ORIGINAL ARTICLE

Treatment of Linear Alkyl Benzene Sulfonate in an Intermittent Cycle Extended Aeration System

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Abstract

Background: Discharge of raw or treated wastewater containing linear alkyl benzene sulfonate (LAS) into the environment causes significant public health and environmental problems. The purpose of this study was the treatment of hospital wastewater using an intermittent cycle extended aeration system (ICEAS).
Methods: Experiments were carried out on Yazd Shohaday-e-Kargar hospital wastewater treatment system and samples were collected in a 2 month period from the influent and effluent of the system. The used pilot study carried out consisted of two zones: pre-react and main react zones. They were divided using a baffle wall. Firstly, wastewater enters a pre-react zone and then through the opening at the bottom of the baffle wall it enters the main react zone. The cycle time and flow rate for the system were considered 6 h and 2 L/h, respectively. Then, the necessary tests were performed on the system's influent and effluent.
Results: The removal of BOD_5, COD, and LAS by ICEAS were 94.54%, 92.97%, and 84.99%, respectively. The averages of SVI, F/M, MLSS and MLVSS in the system were 113 mL/g, 0.086 $Kg.BOD_5/Kg.MLSS.d$, 4327 mg/L and 3172 mg/L, respectively.
Conclusion: This work showed the excellent efficiency of ICEAS to effectively remove BOD_5, COD, and LAS from hospital wastewater. The results of this research can help to manage wastewater treatment in hospitals.

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Introduction

Development of hospital wastewater management has received enhancing attention throughout the world since hospitals produce a significant amount of medical waste each year.[1] Production of waste in hospitals has been increasing due to the improvement of medical services and products. Today, several thousands of additives are used for drugs and other products.[2] In hospitals, a diversity of materials besides pharmaceuticals are used for medical objectives, including diagnostics and disinfections. Besides the active materials, formulation adjutants, pigments, and dyes are also drug components. Disinfectants, in particular, are often complex products or mixtures of active materials. After application, many drugs are excreted non-metabolized by the patients and enter into wastewater. Diagnostic factors and disinfectants also reach the wastewater as residual quantities.[3]

Different studies reported that quality of hospital wastewater is similar to medium strength values of the domestic sewage. The discharge standards for hospital wastewater should adjust to EPA, 1986. The tolerance limit for sewage effluent discharged into surface water source will be per BIS standards IS 4764:1973.[4]

LAS is most common synthetic anionic surfactant so that it generates 1,040,000 ton per year in the USA and Western Europe.[5] Some researchers have reported that 0.02–1.0 mg/L of LAS in the aquatic environment can damage fish gills, cause excess mucus secretion. LAS concentration of 40–60 mg/kg.dry.wt. of sludge interfere with the reproduction and growth of soil invertebrates and earthworms.[6,7] Surfactants are also responsible for causing foam in rivers and effluents of treatment plants and reduction of water quality.[6]

Wastewaters can treat through various physical, chemical, and biological methods. Activated sludge process is one of the biological treatment processes which have various modifications. One of these systems is sequencing batch reactors (SBR) which have proved can be an efficient method for wastewater treatment.[8] Up to now, a large number of developed and developing countries have succeeded in the usage of SBR for the treatment of municipal and industrial wastewater.[8] The ICEAS rector is a kind of activated sludge processes which operates with continues flow.[9] The conventional SBR has five phases including fill, react, settle, decant and idle; but the ICEAS has three phases including react, settle, and decant.[10] The ICEAS has several advantages including no need to the primary and secondary settling tank, operation cost reduction, high efficiency, the simplicity of operation, high nitrogen and phosphorus removal efficiency, and bulking sludge reduction.[9] ICEAS has been approved of possessing removal efficiency of BOD_5, COD, total kjeldahl nitrogen (TKN), total suspended solids (TSS), and mean removal efficiency for total nitrogen (TN), total phosphorous (TP).[11]

