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REMOVAL OF ORGANIC MATTER IN WASTEWATERS OF A MILK FACTORY AND A HOSPITAL USING A CUBIC LATTICE BASED ROTATING BIOLOGICAL CONTACTOR IN VIETNAM

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ABSTRACT: Pilot tests of a cubic-lattice-based rotating biological contactor were implemented to remove organic matter from wastewater from a milk factory and a hospital in Vietnam. In the milk factory wastewater, the biochemical oxygen demand (BOD) removal ratio was stable between 60% and 90% (average 75%) using this method, with a BOD surface load of 0.002–0.020 kg•m−2•day−1. The average nutrient ratio of the raw wastewater was 0.13 of total nitrogen and 0.015 of total phosphorus compared with 1.0 of BOD. The BOD of treated water was less than 50 mg•L−1, achieving category B of the industrial wastewater standard of Vietnam (QCVN 40:2011). For the hospital wastewater, the BOD removal ratio was stable between 60% and 90% (average 78%), with a BOD surface load of 0.005‐0.022 kg•m−2•day−1. The average nutrient ratio of the raw wastewater was 0.25 of total nitrogen and 0.018 of total phosphorus compared with 1.0 of BOD. The BOD of treated water was less than 50 mg•L−1, satisfying category B of the medical wastewater standard of Vietnam (QCVN 28:2010/BTNMT). The electric power consumption was 0.73 KWh•m-3 of wastewater. The sludge conversion ratio from BOD was 0.51 kg TSS•kg BOD−1 based on the excess sludge and suspended solids in raw wastewater and treated water.

Keywords: Organic Matter, Rotating Biological Contactor, Wastewater, Vietnam

1. INTRODUCTION

A rotating biological contactor comprises a number of disc-shaped rotating contactors. Approximately 40% of the contactor surface is dipped into wastewater in a reactor [1]. The contactors are rotated by an electric motor through their axes (Fig.1). Microorganisms adhere on the surface of the contactor, forming a film known as a biofilm. The biofilm decomposes organic matter in wastewater by taking up oxygen when the biofilm emerges from the wastewater.

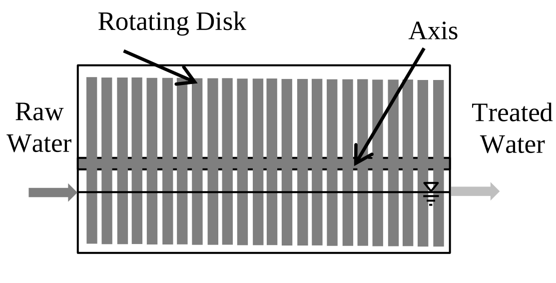

Fig.1 Schematic of the rotating biological contactor

The rotating biological contactor disk used for this research is illustrated in Fig.2. The disk comprises a cubic lattice made from polypropylene to ensure a larger surface area. The manufacturer is Sekisui Aqua Systems Co., Ltd [2].

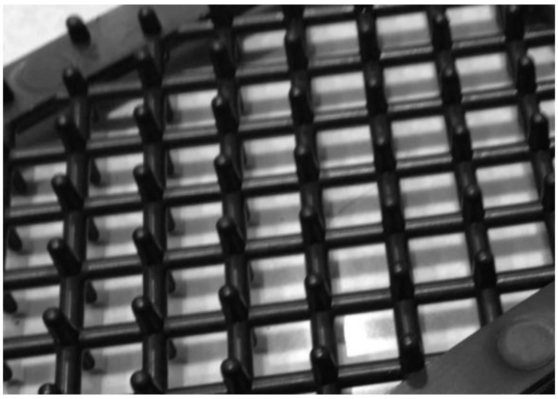

Fig.2 Disk of the rotating biological contactor

This wastewater treatment process does not use a blower for aeration to supply oxygen to wastewater, and thus does not consume more energy compared with the activated sludge process.

