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Design Basis of RBCp Systems for Petrochemical Industries Wastewater Treatment for Use in Agricultural

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Abstract: Oil and petrochemical industries, Military industries, food producers along with livestock slaughter houses are among the high water using industries producing wastewaters that contain very high concentration of ammonia. Common treatment sites are unable to treat these wastewaters. Moreover, having toxic chemical and nutrients, they are of high contamination potential in water resources. Nitrification is the first and the most important stage of biologically removing ammonia compositions. In this stage toxic ammonia is turn into nitrate (NO_3), which is a stable form and can be absorbed by plants. This stage can be done in bio-film systems. Requiring minimum land and energy, simple operation procedure and not needing aeration and returning of sludge, these systems and particularly RBC (Rotating Biological Contractors) reactors are of real privilege. In this study by modifying RBC systems to RBCp (Rotating Biological Contactors with pacing bed) in a pilot scale, reactors performance in treatment of waste waters with high ammonia concentrations was assessed and a design basis is prepared. Required space and hydraulic retention time is reduced to ¼ in the modified system. Temperature, pH, concentration and load of inlet ammonia, hydraulic load, the ratio of Biological Oxygen Demand (BOD) to Total Nitrogen (TN) and system rotation velocity are the factors discussed in this study. With an ammonia concentration of 200 mg/l and hydraulic load between 0.02 to 0.04 $m^3/m^2.d$ the performance of the reactor was reliable in temperature range over 30°C and efficiencies of ammonia removal and nitrification are 98 and 89/8% respectively.

Key words: RBCp System · Petrochemical · Wastewater · Nitrification · Irrigation

INTRODACTION

Biological methods are one of the most effective and important methods in ammonia removal which consists of two stages: Nitrification and Denitrification. Nitrification is the first and most important step in biological removal of these compounds from wastewater which is done by two groups of aerobic bacteria: Nitrosmonas and Nitrobacter [1, 2]. Bio-film systems, especially RBC_P reactors, with minimal need for land and energy, simple operation, no need for aeration and sludge return, have priority over other biological systems. RBCp method is the optimized mode of RBC method which in that cylinder with plastic Packing Bed is used as substrate instead of disks [3-5]. The sewage purification microorganisms grow on the substrate as shown in Figures 1 and 2 and produce the biological layer. In these systems the surface layer of the substrate and thus the produced biological layer are more than 3 times of RBC system and so the cost of construction is half of it [6]. The first system was created by Vigand (Vigand 1900) in Germany and it was expanded in Europe since 1950 during the investigations of Popel and Hartman [7]. From late 1975 research about Nitrification in bio-film systems and RBC was started. Bishope's research about the nitrification of urban sewage showed that the rate of nitrification in winter is 16% less than that in summer [8]. Sutton and colleagues in 1978 showed that by reducing the temperature from 26 to 5°C the nitrification rate was reduced by 53%. According to Painter research (Ankaitis, 1995) optimum temperature of Nitrification is 28 to 35°C [9]. The investigation of Ahn, (Ahn *et al*., 1997) showed that the effluent concentration, temperature and hydraulic load are effective factors on nitrification in RBC method. Researches conducted in the field of nitrification are mainly related to urban sewage with low ammonia and the results are not applicable to industrial wastewater. This research is mainly performed in suspended growth systems especially activated sludge [10].

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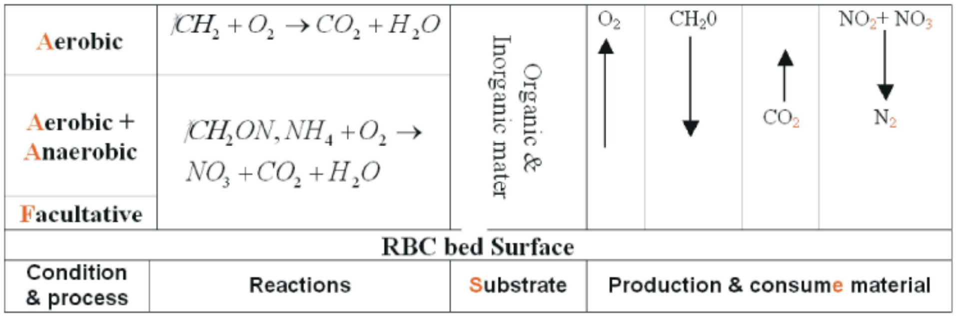

