu Duong Lake. There exist two islands inside the lake with the area of 2.500 and 3.000 square meters, respectively. These islands are considered as the habitat of approximately 18.000 storks and cauldrons (Yem, 2012). Therefore, this

place is named as Chi Lang Nam Stork Colony which becomes a very famous stork and cauldron conserving place in the north of Vietnam. This stork island attracts thousands of people visiting annually. Chi Lang Nam Stork Island turns out to be one of most noticeable tourism destinations and historical relic of Hai Duong Province, Viet Nam.

In fact, An Duong Lake now is contaminated by storks' and cauldrons' feces, domestic waste water, livestock waste water, run-off from rice fields and solid

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waste dumping. Bad smell from storks' feces and dirty water has caused nuisance to visitors and people living in surrounding areas (Yem *et al.*, 2012).

The overall purpose of this study is to find out some mitigating measures for improving An Duong Lake water quality in order to conserve herein stork island and ecotourism development. The specific purpose of this study is to: (i) Identify An Duong Lake pollution sources; (ii) Assess An Duong Lake water quality; (iii) Suggest water pollution mitigation measures.

2. MATERIALS AND METHODS

2.1. Methods

2.2. Field Survey

Water sampling site selections: 12 water sampling sites in An Duong Lake are selected (**Table 1 and Fig. 1**):

2.3. Measurement

Use portable instruments for measurement of some parameters like: pH, DO... The instrument model U-10 Horiba-Japan was used.

Water pollution source survey.

2.4. PRA

- Organizing a meeting with 40 farmers of An Duong Village
- Interview:
 - Chairman and two officers of Chi Lang Nam People Committee
 - Mr. Ban-Chief of Management Board of Stork Island
 - Mr. Dao Quang Canh-74 years old, An Duong Villager

2.5. Laboratory Analysis

Chemical analyses were conducted in the environmental analysis laboratory of faculty of environmental sciences, VNU University of Science (HUS), belonging to Vietnam National University, Hanoi (VNU).

2.6. Experiment

2.7. Stimulation Filtration Trench

- 3-compartments horizonetal filter with each apartment dimension of 50×30×30 cm
- Gravels with diameter of 2-2.5 cm, coarse sands
- Use 100, 200, 300gr of storks' feces diluted in 10l of wells water

