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Effect of Dissolved Air Flotation Process on Thickening of Activated Sludge

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Abstract
Aims: Sludge is an inescapable component of all wastewaters that originated from their treatment. dissolved air flotation (DAF) process as an alternative clarifier is used in treatment of drinking water, pretreatment of wastewater, and as a phase separator in sludge activation processes. This study aimed to calibrated the usage of DAF process in a laboratory scale and under various conditions, to achieve the optimum efficiency in recycling the activated sludge.
Instrument & Methods: In this experimental study, of Kashan's Shahid Beheshti hospital and immediately transported to the laboratory. The optimal dose of polyaluminum chloride coagulant and pH was determined and then applied in DAF process. Finally turbidity, electrical conductivity (EC) and total solids (TS) parameters were measured and compared with control sample.
Findings: The optimal pH and optimal dose of coagulant were 6.5 and 25mg/l, respectively. Also Optimal process efficiency to reduce EC, TS and turbidity parameters were 23.4, 44.5 and 88%, respectively.
Conclusion: Dissolved air flotation process removes the turbidity, EC and TS effectively; however, it has minimal impact on EC and TS.

Keywords
Dissolved Air Flotation [Not in MeSH];
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Introduction

Every year, 330km^3 of municipal wastewater is generated around the world, continuously [1]. Recently, hospital wastewaters have become an associated issue as a water source contaminant that has higher concentrations of pharmaceuticals, mainly antibiotics and analgesics, compared with municipal wastewater [2]. Sludge is an inescapable component of all wastewaters that originated from their treatment [3]. Sludge activation process can remove pharmaceutical about 85% [4]. Intensification of current environmental legislation leads to increase the wastewater treatment sludge volume [5]. 25-60% of wastewater treatment total operating cost is related to the disposal of excess sludge. Therefore, reducing the sludge is considered as a strategy to improve and solves the problems of secondary pollution of sludge [6].

While treatment of wastewater liquid portions takes about several hours, processing and preparation sludge for disposal or beneficial uses with advanced equipment, will take several days or several weeks [7]. Fermentation, denitrification, and anamox can remove the nitrogen and reduce the sludge volume for reusing [8]. In addition, sludge volume decreasing up to 20% was observed [9]. Due to low energy consumption, reducing the volume of sludge by mechanical dewatering process is usual in comparison with thermal drying [5]. Sedimentation, as a final clarifier and sludge thickener, has some limitations; Not operating in sludge bulking occurrence and large retention time resulting in high land use and capital cost. Flotation has also been used for solid/liquid phase separation in water and wastewater treatment and has shorter residence time than sedimentation [10].

Literature has reported effective coagulation and flotation by nano-bubbles [11, 12]. DAF process as an alternative clarifier is used in treatment of drinking water, pretreatment of wastewater, and as a phase separator in sludge activation processes [13, 14]. For decades, a large number of wastewater treatment plants have used DAF to access a high amount of thickened sludge [15]. High efficiency of DAF as a secondary clarifier in sludge activation have been demonstrated [16]. In DAF system, air dissolve in water at an air-pressurized tank. Saturated water then conducts to flotation region with atmospheric pressure. As a result, thousands of bubbles are generated and move upward. This movement causes particle separation from liquid [17].

Due to the importance of sludge volume, its complications, and sludge thickening high cost allocation, this study aimed to calibrated the usage of Dissolved Air Flotation process in a laboratory scale and under various conditions, to achieve the optimum efficiency in recycling the activated sludge.

Instrument & Methods

In this experimental study, all tests were performed in the Research Laboratory of Public Health School, Kashan University of Medical Sciences.

The lab-scale reactor was built based on a sequence batch reactor (SBR) and consists of a flotation tank, a pressure tank (117 liters), and an air compressor with a capacity of 25-liters (Figure 1). The floater tank had a cross sectional area of 10×10cm^2 and a height of 35cm, which occupied by 3 liters of water (30cm). Sampling port placed at a distance of 3cm from the bottom of the tank. Given the DAF laboratory scale based on a SBR system, coagulation, flocculation and flotation steps were done in the flotation vessel, respectively.