This process is widely used for industrial wastewater treatment in Japan and Europe [3][4][5][6][7], and has been researched and developed for mainly wastewater treatment of small and medium sized factories, and in developed countries so far. The manufacturer has experiences for industrial wastewater treatment using this process, mainly in Japan. However, they are not yet used in Vietnam and other Asian countries, and nor are they used for sewage treatment, even in Japan.

The manufacturer recently starts manufacturing apparatus of the process in China for promoting sales.

This research had two aims: to apply this process to industrial wastewater to remove organic matter in Vietnam, and to use the process for sewage treatment to remove organic matter. The sites of the pilot tests of the research were a milk factory and a hospital in Hanoi city.

The main industry of Vietnam is agriculture, mainly rice cropping, with an active livestock industry in mountainous areas and a substantial fishing industry on the coast. In recent years, the Vietnamese diet has become increasingly westernized, so the consumption of milk and milk products has gradually increased and the amount of milk and milk products in Vietnam has risen.

However, many factories have not conducted appropriate wastewater treatment, and the water quality of public waters such as rivers and lakes has deteriorated. Both factories and public facilities such as hospitals have not treated wastewater properly.

Industrial wastewater standards have been established by law (called QCVN 40:2011), as have medical wastewater standards (called QCVN 28:2010/BTNMT). The values for biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of both standards are listed in Tables 1 and 2. BOD analysis uses the five-day method, based on the Vietnamese standard, as for the Japan Industrial Standard and USEPA methods. COD analysis uses potassium dichromate as an oxidizing agent, based on the Vietnamese standard, which is the same as the USEPA method.

In the Vietnamese standards, category A means that the treated water outlet is located in public water that is a water source for domestic and industrial use; category B means that the treated water outlet is not located in public water that is a water source for domestic and industrial use.

Table 1 BOD and COD of QCVN 40:2011

Items	Unit	Category A	Category B
BOD	mg•L^{-1}	30	50
COD	mg•L^{-1}	75	150

Table 2 BOD and COD of QCVN 28:2010/BTNMT

Items	Unit	Category A	Category B
BOD	mg•L^{-1}	30	50
COD	mg•L^{-1}	50	100

2. OBJECTS AND METHODS

Objects of the research are to remove organic matter such as BOD and COD under each standard continuously and confirm sludge production of this process.

Two pilot tests used the same test plant, the specifications of which are listed in Table 3.

To confirm the removal capability of organic matter in terms of BOD and COD, inlet samples were obtained between the flow control unit and the reactor, and outlet samples were taken between the reactor and the equalizing tank. BOD removal was calculated using Eq. (1). COD removal was calculated using Eq. (2) [1].

Table 3 Specifications of the test plant

Component	Flow Control Unit – Reactor with Disks – Equalizing Tank – Sedimentation Tank
Reactor Volume	1.78 m^3
Diameter of Disk	1.2 m
Total Surface Area of Disks	420 m^2
Electric Power	1.5 KW
Design Drainage Discharge	30 m^3•day^{-1}

$$BOD\ Removal\ (\%) = \frac{BOD_{\ Inlet} - BOD_{Outlet}}{BOD_{Inlet}} \times 100 \quad (1)$$

$$COD\ Removal(\%) = \frac{COD_{\ Inlet} - COD_{Outlet}}{COD_{Inlet}} \times 100 \quad (2)$$

The BOD surface load was calculated using Eq. (3) [1].

$$L_{Surface} = \frac{L_f \times Q}{A} \quad (3)$$

$L_{Surface}$: BOD surface load (kg BOD•m^{-2}•day^{-1})
L_f: BOD inlet (mg•L^{-1})
Q: Inlet flow (m^3•day^{-1})
A: Total surface area of disks (m^2)

The hydraulic detention time (HDT) was calculated using Eq. (4) [1].

$$HDT(hours) = \frac{Reactor\ Volume\ (m^3)}{Q(m^3 \cdot day^{-1})} \times 24 \qquad (4)$$

Equation (5) was used to calculate the hydraulic loading rate [8].

$$Hydraulic\ loding\ rate(m^3 \cdot m^{-2} \cdot day^{-1}) = \frac{Q(m^3 \cdot day^{-1})}{Total\ Surface\ Area\ of\ Discs(m^2)} \qquad (5)$$

In addition, the total nitrogen (TN) and total phosphorus (TP) levels of the samples were analyzed to assess the relations of these parameters with BOD, based on Vietnamese standards.