Figure 2 present the experiment of stimulation filtration trench

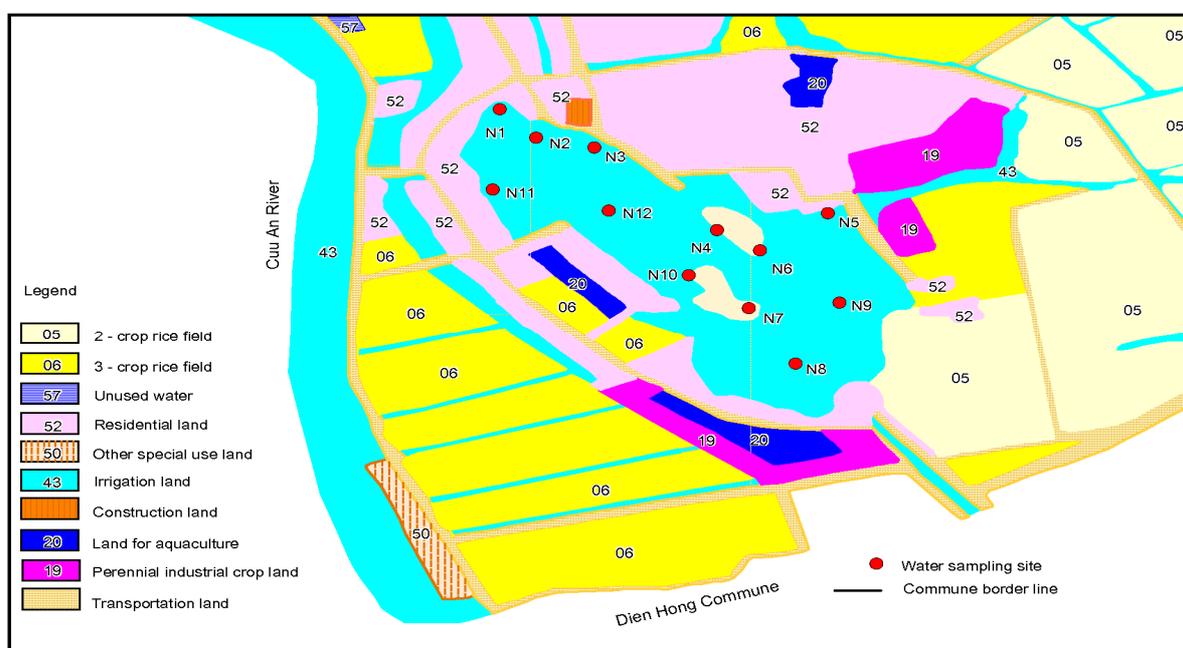


Fig. 1. Water sampling sites

Table 1. Water sampling site description

Sampling site no.	Sampling site	Geographic coordinates	Description
N1	At inlet-WEST North of the Lake	E: 105°43'27,3" N: 20°43'24,5"	Households near inlet
N2	Close to floating restaurant	E: 105°43'28,4" N: 20°43'23,8"	
N3	At the marina	E: 105°43'29,9" N: 20°43'23,5"	There are some small shop at the shore
N4	At the Western part of the New Island	E: 105°43'34,1" N: 20°43'18,9"	1.5m from shoreline, in the hyacinth plot (piece)
N5	At the North East drainage gate	E: 105°43'38,6" N: 20°43'19,9"	Close to Dong Trau rice field, households at the left site of the drainage gate
N6	At the South East part of the New Island	E: 105°43'35,9" N: 20°43'17,7"	3 m from shoreline, out of hyacinth plot
N7	At the South East part of the Old Island	E: 105°43'35,3" N: 20°43'15,7"	The water area between two island, no hyacinth
N8	At the South East part of the lake	E: 105°43'38,7" N: 20°43'11,6"	10 m from North East outlet (drainage gate)
N9	At the fishing tent in the South East part of the lake	E: 105°43'38,3" N: 20°43'15,3"	15 m from shoreline of New Island
N10	At the North West part of the OLD Island	E: 105°43'33,1" N: 20°43'17,1"	1.5 m from shoreline, no hyacinth
N11	At the North West part of the lake	E: 105°43'26,6" N: 20°43'21,3"	2 m from shoreline, on the lakeshore, there are some households
N12	At the centre of North West part of the lake	E: 105° 43'30,2" N: 20°43'20,5"	30 m from the Old Island

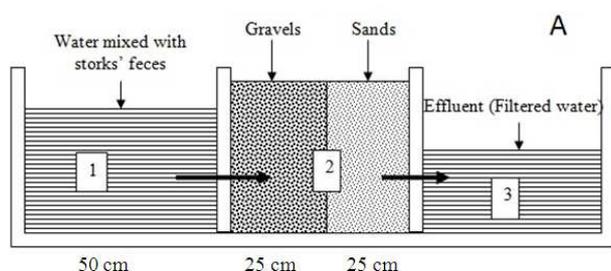


Fig. 2. (A and B): Experimental pattern of horizontal filter

2.8. Experiment with Hyacinth

- 3 separate foam boxes are used for experiment. Dimension of each box is 65×40×30 cm
- Water is taken from An Duong Lake
- Hyacinths with height (root + leaf) of 15-20cm.
- Hyacinths cover in: Box 1: 100% surface area of box; Box 2: 50% surface area of box; Box 3: 30% surface area of box



Fig. 3. Water treatment experimental pattern by hyacinths

Figure 3 present the experiment of water treated by hyacinth.

