# Purification Performance of Biological Water Purification System in Amagasaki Canal

by

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Amagasaki Canal has been polluted because it is sheltered by artificial vertical structures and is contaminated by waste water from factories. To restore the water quality in the brackish water to meet recreational demands, a new water quality improvement plant was constructed in May of 2012, on the basis of the findings of the Amagasaki Sea Blue Project of Hyogo Prefecture. The new water quality improvement plant comprises a tank for removing suspended solids and an algae channel with algae harvesting for composting by civic collaboration. The suspended solids removing tank reduces organic suspended solids in the pumped surface seawater and converts organic suspended solids to dissolved nutrients using bivalve biology. Algae channels serve to assimilate the dissolved nutrients in the canal's treated water from either the suspended solids removing tank or the water pumped up from the bottom of the sea, using the primary productivity of green algae and blue-green algae that grow naturally in the channel. In this study, we quantified purification effect of the system by field observation. In the algae channel, the dissolved inorganic nitrogen (DIN) and $PO_4$-P reduction function was estimated by measuring the distribution of dissolved nutrient in channel. The values after reduction by advanced sewage treatment were varied in every season because amount of algae and concentration of nutrient were varied seasonally, especially about more than 65% of the amount of DIN was removed in the channel. Purification rate of the suspended solids removing tank was estimated more than 42% until summer and the rate decreased in winter because lack of food (phytoplankton) for bivalves occurred in the tank.

**Key words**: Amagasaki Canal, *Xenostrobus secures*, Water quality restoration, Biological Nutrient Removal

## 1. Introduction

The Amagasaki Canal is located in the northern part of Osaka Bay, Japan (see Figure 1). The Amagasaki Canal is an enclosed area of the sea with two water gates and sheltered by artificial vertical structures. Eutrophication and a high concentration of suspended solids is a serious problem in this area throughout the year. There is deteriorated sediment, and anoxic oxygen water near the sea bottom, on account of which fish were killed by blue tides. To improve the water quality, the Hyogo Prefecture authorities started "The Sea Blue Project of Amagasaki" in 2006. To restore the water quality in the canal to meet the recreational demands, a new restoration plant was designed for a new water quality improvement system on the basis the findings of the Sea Blue Project of Amagasaki. Due to the project's requirements such as low cost, low environmental load, and sustainability, we decided to apply biological techniques and use a civic collaborative approach (*e.g.* Mori et al,2009 and Yamanaka et al, 2008 ). The objective of the study was to evaluate the purification ability of new water quality improvement techniques in the Amagasaki canal, which was constructed in March 2012. In particular, the reduction function of nutrients was examined.

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The new water-quality-improvement-plant consists of three different parts (see Figure 2). The first part removes suspended solids using bivalves. The second part removes dissolved inorganic nitrogen (DIN) and phosphorus (DIP) from the channel using algae. The third part was expected water self-purification and to provide a benthic habitat of tidal flat. Figure 3 shows the material flow in the new system. First, surface and bottom seawater in the canal is pumped into the first part of the experimental setup called SS-Removal-Tank. This part reduces organic suspended solids in the water and converts the organic suspended solids into dissolved nutrients using bivalve biology. The second part, Nutrient-Removal-Channel, assimilates dissolved nutrients in the treated water from the first part using green algae and blue-green algae that grows naturally in the channel. The third part removes both organic and inorganic nutrients using benthic organisms of tidal flat. Finally, the fourth part removes nutrients from the system by removing enriched bivalve and algae by participatory cleanup action and local citizen composted all collected marine organism. In this study, we focused on the first and second part of the system.