In different studies are used the SBR various modifications to remove organic materials and detergents from wastewater including advanced sequencing batch reactor (ASBR),[8] intermittent cycle moving bed biofilm reactor (ICMBBR),[11] and integrated anaerobic-aerobic fixed film bioreactor (IAAFFBR)[12] have been investigated. Some researchers used from ICEAS reactor to removal of different organic materials such as nitrogen and phosphor,[9] sodium dodecyl sulfate,[13] TN, TP, COD, and BOD_5,[10] nitrogen, phosphor, and heavy metal.[14] Khararjian et al.[15] reported that more than 100 plants worldwide and 25 within USA that are built and operating successfully by ICEAS reactor. In different studies has been used from ICEAS mainly to the treatment of the municipal and industrial wastewaters. Few studies have been conducted to the treatment of the hospital wastewaters using ICEAS. Although many years have passed since the establishment of health and medical centers in Iran, the problem of hospital wastes (solid and liquid) has not been solved yet. Due to the appropriate properties of the ICEAS system for wastewater treatment and the inefficiency of other wastewater treatment systems of Yazd town in removing detergents, Yazd's company of water and wastewater has designed an ICEAS system to treat the hospital wastewater. Therefore, the primary objective of this work was to investigate the removal efficiency of BOD_5, COD, and LAS under the ICEAS system.

Materials and Methods

The chemical materials used in this study was including chloroform, sulphuric acid, sodium hydroxide, sodium dihydrogen phosphate monohydrate, methylene blue, phenolphthalein, LAS standard solution, and isopropyl alcohol. All chemicals were purchased from Merck Company (purity: 99.7%, analytical grade, Germany). The rate of absorption of the standard samples at a wavelength of 652 nm was measured by a UV-visible spectrophotometer (LAMBDA 750 UV/Vis/NIR Spectrophotometer, Perkin-Elmer, USA). The reactor was controlled by the LED timers (SUDT-110-4-4, Signaworks, USA). The amounts of dissolved oxygen were measured by the DO meter (Kit-850049, Sper Scientifi, USA). The amounts of COD were determined by the electrothermal soxhlet (Electrothermal™ EME60100CEB, Fisher Scientific, USA). The samples were dried and cooled by the kiln (Easy-Fire E28T-3 Kiln, Bigceramicstore, USA) and the desiccators (EF5453A243025, Daigger Scientific, USA), respectively.

The study was carried out using a pilot plant (L=35 cm, W=25 cm, and H=35 cm) with a capacity of 30.62 L (Figure 1). The reactor was placed in the Yazd

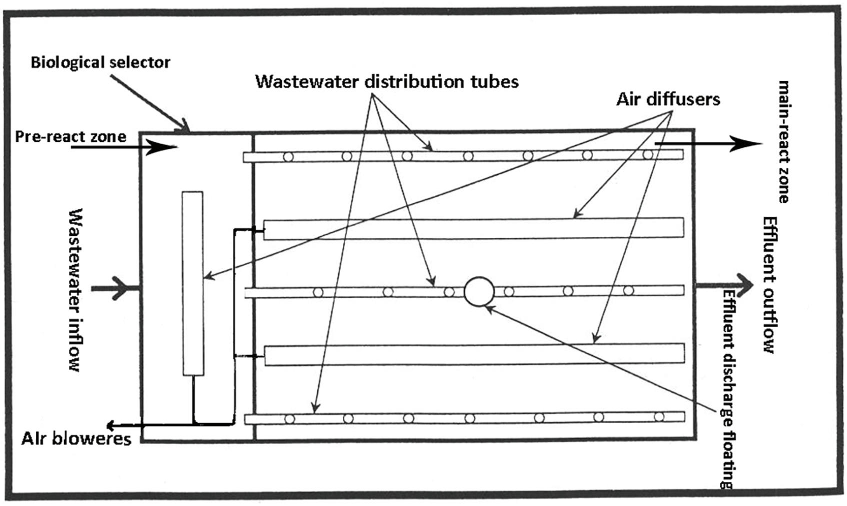

Figure 1: A view of the ICEAS rector

Shohaday-e-Kargar hospital wastewater treatment plant. The ICEAS reactor was started up using activated sludge from return line of settling tank in the hospital wastewater treatment plant. Considering the flow rates (1, 1.5, and 2 L/h) and retention times (2, 4 and 6 h), to obtain piston flow in the reactor was designed. With the different experiments, the best cycle time and flow rate for the system were considered 6 h and 2 L/h, respectively. The air pump and several diffusers provided required air and mixing in temperature domain between 20–30 °C. Wastewater flowed to the pre-react zone using a dosing pump and then entered the main-react zone through openings in the bottom of baffle wall. The system was controlled by automatic five LED timers. A view of the ICEAS reactor illustrated in Figure 1.