2.9. Tools

- Instruments for water sampling: DR 2010 (USA), Plastic bottle and container
- GPS, Portable instruments for water measurement (TOA Model U-10 Horiba-Japan)
- Maps
- Questionnaire

3. RESULTS AND DISCUSSION

3.1. An Duong Lake Water Quality

3.1.1. Water Pollution Sources

The main sources causing the degradation of An Duong Lake water quality:

- Storks' and cauldrons' feces: It is estimated that about 500 kg of storks' and cauldrons' feces produced per day. A large part of feces are

absorbed by the soil layers of the islands. The smaller amount of feces runs directly into lakeshore water (the water area surrounding islands). In rainy days, run-off from islands brings storks' and cauldrons' feces into the lake and cause pollution for the lake

- Domestic waste water: Everyday, about 140-150m³ of domestic waste water are discharged into An Duong Lake. This waste water come from households of An Duong Village in which 50 households are located on the lakeshore. Based on loading coefficient of domestic waste water (Table 2) provided by WHO, 1993, everyday, An Duong Lake may receive 75 kg BOD₅, 130 kg COD, 150 kg SS, 13.5 kg N, 5 kg Ammonia and 3.5 kg P_{total}
- Livestock waste water: There have been about 50 households around the lake having pig farms. Everyday, these households may discharge into An Duong Lake about 4-5 m³ of waste water. Base on the guideline of JSWA (1997) on Sewage planning for watershed, pollutant loading of pig farming discharged into An Duong Lake is estimated: 10kg of BOD₅, 35kg of SS, 2kg of N_{total} and 1kg of P_{total}

- Run-off: heavy rains (about 100 mL/day) may cause run-off in this area. It is estimated 1.800 m³ run-off of one heavy rain being discharged into An Duong Lake (300ha×100 mL⁻¹ × 60% of rain fall). Pollutant loading from run-off is calculated: 36kg of BOD₅, 4 500kg of SS, 57kg of N_{total} and 0.6kg of P_{total}

3.1.2. Water Quality

3.1.2.1. Dry Season (From December to April Next year)

In comparison with Vietnam National Technical Regulation 08:2008/BTNMT, in dry seasons, concentration of SS of Samples N2, N4, N5 is lower than B1 class, BOD₅ of N8 is lower than the Permissible level (B1 class). Concentration of COD of water samples N8, N12 is lower than B1 class. pH of all samples is nearly the same as pH Permissible level (Table 3).

Concentration of N-NH₄⁺ and N-NO₃⁻ is lower than Permissible level (both A2 and B1 class).

Analysis from Table 4 and Fig. 1 shows that quality of water area close to islands and residents (sample No. N1, N6, N7, N11) is lower than quality of water area which is far from islands and lakeshore line and covered by hyacinths (N4, N5, N12).