2.1 Milk Factory

The milk factory is located in Hanoi city. The designed drainage discharge of the factory is 300 m^3•day^{-1}; however, it was operated at 100 to 250 m^3•day^{-1} during the pilot test. The factory has a wastewater treatment plant that uses a trickling filter process and an activated sludge process.

The pilot test plant was installed in front of the existing wastewater treatment plant. Water samples in the form of raw water for the pilot test were obtained at the equalizing tank of the existing wastewater treatment plant, as shown in Fig.3.

The pilot test at the milk factory ran from July 2013 to January 2014. During this time, samples were taken at the inlet and outlet on 28 occasions. The inlet BOD was 40–320 mg•L^{-1}, inlet COD was 140–640 mg•L^{-1} , inlet TN was 1.0–46 mg•L^{-1}, and inlet TP was 0.2–3.3 mg•L^{-1}. The average ratio of BOD, TN, and TP was 100 BOD: 13 TN: 1.5 TP. The average inlet flow was 29 m^3•day^{-1}, so the average HDT was approximately 1.5 hours and the hydraulic loading rate was 0.07 m^3•m^{-2}•day^{-1}.

Figure 4 shows rotating disks with biofilm in the reactor at the milk factory.

Fig.3 The pilot test plant at the milk factory

Fig.4 Rotating disks with biofilm at the milk factory

2.2 Hospital

The hospital is located in Hanoi city. The hospital has approximately 800 beds and an average drainage discharge of 400 m^3•day^{-1}. The hospital has a wastewater treatment plant that uses an anaerobic treatment process and a trickling filter process. The wastewater is mainly from the linen room.

The pilot test plant was installed in front of the existing wastewater treatment plant. During the pilot test, raw water samples were obtained at the equalizing tank of the existing wastewater treatment plant, as shown in Fig.5.

The pilot test at the hospital was conducted from July to December 2014. During this period, samples were taken at the inlet and outlet on thirteen occasions. The inlet BOD was 51–270 mg•L^{-1}, inlet COD was 91–300 mg•L^{-1}, inlet TN was 21–44 mg•L^{-1}, and inlet TP was 1.1–3.5 mg•L^{-1}. The average ratio of BOD, TN, and TP was 100 BOD:25 TN:1.8 TP. The average inlet flow was 31 m^3•day^{-1}, so the average HDT was approximately 1.4 hours and the hydraulic loading rate was 0.07 m^3•m^{-2}•day^{-1}.

For the hospital, the production of the sludge generated in the reactor was calculated.

Figure 6 shows rotating disks with biofilm in the reactor at the hospital.

Fig.5 The pilot test plant at the hospital

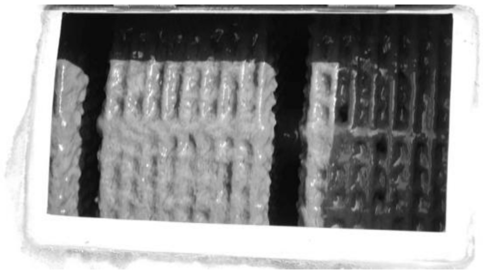

Fig.6 Rotating disks with biofilm at the hospital

3. **RESULTS AND DISCUSSION**

3.1 Milk Factory

Figure 7 shows the BOD of the inlet and the outlet, and the BOD surface load for the milk factory. The average BOD surface load was 0.009 kg BOD•m^{-2}•day^{-1}. At the beginning of the test, BOD removal was lower, but it gradually increased with time. The average value of BOD removal was 75%. The BOD outlet value was less than 50 mg•L^{-1}, falling into category B of the industrial wastewater standards of Vietnam, except at the beginning of the test, and the BOD of half of the samples was less than 30 mg•L^{-1}, satisfying category A of the Vietnamese standard.