Fig. 1: Microorganisms and biochemical reactions in bio film

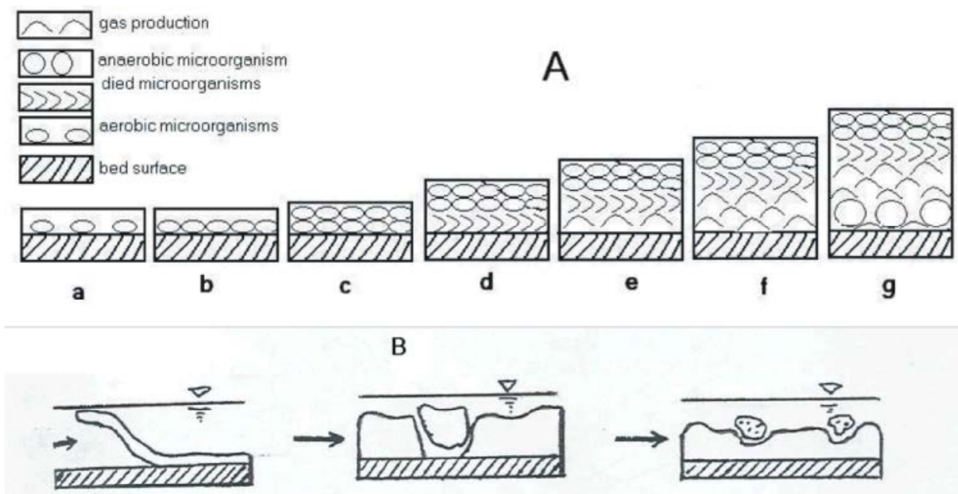

Fig. 2: Profile of intrinsic bacterial population of bio film (A), decrease of bio film thickness (B)

According to high sensitivity of bio-film systems (especially RBC) to temperature changes, hydraulic and pollution load the main objective of this research was to test the RBCP reactor at different conditions of temperature, hydraulic and pollution load in order to achieve the principles of design and its users in waste water's treatment of oil and petrochemical industry with high ammonia concentrations.

MATERIALS AND METHODS

In this research, RBCp was designed in Laboratory scale (90×30 cm) with fiberglass (Fig. 3) and divided into three equal parts through vertical plates. The parts were connected parallel to each other and equipped with sensitive cells to check pH and temperature. RBCp's bed contains three steel rotating cylinders, each of 20 cm in length and diameter. They were then positioned and rotated around the central axis. The cylinders' base was from latticed steel and their body from thin steel rods with 3 cm space. The cylinders were filled with poly propilen ball rings (Fig. 4). These ball rings have the role of disc in RBC and resulted to this fact that the ratio of surface (specific surface) to volume of RBC is 3 times more than the common RBC. Therefore, the bio-film increased as well as the system's effectiveness. The ball rings were put into the cylinders randomly and to avoid stickiness caused by bio-film formation, about 15% of the space within the cylinders was left empty. The rotating cylinders were positioned on the central axis and joined to the system with 5 ball bearings. The rotation force generated by electrical motor is transmitted to the axis through three gears and a chain and makes the cylinders rotated. The gears diameters were chosen in the manner that allows the system rotates in two different speeds; besides their temperature was adjustable in a 15-35°C range. Tables 1 and 2 show the features of RBCp and its ball rings.

The inlet wastewater was made artificially which in that malas was used as carbon source, NH_4Cl was used as an ammonia source and K_2HPO_4 was used as phosphate and potash source. In order to compensate the used alkalinity according to under equations adjusting pH in the range of 8±0.5, 1 Molar solution of $Ca(OH)_2$ and Na_2CO_3 was used.