After completing the reactor construction, the system was operated continuously for 5 days to achieve a steady state in BOD_5, COD and LAS removal. To provide high F/M ratio and prevent of filamentous bacteria growth (cause of bulking sludge), the wastewater entered the pre-react zone (biological selector) which had a low MLSS concentration. After a short time (about 1.5 h), the wastewater entered the main-react zone. During each 24 h, hospital wastewater was treated in two cycles of 6 h.

The reactor had three phases including reacting (3 h), settle (2 h), and discharge (1 h). In the react phase, the air diffusers provided a mixture of MLSS in the aeration tank. In the settling step, a thick sludge blanket was formed. Because of this thick blanket, the entered wastewater did not disrupt. Microorganisms consumed organics during passage to this layer. In the discharge phase, using discharge mechanism, a clear supernatant was discharged.

During 2 months, sampling was done in 20 days. The samples were obtained from the system influent and effluent using appropriate sampling containers. Considering the variability of the quality and quantity of the hospital wastewater, two samples daily collected from the system's influent and effluent. The samples sizes were determined based on the number of necessary samples for each experiment. The necessary tests, including BOD_5, COD, LAS, MLSS, MLVSS, SVI and F/M were performed on the system influent and effluent during 20 days. After collection of data, the results were analyzed by the Excel (Ver. 2007) and Matlab (Ver. 2016) software.

For determinate the concentrations of LAS, first, the sample solution was poured into the separator funnel. It was alkaline by adding NaOH 1N, and 10 drops of phenolphthalein. The pink color was wiped by adding H_2SO_4 1N. To prevent the formation of emulsions, 10 mL chloroform, 25 mL methylene blue, and 10 mL isopropyl alcohol were added to the sample. The separator funnel was agitated for the 30s and allowed to separate phases. The accumulated pressure was released by tilting the hopper and fast opening valve. Before emptying the chloroform layer, the samples were gently agitated to be fully settled. This way, the chloroform phase and the aqueous phase were placed at the separator funnel top and bottom sections, respectively. After separating the layers, the chloroform layer was poured into another separatory funnel. Then, using 10 mL of chloroform, the extraction operation was repeated three times. All materials obtained from the chloroform extraction poured into the second separator funnel. After that, 50 mL washing solution (6.8 mL H_2SO_4 + 50 g $NaH_2PO_4 \cdot H_2O$ + distilled water) was added and agitated vigorously for the 30s (at this stage, the emulsion was not created). After depositing, the chloroform layer separated from the aqueous phase was transferred into 10 mL volumetric flask. The volume of chloroform extracted after pouring in a volumetric flask reached 100 mL with chloroform. Then, before measuring, contents of the volumetric flask were agitated several times by mixing. Spectrophotometer system measured the rate of absorption of the standard samples at a wavelength of 652 nm against the control chloroform. By having absorption rate and standard concentration, calibration curves were drawn (Figure 2).[16] BOD_5, COD, MLSS, MLVSS, settleable solids, and SVI were analyzed based on standard methods for water and wastewater examination.[16]

The F/M ratio is required for determining the biological mass for the nitrification loads. This parameter shows the activated sludge system organic load. The F/M ratio used for the ICEAS system was in the range of 0.05–0.2 kg.BOD_5/kg.MLSS.d. In this work, the ratio of F/M was calculated by the following equation (Eq. 1):

$$F/M = Q \times BOD_5 / V \times MLSS \qquad (1)$$

In this equation, Q is wastewater stream rate per day (m^3/d); BOD_5 is biochemical demand oxygen per day (mg/L); MLSS is mixed liquor suspended solids per day (mg/L), and V is aeration tank volume (m^3).

Results

The results of the study showed that the average removal efficiency BOD_5, COD, and LAS using ICEAS reactor were 94.54%, 92.97%, and 84.99%, respectively (Figure 3).

Another investigation showed that the averages of MLSS and MLVSS in the main reaction chamber were 4327 and 3172 mg/L, respectively (Figure 4).