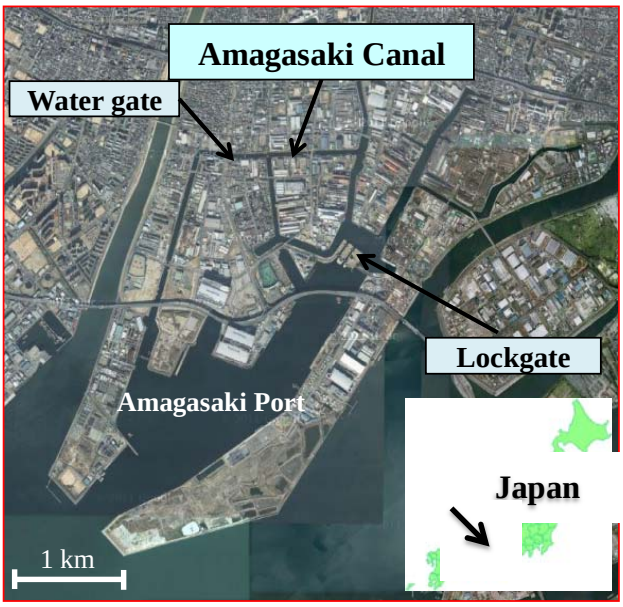



Fig.1 Location of study site. Amagasaki canal is enclosed brackish canal surrounded by reclaimed area. Water level is controlled strictly because ground height of the area is below sea level.

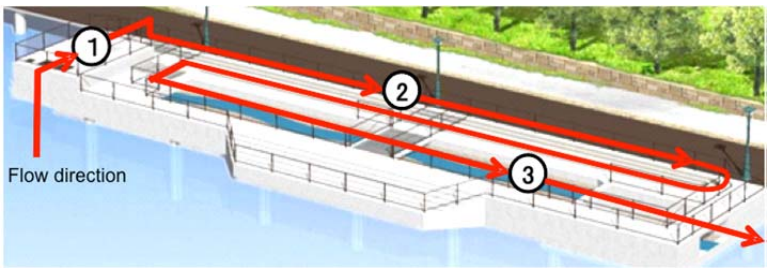



Fig.2 Structural configuration of the water-quality-improvement-plant. The plant was semi-submerged concrete structure with 35 m in length and 7.6 m in width. Eutrophic canal water was pumped up and run down following the number shown in the figure

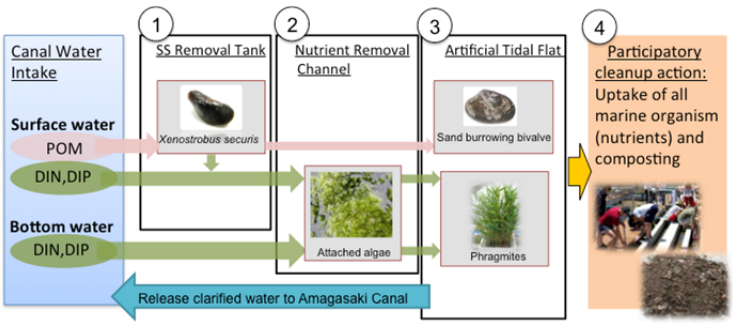



Fig.3 Material transport system of the Water-Quality-Improvement-Plant.

## 2.Method

### 2.1 Removal ability of SS-Removal-Tank

Nutrient transport rate of an adhesive bivalve (*Xenostrobus securis*), which was one of the dominant species in Amagasaki Canal, was measured by field experiments in summertime. The experiment was conducted during the period from September 19th to September 20th. Figure 4 shows a sectional plan of the tank. A colony of *Xenostrobus securis* was cultured using hanging rope in the middle depth of the tank. An amount of inputted bivalve was 24 wet.kg. The tank was covered by a hatch for the avoidance of primary production. Canal water was pumped up from the depth of 1 m of Amagasaki Canal and influent quantity was held 25 L/min constant. The water volume of the tank was 1800 L and a residence time of water was 72 minutes. Water sampling was conducted at the points that were shown in Fig.4. Sampling point A and B were set for evaluating a reduced rate of particulate organic nitrogen (PON) and point C was for evaluating a feces production rate of the bivalve. Water sampling was conducted at 14:00 and 20:00 on September 19 and 8:00 on September 20. In this study, we estimated PON reduction rate of the bivalve colony by following equation (1).

$$R_{PON} = \frac{PON_{in} - PON_{out}}{PON_{in}} \times 100 \qquad (1)$$

where

$R_{PON}$: PON reduction rate (%)

$PON_{in}$ : Concentration of PON of influent water (mg/L)

$PON_{out}$: Concentration of PON of effluent water (mg/L)

Similarly, we estimated reduction rate of Chlorophyll-a by following equation (2).

$$R_c = \frac{Chl.a_{in} - Chl.a_{out}}{Chl.a_{in}} \times 100 \qquad (2)$$

where

$R_c$: Chlorophyll-a reduction rate (%)