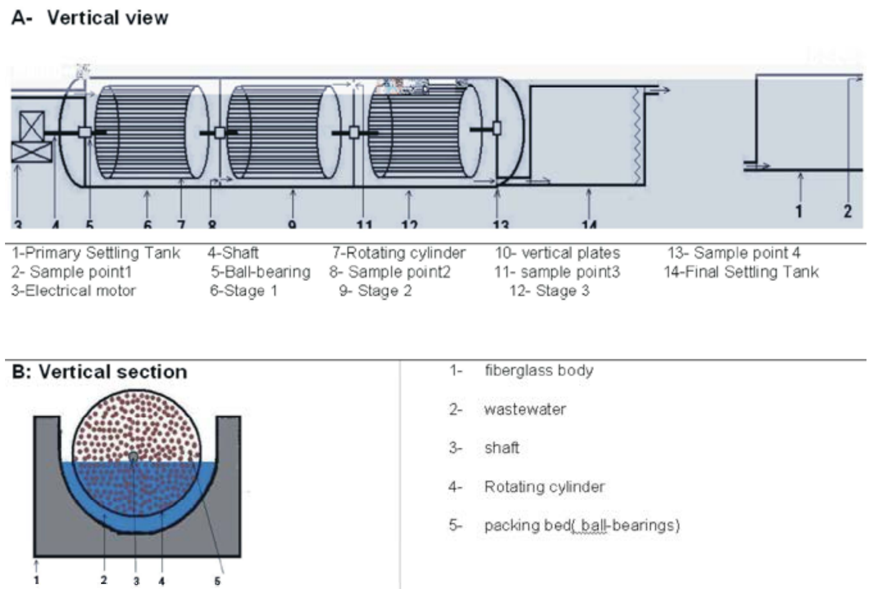

Fig. 3: Schematic representation of the RBCp pilot plant

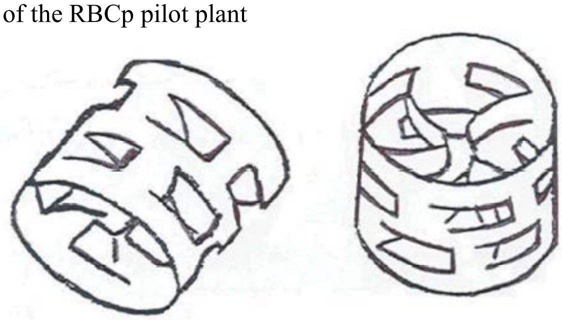

Fig. 4: packing bed(ball-bearings) used in RBCp pilot plant

Table 1: Features of the ball ring used in the sample RBCp

Type	Material	Size (in)	Density (lb/ft^3)	Specific Surface (ft^2/ft^3)	Porosity
Ball ring	Poly propilen	1	5.5	210	95%

Table 2: Features of RBCp pilot plant

Factor	Quantity
Length (m)	0.9
Width (m)	0.3
Height(m)	0.2
Rotating cylinder length (m)	0.2
Rotating cylinder diameter (m)	0.2
Effective volume (m^3)	0.18
Bed total surface (m^2)	3.36
Bed surface to volume ratio m^2/m^3	190
Rotation per minute [1](RPM)	16-19
Rotation speed [2](m/sec)	0.17-0.20
Temperature[3] (centigrade)	20-25
Hydraulic load [4](m^3/m^2.d)	0.025-0.10

1. Rotation per minute is adjustable in 16-20 range.
2. Rotation speed is adjustable in 0.17-0.20 m/s range.
3. The temperature is adjustable in 15-35±2.5 range.
4. The water load is adjustable in 0.025-0.1m^3/m^2.d range.

$$55NH_4^+ + 76O_2 + 109HCO_3 \rightarrow C_5H_7NO_2 + 54NO_2^- + 57H_2O + 104H_2CO_3$$

$$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \rightarrow C_5H_7NO_2 + 3H_2O + 400NO_3^-$$

In order to setup the pilot, 10 liters of Tehran's wastewater sludge was aerated for 3 days and then it's ammonia concentration was reached to 200 ppm (mg/l) over a period of 1 month and in 5 phases. During this process, nitrofiers became dominant microorganisms and were adjusted to high ammonia concentrations. Then the aerated sludge brought to stasis and after sedimentation, it was added 300 ml from deposition part to each section of RBCP and the system was set up discontinuously (batch flow) with 200ppm (mg/l) ammonia concentration. After 10 days with observing first biological layers system was launched continuously (continuous flow) with 0.01 m^3/m^2.d hydraulic load and 16RPM Rotational speed and the performance was evaluated. In this research nitrate, nitrite, ammonia nitrogen, COD (Chemical oxygen demand), pH, DO (Dissolved oxygen) and alkalinity were performed according to standard methods. Sampling was done automatically at intervals of 12 hours from stages outlet.