Figure 5 shows that the maximum, minimum and average of SVI in the main reaction chamber were 174, 92 and 113 mL/g, respectively.

Also, Figure 6 indicates the maximum, minimum

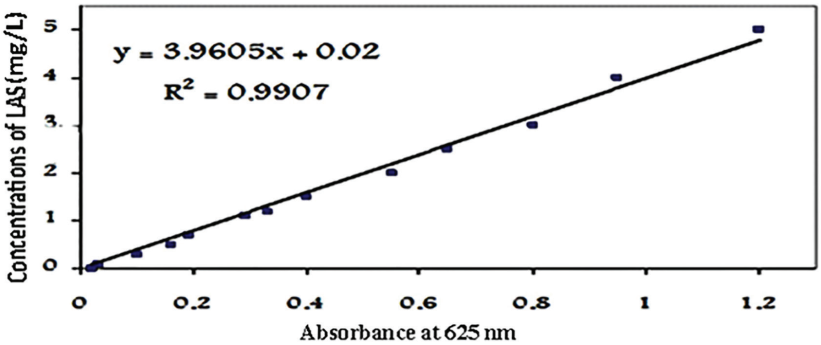

Figure 2: Calibration curve of the LAS concentrations.

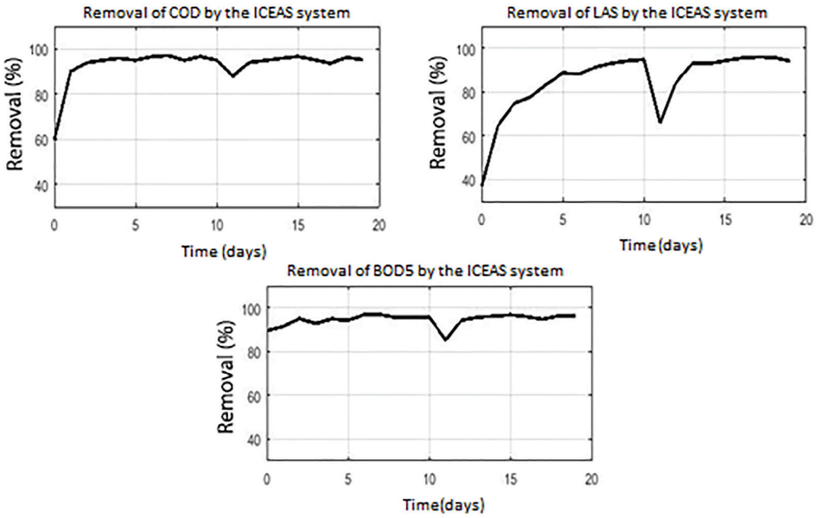

Figure 3: Removal (%) of LAS, BOD5, and COD by the ICEAS system.

and average, of F/M ratios in the primary reaction chamber were 0.11, 0.042, and 0.086 $Kg.BOD_5/Kg.MLSS.d$, respectively.

Discussion

Based on data, the average removal efficiency BOD_5, COD, and LAS using ICEAS reactor were 94.54%, 92.97%, and 84.99%, respectively (Figure 3). Other researchers investigate removal efficiency of LAS by activated sludge (AS)[18] and trickling filter (TF),[19] their results indicated that removal efficiency was 99% and 91%, respectively. Comparison, the LAS removal efficiency using ICEAS reactor (84.99%) with the AS and TF systems showed that is considerable. In most of the hospitals, the BOD_5 and COD concentrations of