$Chl.a_{in}$ : Concentration of chlorophyll-a of influent water (mg/L)

$Chl.a_{out}$: Concentration of chlorophyll-a of effluent water (mg/L)

A feces production rate of the bivalve was estimated by a difference of concentration at point C during 10 minutes under the condition of no inflowing water. Water quality of nitrogen and phosphorus were analyzed by TNTP Auto Analyzer (BLTEC AACS-V) . Concentration of particulate organic nitrogen was analyzed by NC Soil Analyzer (Thermo Finigan Inc.) . Concentration of Chlorophyll-a was estimated by DMF method and Lorenzen's method (1968).

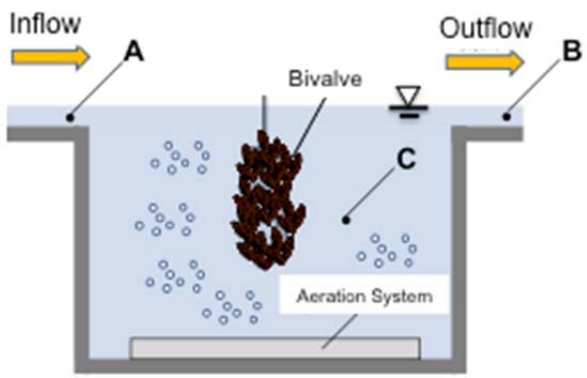



Fig.4 A sectional plan of the SS removal tank and observation points.

### 2.2 Nutrient reduction rate of Nutrient-Removal-Channel

A schematic of the Nutrient-Removal-Channel is shown in Fig.3. The small channel is a concrete structure with 60 m in length, 0.3 m in width and about 0.2 m in depth. Seawater from the surface and bottom of the canal was pumped into the channel though SS-Removal-Tank by adjusting the flow rate to 25 L/min. We monitored water temperature and concentration of

nitrogen once a month at the start and end point of the channel. Sampling water was filtered on site immediately (GF/C:Whatman), and after taking due care to avoid light and heat exposure, the samples were brought back to the laboratory, where $NO_3$-N, $NO_2$-N, $NH_4^+$-N and $PO_4^{3-}$-P concentrations were analyzed using a TNTP automatic analyzer (AACS-V: BLTEC).