Figure 8 shows the relation between BOD removal and BOD surface load. These results indicate that more than 60% of BOD could be removed irrespective of the BOD surface load, which was less than 0.020 kg BOD•m^{-2}•day^{-1} in almost all cases.

Figure 9 shows the COD measurements for the inlet and outlet of the milk factory. Similarly to the BOD results, COD removal was lower at the beginning of the pilot test; however, COD removal gradually rose, and the average COD removal was 72%. According to the industrial wastewater standards of Vietnam, 64% of the outlet COD values were less than 75 mg•L^{-1}, falling into category B.

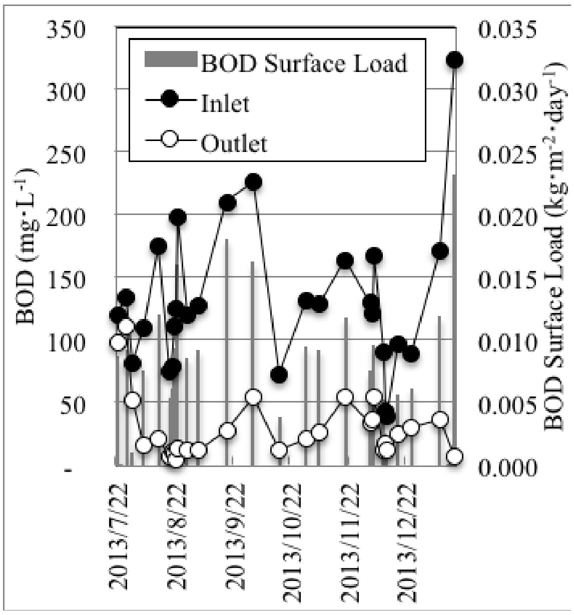

Fig.7 BOD and BOD surface load of the milk factory

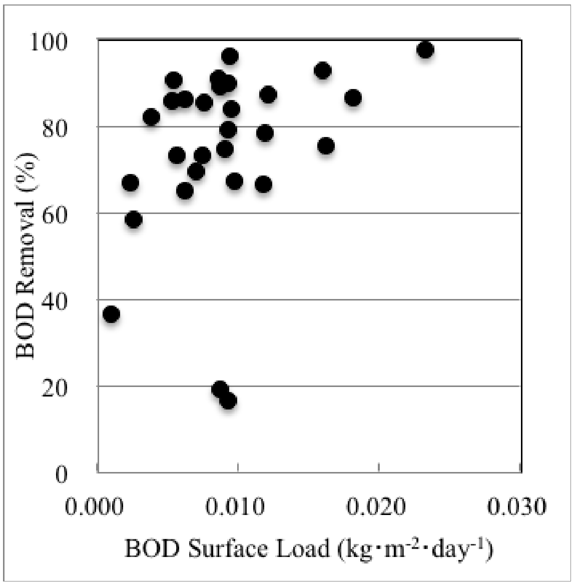

Fig.8 Relation between BOD removal and BOD surface load for the milk factory

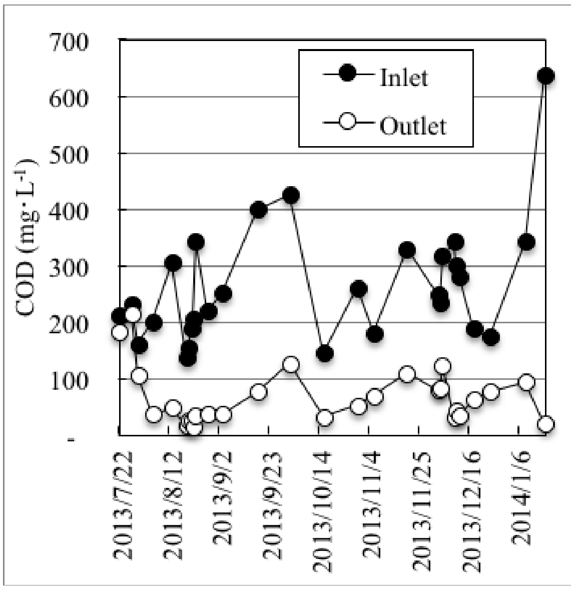

Fig 9. COD of the milk factory

3.2 Hospital

Figure 10 shows the inlet and outlet BOD and BOD surface load of the hospital. The average BOD surface load was 0.010 kg BOD•m^{-2}•day^{-1}. The BOD of the inlet gradually increased from 51 mg•L^{-1} to 270 