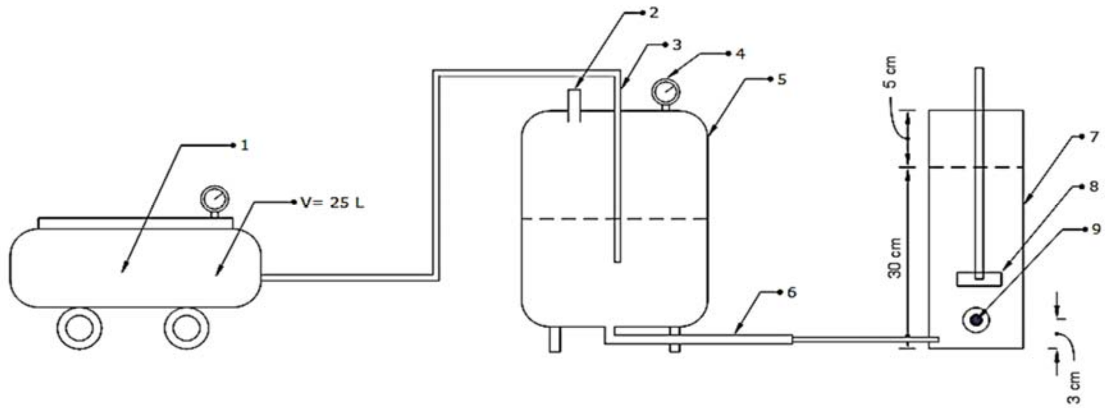
At first, pH and coagulant dose were optimized via jar test. Poly aluminum chloride (PAC) was used as the coagulant (Falizan; Iran).

The effect of recycling rate on flotation efficiency was carried out at 20, 35 and 50%. Recycling rate (R) was calculated by r/v, where r is saturated flow/volume and v is sludge flow/volume [18]. Considering the flotation tank volume in all experiments, sums of r and v amount were calculated 3000ml.

According to the following equation, DAF performance depends on the air to solids ratio (A/S) which affects solid/liquid separation [19].

$$\frac{A}{S}=\frac{1.3\,Sa(fP-1)R}{Su}$$

Where S_a is air solubility (18.7 ml/l at 20), R is recycling rate (%), f is fraction of air dissolved at pressure P (usually 0.5), P is pressure (atm), and S_u is suspended solids (mg/l). Typical A/S ratio in the wastewater sludge thickening is about 0.005-0.06 [20].



1	Air Compressor	4	Air pressure gage	7	Flotation tank
2	Water transport pipe	5	Pressure tank	8	Mixer
3	Air transport pipe	6	Air/water transport pipe	9	Sampling tap

Figure 1) A schematic diagram of DAF lab-scale

Daily samples were taken from the wastewater treatment plant of Kashan's Shahid Beheshti hospital and immediately transported to the laboratory. Sludge characteristics, e.g. pH, TS, total suspended solids (TSS), turbidity, and EC were measured at room temperature. The variation of turbidity, EC, and pH were analyzed by Turbiditimeter 2100P (HACH; United States), Conductivometer (Metrohm; United Kingdom), and 262 pH-meter (Tajhizat Sanjesh; Iran), respectively. TS and TSS analyses were done according to APHA [21].

For assessment of DAF efficiency, a specified volume of water was dumped into the pressure tank for 30min under 5 and 7atm. At the same time, certain amount of sludge sample according to the determined recycling rate (20, 35 and 50%) was dumped into the flotation tank. Then, coagulation took place at 180rpm for 1min and flocculation was done at 30rpm for 20min. In the next step, saturated water with an average flow rate of 0.127m^3/h was entered to the flotation tank (up to 3 liters) and the tank was filled. Finally, samples were taken with an interval time of 2 and 5 minutes from the bottom of flotation tank and TS, turbidity, and EC parameters were measured for comparing with control samples to assess the efficiency of DAF process.

All experiments were done 3 times and the data was entered to SPSS 19 software. Averages were used to report the results.

Findings

The average pH of activated sludge was 6.4. Therefore, considering to the cost saving, pH adjustment during the experiments was avoided. The average amount of suspended solids in daily samples was 323mg/l. At the pressure of 7atm and recycling rates of 20, 35 and 50%, A/S ratios were calculated 0.037, 0.065 and 0.097 and at 5atm, were calculated 0.022, 0.039, and 0.056, respectively.