## 5. Results and Discussion

### 5.1 Removal function of SS-Removal-Tank and a mechanism of its variation in a day

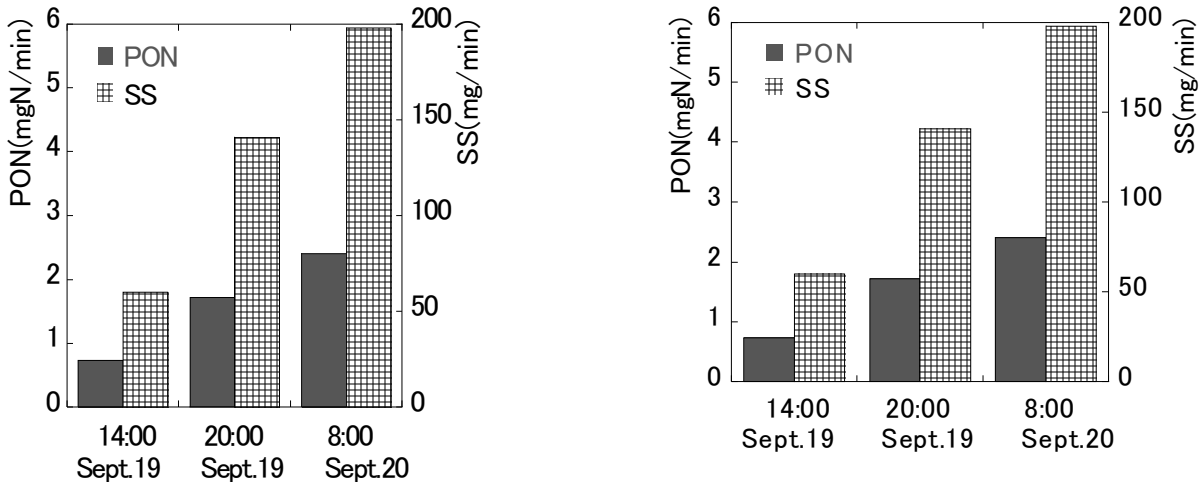
Figure 5 shows the mass inflow rate of Chlorophyll-a, Suspended Solids (SS) and Particulate Organic Nitrogen (PON) of surface water. The rate of Chlorophyll-a was increased slightly in a day and remained at high value. On the other hand, the mass inflow rate of SS and PON increased in a day and represents the maximum value at 8:00 on September 20th. It requires a further examination to clarify a mechanism of the water quality variation because SS and PON were consisted of not only phytoplankton but also the small decomposed detritus and zooplankton, and also dominated by flow and stratified condition in the Amagasaki Canal. Figure 6 shows a removal rate and the ratio of the tank that was estimated by eq. 1 and 2. Material removal rate and ratio of Chlorophyll-a was almost stable in a day and the ratio was about 42 %. We assumed before the experiment that an activity of food consumption of the bivalve has a diurnal rhythm. However, it was not founded significant tendency of the diurnal rhythm from the result of Chlorophyll-a. Meanwhile, the removal rate of PON changed drastically in a day. Especially, removal ratio of PON decreased at 20:00 on September 19th in spite of the concentration of PON was increasing which was shown in Fig.5(b). The PON removal ratio was almost same as the one of Chlorophyll-a only except at 20:00 on September 19th. The removal rate decreasing at night might be caused by (A) declining in activity of food consumption of the bivalve, (B) increasing of uneatable PON in inflowing water and/or (C) declining of bivalve's digestive efficiency. There is the contradiction between the assumption (A) and result of removal rate of Chlorophyll-a. The assumption (B) is possible, but if the assumed situation was caused by increasing of zooplankton, the removal rate of Chlorophyll-a at night might decrease more. The assumption (C) looks most possible if bivalves only decomposed inhaled PON and egested it without absorption. Figure 7 shows that bivalve's fecal shedding rate of the moment. According to the result, it seems that bivalve digestive efficiency was low at night because the fecal shedding rate didn't increase in spite of the concentration of PON of inflowing water was increasing at night. It seems that this result back up the assumption (C).

### 5.2 Nutrient reduction ratio of Nutrient-Removal-Channel

Monthly variation of nutrient reduction ratio of Nutrient-Removal-Channel was shown in Figure 8. The nutrient reduction ratio represents a ratio of DIN and DIP which was assimilated by green algae and blue-green algae while seawater flowed down a distance of 60 meters long in the daytime. For example, 65% of inflowing dissolved nitrogen was assimilated by algae in July of 2012 and this is the highest value of observed data. Kunoh(1997) and Sato(2004) have pointed out that high activity causes the water temperature to rise in spring and autumn, while water temperature drops down in the winter due to loss of activity. Meanwhile, maximum value for dissolved inorganic phosphorus appeared in April due to decreasing of DIP concentration during springtime in the Canal.

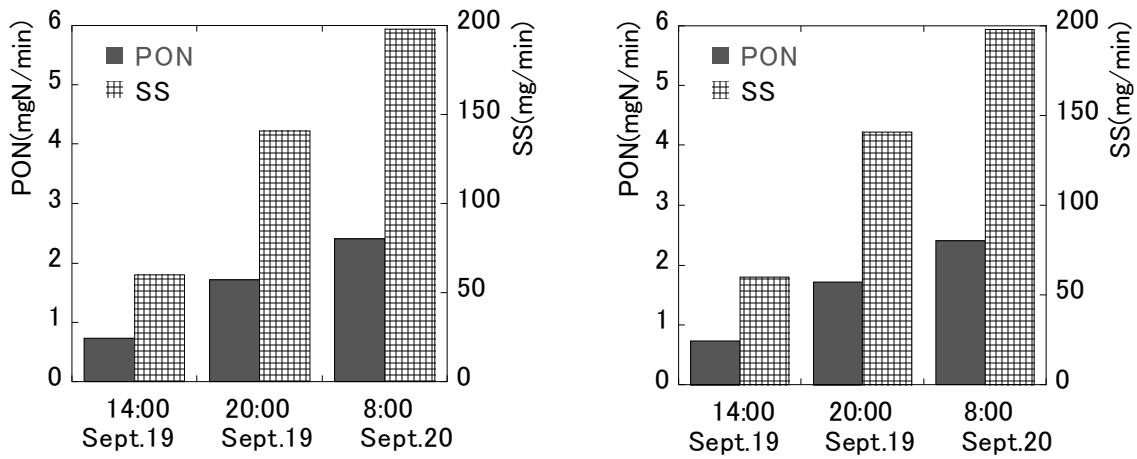
Figure 9 and 10 shows a nutrient concentration at the start and the end point of the Nutrient-Removal-Channel on September 19th, 2012. Both DIN and DIP were decreasing in the daytime. On the other hand, DIP was increasing in the nighttime due to a nutrient recurrence from a decomposed algae in particular. We calculated an amount of removed nutrient of the day