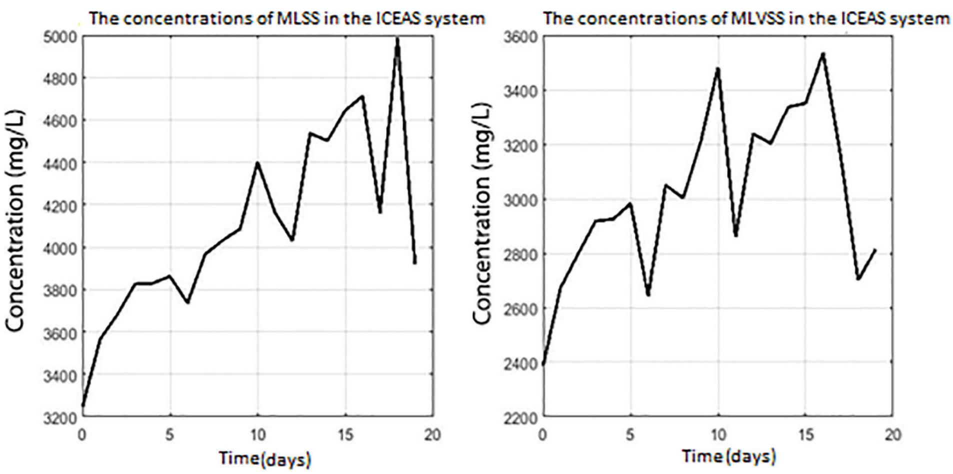

Figure 4: The concentrations of MLSS and MLVSS in the ICEAS system.

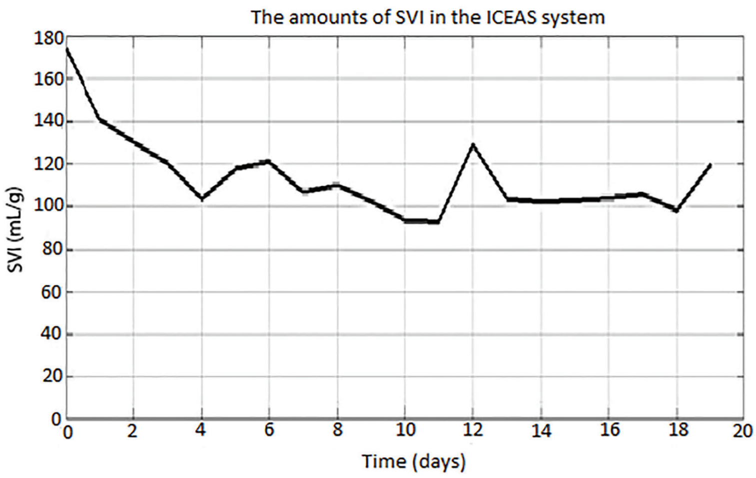

Figure 5: The amounts of SVI in the ICEAS system.

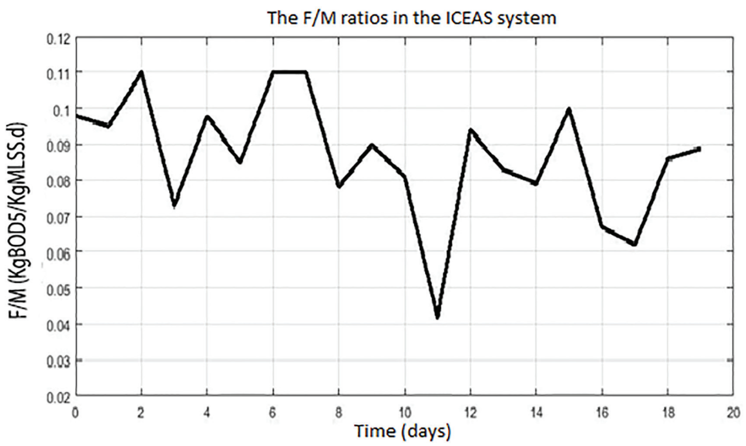

Figure 6: The F/M ratios in the ICEAS system.

wastewater are almost equal to the residential wastewater values. According to data, BOD_5 and COD concentrations of the ICEAS reactor meet to required limits of WHO standards.[20] So, the system's effluent can be used for watering the hospital green spaces. Other studies using the same reactor achieved similar results to this study. In Eslami et al.[8] study found that the removal efficiency of BOD_5, COD and LAS in wastewater treatment plant (WTP) using ASBR was 92.95%, 90.06% and 81.6%, respectively. In Nasr and Yazdanbakhsh study[21] were investigated physical and chemical specifications of produced wastewater in hospitals of Iran, results showed that the average of BOD_5 and COD in the effluent of wastewater treatment systems were 113 and 188 mg/L, respectively. The removal efficiency of COD using ICMBBR for a hospital wastewater with the influent of COD 700 mg/L was 95.1%.[12] In Sarafraz et al.[22] study when the hospitals sewage treatment systems were worked correctly, the concentrations of BOD_5 and COD decreased from 242.25 and 628.1 mg/L to 12.53 and 51.7 mg/L, respectively. Other studies indicated lower removal efficiency of COD in comparison this study.[23,24] Also, results of this work showed that removal (%) of LAS, BOD_5, and COD by the ICEAS system was decreased on days eleven that lowering of removal can be attributed to malfunctions of air diffusers and create anaerobic conditions in the reactor on days eleven (Figure 3).