mg•L^{-1}; however, the outlet BOD was always less than 50 mg•L^{-1}, falling into category B of the medical wastewater standards of Vietnam. Approximately 60% of the outlet BOD measurements were less than 30 mg•L^{-1}, satisfying category A of the Vietnamese standard.

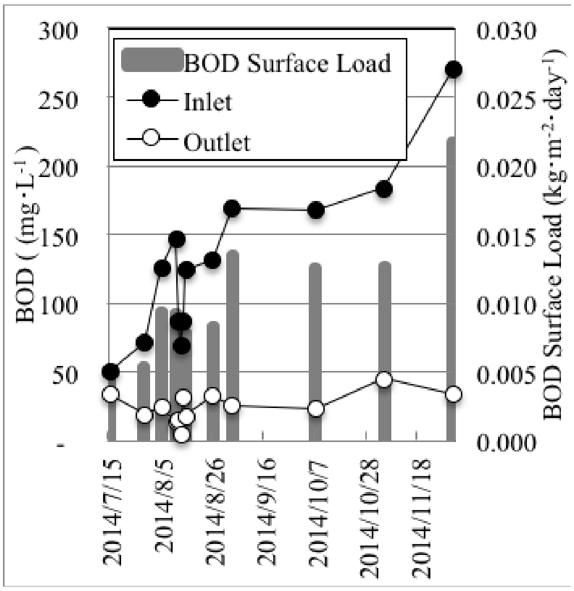

Fig.10 BOD and BOD surface load of the hospital

Figure 11 shows the relation between BOD removal and BOD surface load. The graph indicates that more than 60% of BOD could be removed in most cases, irrespective of the BOD surface load, which was less than 0.015 kg BOD•m^{-2}•day^{-1}.

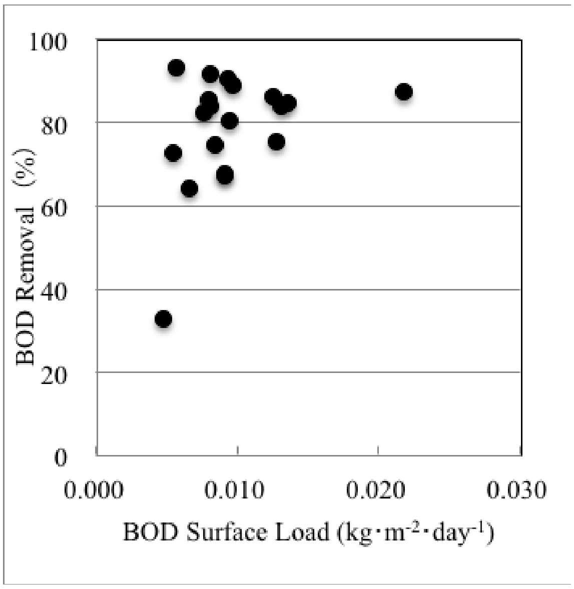

Fig.11 Relation between BOD removal and BOD surface load for the hospital

Figure 12 shows the inlet and outlet COD measurements for the hospital. Similarly to the BOD results, the inlet COD values gradually increased from 91 mg•L^{-1} to 300 mg•L^{-1}. However, the outlet COD was always less than 100 mg•L^{-1}, falling into category B of the medical wastewater standards of Vietnam. Approximately 70% of the outlet COD values were less than 50 mg•L^{-1}, satisfying category A of the Vietnamese standard.