The highest removal efficiency of turbidity was 88% for both 2- and 5min at 7atm by 50% of recycling rate and the lowest was 33% for 2min by 35% of recycling rate. The highest removal efficiency of TS was 44.5% for 5min at 7atm by 50% of recycling rate and the lowest was 8% for 2min at 7atm by 20% of recycling rate. The highest removal efficiency of EC was 23.2% for 5min at 7atm by 50% of recycling rate and the lowest was 10% for 2min at 5atm by 20% of recycling rate (Figure 2).

Figure 2) Removal percentage of TS, turbidity, and EC

Parameter	**Time** (min)	**Recycling Rate** (%)	**Pressure** (atm) 5	7
Turbidity	2	20	41	54
		35	33	60.5
		50	62.5	88
	5	20	66.5	58
		35	73.5	67
		50	64	88
TS	2	20	8.5	8
		35	21.5	12.6
		50	27	27.3
	5	20	15.5	10.2
		35	22	12.3
		50	24	44.5
EC	2	20	10	13.4
		35	15.5	15.6
		50	17	19.5
	5	20	11	15.3
		35	17	16.6
		50	18	23.2

Discussion

The aim of this study was to assess the efficiency of DAF process on recycling the activated sludge in wastewater treatment plant of Kashan's Shahid Beheshti Hospital. Optimal efficiencies in removing of EC, TS and turbidity parameters were determined to be 23.3, 44.5, and 88%, respectively. By increasing the amounts of recycling rates, removal efficiency has been increased. The average removal efficiency of TS at recycling rates of 20, 35, and 50% were determined to be 10.5, 17.1, and 30.7%. These amounts at turbidity removal were 54.2, 58.5, and 76.2%. In addition, percentages of EC removal were calculated 12.4, 16.1, and 19.4, respectively. De Nardi *et al.* have demonstrated the decreasing of COD by increasing of recycling rate [22].

Average percentages of EC removal at 2 and 5 minutes determined 15.1 and 17.5. Also, during the specified times, TS removal 17.5 and 21.4% and turbidity removal 56.5 and 69.5% were calculated, respectively. Therefore, it can be concluded that during the time, all parameters of removal efficiencies were increased. This increase was insignificant for EC and TS. In some investigations, increasing of efficiency during the time has been seen [7, 11, 23-25].

Generally, the solubility of air in water increases linearly with increasing pressure, leading to higher efficiency [26]. The results of the removal efficiency of EC, TS and turbidity based on pressure changes (5 and 7 atm), showed not certain relationship. They calculated for EC 14.7, 17.9%, for TS, 19.7, 19.1 and for turbidity 56.7 and 62.9%. Mohd Nordin Adlan *et al.* have reported that the flow rate and pressure are not critical parameters to leachate treatment [27]. However, Qidian Zhang *et al.* have shown that the total amount of suspended solids by increasing the pressure from 0.1 to 0.5MPa, decreased from 25mg/l to 12mg/l [28]. Also, the increasing of 15% of efficiency was observed at another study, with increasing the pressure from 2 to 6 bars [29].

However, in the cases of EC and turbidity, this relationship was direct and it can be deduced that the pressure changes only had a significant impact on the turbidity removal efficiency.

Conclusion

Dissolved air flotation process removes the turbidity, EC and TS effectively; however, it has minimal impact on EC and TS.

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References

1- Balasubramanian S, Tyagi RD. 2-Value-added bio-products from sewage sludge. In: Current developments in biotechnology and bioengineering. Wong JW, Tyagi RD, Pandey A, editors. Amsterdam: Elsevier; 2017. pp. 27-42.

2- Chonova T, Keck F, Labanowski J, Montuelle B, Rimet F, Bouchez A. Separate treatment of hospital and urban wastewaters: A real scale comparison of effluents and their effect on microbial communities. Sci Total Environ. 2016;542(Pt A):965-75.

3- Rahmani AR, Nematollahi D, Godini K, Azarian G. Continuous thickening of activated sludge by electro-flotation. Sep Purif Technol. 2013;107:166-71.

4- Choi M, Choi DW, Lee JY, Kim YS, Kim BS, Lee BH. Removal of pharmaceutical residue in municipal wastewater by DAF (dissolved air flotation)–MBR (membrane bioreactor) and ozone oxidation. Water Sci Technol. 2012;66(12):2546-55.