The present study results showed that the averages of MLSS and MLVSS in the main reaction chamber were 4327 and 3172 mg/L, respectively (Figure 4). Because the optimal rate of the suspended solids in the mixed liquid can reach up to 5000 mg/L, the amounts of MLSS and MLVSS were desirable for the study system. In Jadhao and Dawande[25] study that effect of hydraulic retention time on operating parameters in membrane bioreactor system is investigated; results indicated that the MLSS varied from 9.2 to 14.3 g/L and MLVSS ranged from 6.70 to 10.18 g/L. Also, in a study that characteristics and treatability of hospital (medical) wastewaters are investigated; results showed that the average TSS of raw sewage in many hospitals was 101 mg/L.[26]

Based on this study data, the maximum, minimum and average of SVI in the main reaction chamber were 174, 92 and 113 mL/g, respectively (Figure 5). Many researchers introduce SVI as the best indicator for describing the characteristics of the sludge. In fact, the SVI is a good indicator for the sludge bulking. In practice, SVI can vary from 30 to 400 mL/g. In a study, the SVI greater than 150 mL/g was classified as sludge bulking.[27] Many researchers expressed the risks resulting of very low SVI in the conventional activated sludge systems. They were found that rapid sludge sedimentation (SVI of less than 70 mL/g) could be the reason for the effluent turbidity. Also, in the wastewater plant is observed that SVI 127–258 mL/g have tended to sludge bulking. In Albertson study, results showed that amounts of SVI in the first, second, third and fourth tanks were 517, 300, 91 and 51 mL/g, respectively.[28] Similar results are reported by other researchers.[29,30] In the present study, the average of SVI was 113 mL/g; it can be concluded that sedimentable solids have been favorable in this system and amounts of low SVI prevent of the formation sludge bulking.

This work results showed that the maximum, minimum and average, of F/M ratios in the primary reaction chamber were 0.11, 0.042 and 0.086 Kg.BOD_5/Kg.MLSS.d, respectively (Figure 6). The F/M ratio is one of most important wastewater plants design principles. The F/M has a direct relationship with BOD_5 and influent stream. Based on this study, the ratio of F/M had a fluctuation in the system, so that it has been 0.07–0.11 Kg.BOD_5/Kg.MLSS.d from one day to tenth days and after that decreased to 0.04 Kg.BOD_5/Kg.MLSS.d on day eleven (Figure 6). This lowering of the ratio of F/M can attributed to decreasing amounts of the dissolved oxygen and the influent wastewater stream. In a study that the performance and microbial diversity in a sequencing batch reactor (SBR) for domestic wastewater are investigated; the results showed that the F/M ratio increased with decrease volatile suspended solids (VSS) concentration, ranging between 0.07 and 0.48 g.COD/g.VSS.d.[31] Also, in a study that the performance of a pilot-scale membrane bioreactor (MBR) system for the treatment of a highly concentrated mixed wastewater is investigated; the results illustrated that the F/M ratio has been in the range of 0.03–0.07 Kg.BOD_5/Kg.MLSS.d and nitrification also not negatively influenced by the variations of F/M ratio.[32]

Although the research has reached its items, there were some unavoidable limitations. For instance; (i) time and cost factors, (ii) sample number limitation. There are still some interesting and relevant problems to be addressed. On the basis of the promising findings presented in this paper, work on the remaining issues continuing and will be presented in future papers.

Conclusion

The current study confirms that ICEAS reactor considered as an appropriate technology for removal of LAS, BOD_5, and COD from hospital wastewater. The ICEAS reactor successfully removed 94.54%, 92.97%, and 84.99% for BOD_5, COD, and LAS, respectively. The amount of SVI, F/M ratio, concentrations of MLSS and MLVSS were at a desirable level in the system. Overall in future by optimizing the design and operation, the ICEAS introduce as a promising process (technology) for removal of BOD_5, COD, and LAS from hospital wastewater.

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Conflict of Interest: None declared.

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