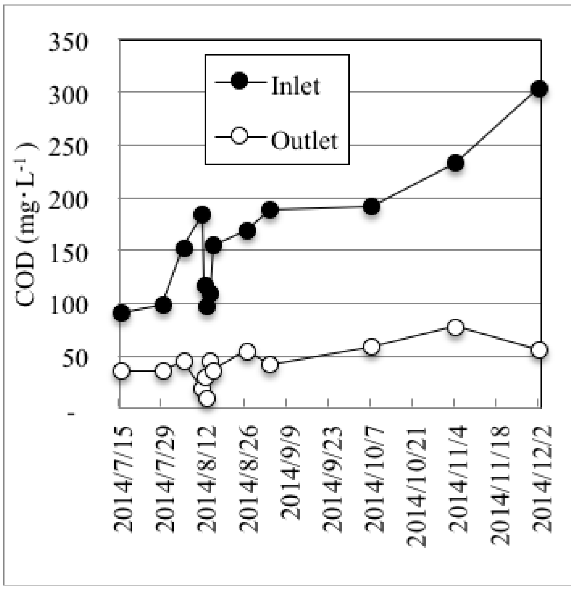

Fig.12 COD of the hospital

For the calculation of the sludge production in the reactor, samples from the inlet and outlet and samples after the sedimentation tank were obtained to measure BOD and TSS in January 2015. The BOD and TSS results are provided in Table 4. The sludge in the sedimentation tank of the pilot test plant was produced at a rate of 0.63 m^3•day^{-1}.

The amount of sludge generated was 1.17 kg•day^{-1} and the removed BOD volume was 2.3 kg•day^{-1}, so the sludge conversion rate was 0.51 kg TSS•kg BOD^{-1}.

Table 4 BOD and TSS values for sludge production

Items	Unit	Inlet	Outlet	After Sed. Tank
BOD	mg•L^{-1}	92	28	-
TSS	mg•L^{-1}	41	36	2,140

During the period of the pilot test, the pilot test plant treated 6,140 m^3 of water and consumed 4,500 KWh of electric power, representing an electric power consumption of 0.73 KWh• m^{-3} of wastewater.

4. CONCLUSION

According to [2], the design criteria for rotating biological contactors are a hydraulic loading rate of 0.08–0.16 m^3•m^{-2}•day^{-1}, a surface load of 0.0098–0.0172 kg BOD•m^{-2}•day^{-1}, HDT of 0.7–1.5 hours, and BOD in the effluent of 15–30 mg•L^{-1}. For the milk factory, the hydraulic loading rate was 0.07 m^3•m^{-2}•day^{-1}, the average surface load was 0.009 kg BOD•m^{-2}•day^{-1}, HDT was 1.5 hours, and the average BOD in the effluent was 30 mg•L^{-1}. For the hospital, the hydraulic loading rate was 0.07 m^3•m^{-2}•day^{-1}, the average surface load was 0.010 kg BOD•m^{-2}•day^{-1}, HDT was 1.4 hours, and the average BOD in the effluent was 25 mg•L^{-1}. Thus, both pilot tests almost fulfill the design criteria.

According to [3], the required sludge conversion rate for rotating biological contactors is 0.75–1.0 kg TSS•kg BOD^{-1}; however, the sludge conversion rate of the pilot test at the hospital was 0.51 kg TSS•kg BOD^{-1}. From this pilot testing, the rotating biological contactor formed of a cubic lattice can be applied for the removal of organic matter from industrial wastewater and sewage water in Vietnam. In addition, there were no mechanical troubles during the pilot test.

5. ACKNOWLEDGEMENTS

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