Table 2. Characteristics of An Duong lake water in dry season and wet season

Samples parameters	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	QCVN 08	
													A2	B1
Dry season														
SS	60.000	50.000	55.000	48.500	45.600	65.000	64.300	60.900	62.000	59.000	53.000	54.000	30	50
BOD ₅	31.000	29.000	30.000	21.000	42.000	25.000	24.000	11.000	34.000	35.000	39.000	15.000	6	15
COD	48.000	44.000	43.000	35.000	62.000	35.000	35.000	16.000	48.000	50.000	57.000	28.000	15	30
pH	7.070	7.210	6.890	6.970	6.840	7.150	7.230	7.190	7.010	6.640	6.870	6.970	6	-8.5
P _{total}	2.340	2.280	2.430	1.920	2.170	2.460	2.810	2.520	2.760	2.020	2.100	2.150		
N _{total}	5.460	5.330	5.550	4.910	4.200	6.150	6.500	5.760	6.000	5.060	5.130	4.640		
N-NH ₄ ⁺	0.015	0.016	0.017	0.012	0.013	0.018	0.020	0.019	0.018	0.012	0.013	0.016	0.2	0.5
N-NO ₃ ⁻	3.280	3.340	3.150	2.170	2.080	3.560	3.730	3.960	3.630	2.320	2.200	2.250	5	10
Wet season														
SS	51.600	48.000	50.000	44.300	42.000	59.000	60.500	57.800	54.000	53.900	52.500	51.000	30	50
BOD ₅	27.000	26.000	28.000	20.000	35.000	18.000	18.000	7.000	27.000	30.000	33.000	10.000	6	15
COD	41.000	38.000	41.000	29.000	51.000	26.000	25.000	13.000	38.000	45.000	54.000	16.000	15	30
pH	7.150	7.220	6.910	6.930	6.940	7.100	7.090	7.110	7.060	6.990	7.020	6.850	6	-8.5
P _{total}	2.040	2.190	2.220	1.900	1.960	2.230	2.450	2.610	2.580	1.700	2.010	1.890		
N _{total}	5.000	5.110	5.230	4.870	4.000	5.920	5.900	5.220	5.460	4.720	4.100	4.960		
N-NH ₄ ⁺	0.014	0.015	0.015	0.010	0.011	0.016	0.018	0.017	0.016	0.010	0.012	0.014	0.2	0.5
N-NO ₃ ⁻	3.200	3.120	2.950	2.110	2.290	3.420	3.330	3.260	3.250	5.200	1.960	3.160	5	10

Note: The classification of surface water to assess water quality and control, for purposes of water use vary; A1-Good use for water supply purposes and other purposes, such as type A2, B1 and B2; A2-For the purpose of water supply but to apply the appropriate; treatment technology; preservation of aquatic plants, or other purposes, such as type B1 and B2; B1-For irrigation purposes or other purposes required or similar water quality purposes as type B2 use; B2-Transport water and other purposes with low quality water requirements.

Table 3. Result of experiment of use hyacinth for water pollutant mitigation

No. Parameters	Experimental result (mg/L)			Treatment efficiency (%)	
	M0	M1	M2	M1	M2
1 pH	7.73	7.700	7.680	-	-
2 BOD ₅	38.40	5.720	18.740	85.1	51.2
3 COD	48.60	9.910	25.610	79.6	47.3
4 N-NO ₃ ⁻	0.33	0.087	0.209	73.5	36.8
5 P-PO ₄ ³⁻	0.39	0.085	0.310	78.2	20.5
6 SS	15.00	4.890	10.990	67.4	26.7

Note: M0: Water sample at first day (An Duong Lake water taken for experiment); M1: Water sample taken after fifteen days of experiment with hyacinth; M2: Water sample for blank (without hyacinth)

Table 4. Result of treatment of water containing storks' feces by horizontal filtration combined with EM

No.	Parameter	Unit	Results		Treatment efficiency (%)
			Sample 1	Sample 1	
1	SS	mg/L	215.00	62.00	71.16
2	BOD ₅	mg/L	54.00	17.20	68.14
3	COD	mg/L	63.00	27.00	57.14
4	pH		6.55	6.58	-0.00
5	P _{total}	mg/L	8.01	4.30	46.31
6	N _{total}	mg/L	14.20	7.12	49.85
7	N-NH ₄ ⁺	mg/L	5.60	1.76	68.57
8	N-NO ₃ ⁻	mg/L	23.10	5.84	74.71

3.1.2.2. Wet season (From May to October)

In comparison with Vietnam National Technical Regulation 08:2008/BTNMT, in wet season, concentration of SS of water samples N4, N5 is lower than B1 class and BOD of water samples N8, N12 is lower than permissible level (B1 class). Concentration of SS and BOD of the others is higher than class B1.

Concentration of COD of samples N8, N12 is lower than B1 class, concentration of COD of 10 other samples is higher than B1 class.

Concentration of N-NH₄⁺ and N-NO₃⁻ of all samples is lower than Permissible level (A2 and B1 class).