RESULTS AND DISCUTION

After setting up and reaching stable system the effect of temperature on nitrification was evaluated and according to the optimum temperature, the effect of hydraulic load on nitrification was investigated. Summary results are presented in two parts as follows:

Temperature Effect on Nitrification: As shown in Fig. 5 at temperature 12.5 ± 2.5 the nitrification rate was low and the concentration of produced nitrite was higher than nitrate, so that the system faced with nitrite accumulation and ultimately reduced the efficiency. Nitrite accumulation at low temperature shows more sensitivity of Nitrobacter in comparison with Nitrosmonas that this sensitivity causes disharmony in the nitrification chain and eventually leads to the accumulation of nitrite. By increasing the temperature up to 22.5 ± 2.5 °C, system performance is improved and nitrification rate is increased so that the problem of nitrite accumulation is resolved and nitrification efficiency is increased. By increasing the temperature to 32.5°C, the amount of nitrification is increased only by 0.8%, which is negligible in comparison with previous step. Reduction of oxygen solubility at high temperatures is one of its causes, which limits the amount of available oxygen for microorganisms and thereby reduces Nitrification rate. The results compared with results of previous studies [11, 12, 13], shows that RBCP systems in comparison with other systems particularly suspended growth systems is more sensitive to low temperatures and this sensitivity is reduced at higher temperatures. Also it is observed that maximum Nitrification occurs at 32.5 ± 2.5°C.

Results of Hydraulic Load Effect on Nitrification: In this step according to the results of previous steps, the temperature and pH of system were adjusted at 22.5±2.5°C and 8±0.5 respectively and system performance was investigated in 200 and 500 concentrations under various hydraulic loads. Results show that (Fig. 6 and 7) the hydraulic load is less, greater percentage of nitrate are produced. Also in low hydraulic load, main portion of

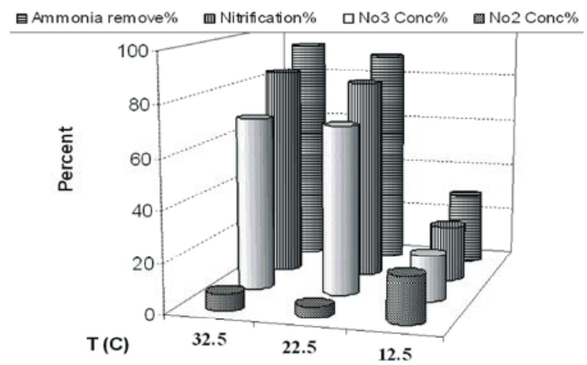

Fig. 5: temperature effect on Nitrification rate in RBCp system.

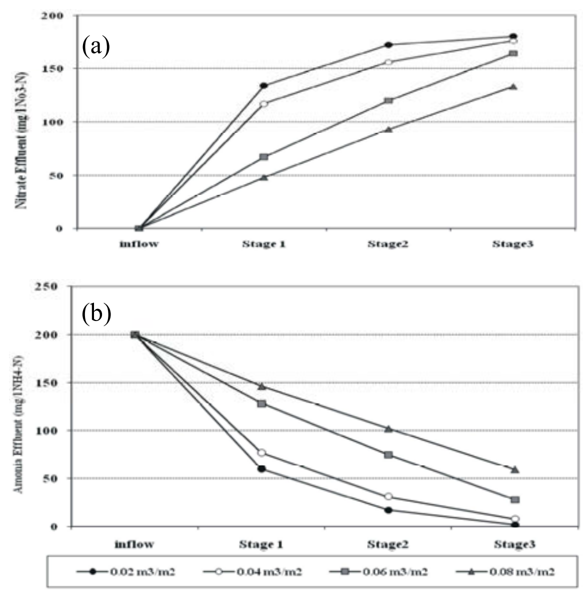

Fig. 6: Effect of hydraulic load: (A) on nitrification rate, (B) on outlet ammonia rate, in different units of system (input ammonia concentration equal to 200 mg/l).

nitrification is of the first stage and less ammonia remains for second and third stages, so these sectors have smaller share in nitrification.

With increasing hydraulic load, the contribution of other units will be more and more uniform use of various parts will be obtained but in all stages the share of the first unit is more than other units.

With increasing hydraulic load due to retention time reduction, the concentration of outlet ammonia increases. As in inlet concentration of 200 *mg*/*l* and hydraulic load of 0.02 $m^3/m^2.d$, the ammonia removal efficiency and nitrification were 98 and 89.5% respectively and in hydraulic load of 0.04 m^3/m^2 these amounts were 85.4 and 80%. The 0.08 m^3/m^2 is equal to 71 and 66.5% respectively.