using the observed data in Fig. 9 and 10. We assumed daylight hours is 12 hours and it became 3.24 gN/day of DIN and 0.132 gP/day of DIP in the case of the removal rate was 19%. It was estimated by considering of difference of the removal rate, maximum value of the amount of daily removed nutrient was estimated to 11.1 gN/day of DIN and 0.45 gP/day of DIP in the case of the removal rate was 68% which appeared in July. Here, we compared these values with an inflow load from a factory which was confined to the northern part of the Canal where the new plant is located. Inflow loads of T-N and T-P were about 2.2 (kg/day) and 0.002 (kg/day) respectively, which were obtained from a report by the Amagasaki City in 2012. According to these values, the inflow load quantity was about 200 times of T-N and 4.5 times of T-P than the eliminable amount of one water-quality-improvement-plant. As a result of this rough estimate, it is considerable that there should be five the plant for phosphorus to avoid from DIP accumulation in the high season of algae activity only for the north part of the canal.




(a)Chlorophyll-a (b) PON and SS

Fig.5 Mass inflow rate of Chlorophyll-a, Particulate Organic Nitrogen (PON) and Suspended Solids (SS) of surface water to the SS-Removal-Tank. Inflow discharge to the tank was set to 25L/min.




(a) Chlorophyll-a (b) PON

Fig.6 Material removal rate and ratio of the SS-Removal-Tank.

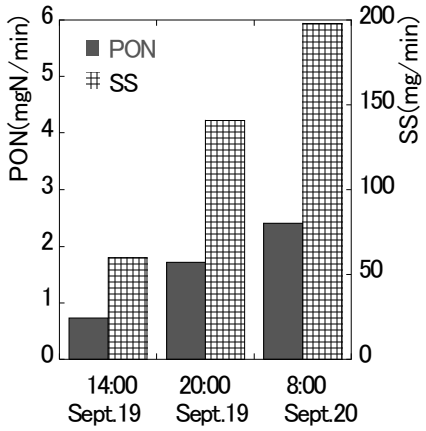



Fig.7 Bivalve's fecal shedding rate in the SS-Removal-Tank

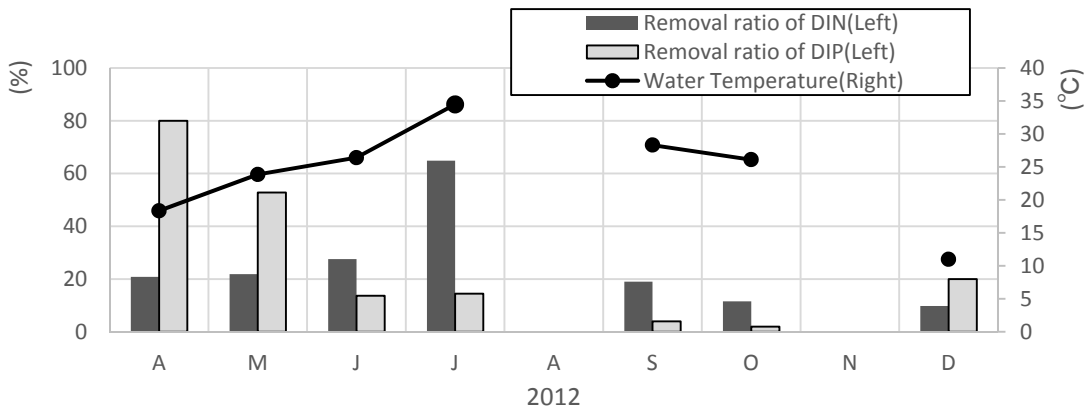



Fig.8 Monthly variation of nutrient reduction ratio of Nutrient-Removal-Channel and water temperature