Concentration of SS of samples: N6, N7, N8 which are located near shoreline or drainage gate is higher than that of other samples.

Concentration of BOD₅, COD of samples: N1, N6 and N9 which are located near shoreline and households on lakeshore is higher than that of other samples.

3.1.2.3. Comparison

In dry season, water of An Duong Lake is more contaminated than in wet season due to small amount of water (rainfall and run-off) for diluting and significantly

decreased water level in the lake. Meanwhile, the pollutant loading of storks' feces, domestic and livestock waste water is almost constant.

Lake and island shore water is much more polluted than central water because of the tiny differences in water-in and water-out in term of its amount and velocity. This prevents the contaminants from moving into the central part of the lake.

3.2. Suggested Comprehensive Measures for Improving An Duong Lake Water Quality and Contribution to Stork Islands Conservation

3.2.1. Water Hyacinth (*Eichhornia crassipes*) Growing (dropping) for Water Pollutant Mitigation

The field survey and results of interviewing people living around An Duong Lake demonstrate that hyacinths are floating plants which are used for feeding domestic animals (cattle, pigs, chickens...) by farmers. In addition, the wind can easily wear out the water hyacinth cover and push it to move. It means hyacinth has a very good adaptation in the water environment and has capacity to remove organic matter containing in water (Loan and Huy, 2006; Thao, 1999; Yem *et al.*, 2010). Therefore water hyacinth has been selected as a pollutant-remover for the lake water. The result of field tests and experiments shows that hyacinth can remove 73.5% NO₃⁻, 78.2% PO₄³⁻, 85.1% BOD₅, 79.6% COD and 67.4% SS. Hyacinth's long and thick roots have supported to absorb a large amount of nutrient substances as well as other pollutants in water (Loan and Huy, 2006; Loan and Quy, 2010). On the other hand, this root is also as a "substrate" helping the microorganism's adhesion, growth and development and rapidly reduces the concentration of organic matter in the water (Yem *et al.*, 2010). After 15 days of experiments, water hyacinths are found out to grow very well (hyacinth cover increasing) (Fig. 4).

3.2.2. Reed (*Phragmites Communis*) Growing for Water Pollutant Mitigation

Reed (*Phragmites communis*): Reed can grow everywhere especially in hot and humid climate (tropical climate), the optimal environmental temperature for reed growth is 12-30°C. Reed can grow in water at the depth of 30-150 cm and with the pH = 2-8 (Loan and Huy, 2006; Thao, 1999). Reed's root grows very quickly and adheres to the soil. Around the reed's root in the soil, there are many bacteria like in the aeration tank.



Fig. 4. Hyacinth in a Duong Lake

Therefore reed fields could be used as a biological treatment unit for domestic and industrial waste water. In the 60s of the 20th century and recent years, Kathe Seidel and many others have applied this method for waste water treatment with the efficiency of 80-90% for NH_4^+ , NO_3^- , PO_4^{3-} , BOD_5 , COD , Coliform (Yem *et al.*, 2010).

Base on previous studies (Loan and Huy, 2006; Loan and Quy; 2010, Phuong *et al.*, 2011; Thanh, 2010, Vymazal and Kropfelova, 2008; Minh and Tuan, 2005) and An Duong Lake field survey, reed planting (15 reeds/ m^2) along some important sections of An Duong lakeshore and in the canal connecting An Duong Lake with Trieu Duong Lake is highly recommended (Fig. 5).



Fig. 5. Reed plants (*Phragmites communis*)

3.2.3. Septic Tank Toilet for Treatment Domestic Waste Water

At present, that An Duong lakeside households have no septic tank toilet and their domestic waste water without any treatment are discharged directly into the lake contributes to water pollution of An Duong Lake (Anh, 2008; Yem *et al.*, 2009; Yem, 2012). It is essential to set up domestic waste water treatment facilities for households in the village. 3-Compartments latrine is recommended for each household.