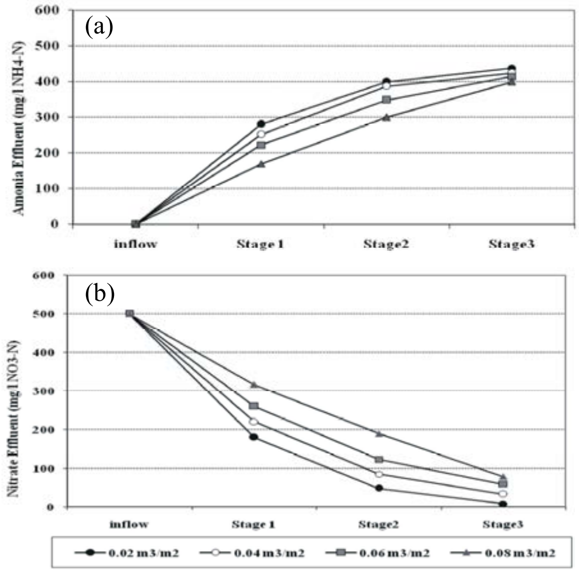

Fig. 7: Effect of hydraulic load: (A) on nitrification rate, (B) on outlet ammonia rate, from different units of system (input ammonia concentration equal to 500 mg/l)

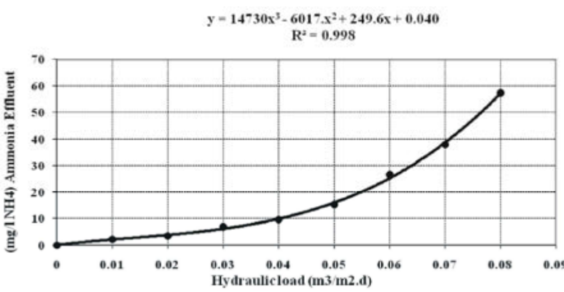

Fig. 8: Relationship between outlet ammonia and hydraulic load (input ammonia concentration equal to 200 mg/l)

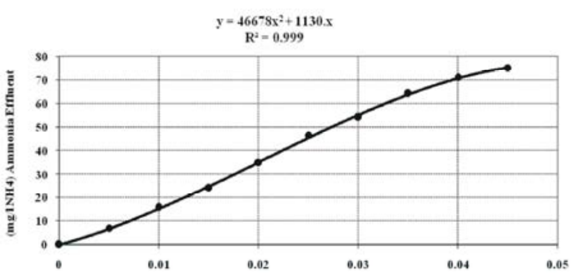

Fig. 9: Relationship between outlet ammonia and hydraulic load (input ammonia concentration equal to 500 mg/l)

The mass of inlet and outlet elements at all stages of balance and in ammonia concentration of 500 mg and hydraulic load, determines that the amount of removed ammonia is more than total amount of nitrate and nitrite. This difference increases with inlet concentration and hydraulic load to system. This difference is due to removal of ammonia with nitrification method, taking as nutrients by microorganisms and escaping out of system in volatile ammonia mode. Dispersed and suspended growth of nitrofaier microorganisms in liquid phase is observed in inlet ammonia concentration of 500 *mg*/*l*, especially in hydraulic load of 0.04 $m^3/m^2.d$. This proves that inlet load exceeds the capacity of the system which causes the effluent turbidity. In low hydraulic load, this case is observed only in first part but with increasing hydraulic load the suspended growth is spread to other sectors.

Figures 8 and 9 show the relationship between outlet ammonia and hydraulic load in RBCp systems with specific surface of 210 m^2/m^3, Rotation speed of 16 RPM and ammonia inlet concentrations of 200 and 500 *mg*/*l* which can be used for designing the refineries of oil and petrochemical industries.

CONCLUSIONS

The results of this study show the ability of investigated system in removing ammonia and changing it into nitrate. According to the results, this system in different concentrations and hydraulic loads is capable of biological oxidation of inlet ammonia over 90% and changing it into nitrate. Since ammonia is a toxic substance and important pollutant for water resources, especially aquatics, this capability is important and in addition to the environmental beneficial effects, regarding the nutritional value of nitrate for agricultural products it can increase production and have significant economic benefits.

Research results in studied temperature range shows that maximum nitrification occurs in 32.5±2.5°C. Comparing these results with previous studies [11-13] shows that this method is more sensitive to temperature, particularly to low temperatures. Therefore, using this system is suitable for tropical regions and has a better performance. According the sensitivity of RBC_P system to temperature, for using this system in cold regions, appropriate cover for protecting against cold is necessary.

Percentage of ammonia removal decreases with hydraulic load increasing but in low hydraulic loads, the other two parts are not made optimal use. For preventing this mode, alternative change of inlet and outlet stream to system is recommended and with repeating this procedure in different hydraulic loads and concentrations, the optimal mode would be determined. Based on these results, Proportional to the effluent ammonia concentration, it is possible to design a system with the desired outlet quality.

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