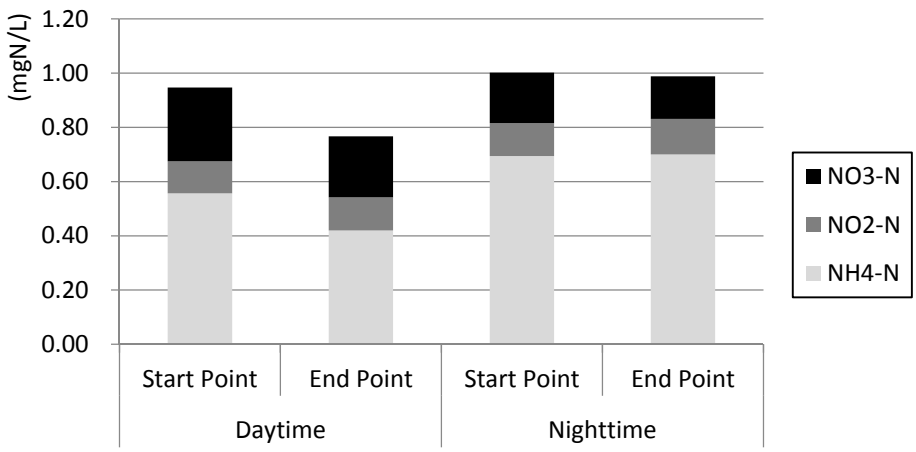



Fig.9 DIN concentration at the start and the end point of the Nutrient-Removal-Channel on September 19th, 2012

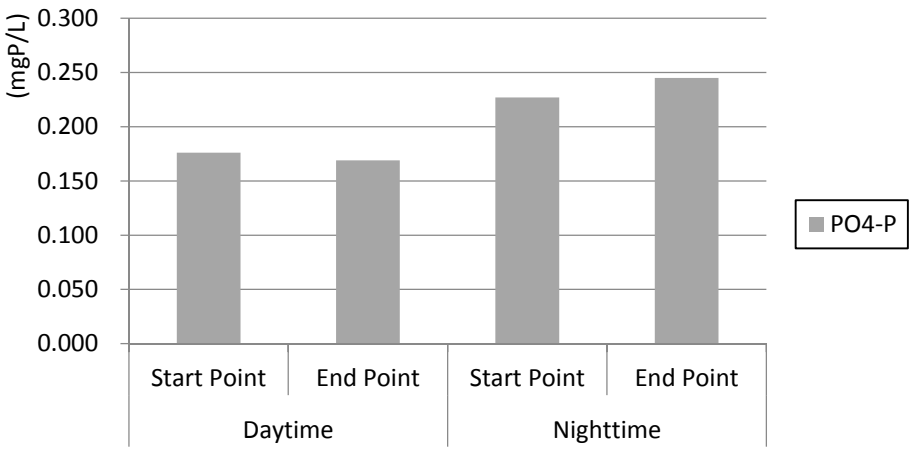



Fig.10 DIP concentration at the start and the end point of the Nutrient-Removal- Channel on September 19th, 2012

## 6.Conclusions

In this study, we evaluated the applicability and effectiveness of a new technology in improving the water quality in the Amagasaki Canal through field observation. The applicability of a water restoration plant using dominant adhesive bivalves and autogenetic algae to the Amagasaki Canal was confirmed by our field experiment. We found the water quality improved in the tank and the channel. Five 60-m channels at least are needed in the north part of the Canal for removing DIP which included in the industrial waste water. According to avoid a nutrient recurrence from a decomposed algae, proper maintenance by cleaning up the decomposed sea algae is required. For this purpose, we have already started a cooperative framework with local junior high school students to convert algae into compost. This indicates that a new water quality restoration system along with citizen participation can be implemented at the Amagasaki Canal. We believe that continued efforts will help restore the water quality in the Amagasaki Canal in an environmentally clean manner.

## Acknowledgements

This study was conducted as part of The Sea Blue Project in Amagasaki (Hyogo Prefecture). We thank our stakeholders for their tremendous cooperation. This work was supported by Grant-in-Aid for Young Scientists (B) Number 23710059.

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