3.2.4. Treatment of Livestock Wastes

Currently, about 50 An Duong lakeside households have pig farming and its waste water and manures are directly discharged into the lake (Anh, 2008; Yem, 2012). Two measures for livestock waste treatment are suggested:

- Household scale biogas production
- Septic tank for collection and treatment of livestock waste water

3.2.5. Filtration in Combination with EM for Mitigating Pollutant in Run-Off

Trench around stork islands should be constructed. The trench is filled gravels and sands and it is considered as a horizontal filter. The experiment of filtration in combination with EM for reducing pollutant in run-off from islands was conducted.

EM technology was invented by Dr. Higa of Ruykyus University, Okinawa, Japan and applied in practice in the early 1980 (CDVJT, 2008).

EM products are currently used in many fields, especially for environmental pollution mitigation. EM can be used for livestock waste water treatment and clean-water of shrimp pond, EM can also be used for solid waste disposal and treatment of lake water in general (MONRE, 2005; Pham, 1998).

By this reasons, EM is used in this study to reduce storks' and cauldrons' feces in run-off by gravels and sands filtration in combination with EM.

In the experimental process (Fig. 2), dilution of EM and Molasses by percentage is as follow:

- EM 5%
- Molasses (or brown sugar) 5%
- Fresh water 90%

Use 0.1 liters of EM added to the compartment No. 2 (compartment with gravels and sands) (the dose recommended by the manufacturer is 1/1000 compared to the amount of waste water), after about 4-5 days, water is taken from compartment No. 3 for chemical analysis in laboratory.

The experimental results show that the filtration system using sand, gravel in combination with EM has reduced a large portion of storks' and cauldrons' feces in run-off from islands flowing into the lake. The treatment efficiency (% removed) of this system is described well by the following statistics: SS (71.16%), BOD5 (68.14%), COD (57.14%), P_{total} and N_{total} (46.31% and 49.85% respectively), $N-NH_4^+$ and $N-NO_3^-$ (68.57% and 74.71% respectively). Waste water treatment system using EM should be very effective if EM is supplemented in the earlier stages. This may promote and enhance the activities of microorganisms. Use of EM is also a good method for reducing odor from wastes.

3.2.6. Fish Farming

The nutrients nitrogen and phosphorus in water will promote growth and development of phytoplankton species (Crites, 1998; IWA, 2011; Thao, 1999). Along with the nutrients, organic material of plant species is also considered as an abundant food source for fish. Thus, fish with a certain scale of its population will help clean water and balance the ecosystem of the lake. In many lakes polluted by organic medium such as West Lake, Hoan Kiem Lake, fish farming method is regarded as the simplest measure that helps improving water quality while maintaining economic efficiency and diversifying tourism activities.

3.2.7. Pollution Sources Control and a Duong Lake water Monitoring

Periodical control should be implemented for An Duong Lake water pollution sources such as: source of storks' and cauldrons' feces, domestic activities, livestock and tourism activities. Pollution sources control focus on:

- Making list of pollution source (pollution source description)
- Treatment facilities
- Wastes discharge facilities and drainage
- Activities of tourists and visitors
- People's compliance with environmental regulations

Monitoring for An Duong Lake water quality should be implemented as follow:

- Monitoring site selection: 12 proposed site as showed on Fig. 1
- Monitoring parameters: toC, pH, turbidity, SS, DO, BOD, COD, $N-NH_4^+$, $N-NO_3^-$, P_{total} , N_{total} , heavy metal, Coliform
- Monitoring frequency: twice a year (dry and wet season)

4. CONCLUSION

An Duong Lake is being regarded as an important part of the habitat of storks and cauldrons, fish farming and ecotourism, but the quality of water has been degraded by increasing storks' and cauldrons' feces, domestic, livestock wastes and run-off. To conserve storks and cauldrons and develop ecotourism, comprehensive measures for improving water quality should be implemented.

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