5- Conrardy JB, Vaxelaire J, Olivier J. Electro-dewatering of activated sludge: Electrical resistance analysis. Water Res. 2016;100:194-200.

6- Zhang J, Zhang J, Tian Y, Li N, Kong L, Sun L, et al. Changes of physicochemical properties of sewage sludge during ozonation treatment: Correlation to sludge dewaterability. Chem Eng J. 2016;301:238-48.

7- Kurama H, Karagüzel C, Mergan T, Çelik M. Ammonium removal from aqueous solutions by dissolved air flotation in the presence of zeolite carrier. Desalination. 2010;253(1-3):147-52.

8- Wang B, Peng Y, Guo Y, Zhao M, Wang S. Nitrogen removal from wastewater and external waste activated sludge reutilization/reduction by simultaneous sludge fermentation, denitrification and anammox (SFDA). Bioresour Technol. 2016;214:284-91.

9- Eusebi AL, Panigutti M, Battistoni P. Reduction of biological sludge production applying an alternating oxic/anoxic process in water line. Water Environ Res. 2016;88(6):483-9.

10- Cho KW, Chung CM, Kim YJ, Chung TH. Continuous clarification and thickening of activated sludge by electrolytic bubbles under control of scale deposition. Bioresour Technol. 2010;101(9):2945-51.

11- Tsai JC, Kumar M, Chen S-Y, Lin J-G. Nano-bubble flotation technology with coagulation process for the cost-effective treatment of chemical mechanical polishing wastewater. Sep Purif Technol. 2007;58(1):61-7.
12- Chu WH, Gao NY, Templeton MR, Yin D-Q. Comparison of inclined plate sedimentation and dissolved air flotation for the minimisation of subsequent nitrogenous disinfection by-product formation. Chemosphere. 2011;83(5):647-51.
13- Lee EJ, Kim HS, Jang A. Application of dissolved air flotation (DAF) with coagulation process for treatment of phosphorus within permeate of membrane bioreactor (MBR). Desalination Water Treat. 2016;57(19):9043-50.
14- Radzuan MA, Belope MA, Thorpe R. Removal of fine oil droplets from oil-in-water mixtures by dissolved air flotation. Chem Eng Res Des. 2016;115:19-33.
15- Lee KY, Kim SJ, Lee Y-W, Yeom IT. Activated Sludge Clarification Using an Advanced DAF Process Based on the Down-Flow Floating Cover Filtration. Sep Sci Technol. 2011;46(12):1915-21.
16- Jung HJ, Lee JW, Choi DY, Kim SJ, Kwak DH. Flotation efficiency of activated sludge flocs using population balance model in dissolved air flotation. Korean J Chem Eng. 2006;23(2):271-8.
17- Ortiz-Oliveros H, Flores-Espinosa R, Jiménez-Domínguez H, Jiménez-Moleón M, Cruz-González D. Dissolved air flotation for treating wastewater of the nuclear industry: preliminary results. J Radioanal Nucl Chem. 2012;292(3):957-65.
18- Sourani M, Mehrabani A, Ghafari Gh, Hasheminezhad H. Oil refinery wastewater treatment by coagulation with ferric chloride and dissolved air flotation. Farayand-e-No. 2014;45(1):27-35. [Persian]
19- El-Gohary F, Tawfik A, Mahmoud U. Comparative study between chemical coagulation/precipitation (C/P) versus coagulation/dissolved air flotation (C/DAF) for pre-treatment of personal care products (PCPs) wastewater. Desalination. 2010;252(1-3):106-12.
20- Inc. Metcalf & Eddy, Tchobanoglous G, Stensel HD, Tsuchihashi R, Burton F. Wastewater engineering: Treatment and resource recovery. 5th edition. New York City: McGraw-Hill Education; 2013.
21- Clesceri LS, Eaton AD, Greenberg AE, Association APH, Association AW, Federation WE. Standard methods for the examination of water and wastewater [Internet]. Washington, D.C.: American Public Health Association [Published 1998, 16 August; Cited 1998, 16 August]. Available from: https://www.standardmethods.org/.
22- de Nardi I, Fuzi T, Del Nery V. Performance evaluation and operating strategies of dissolved-air flotation system treating poultry slaughterhouse wastewater. Resour Conserv Recycl. 2008;52(3):533-44.
23- Li X, Xu H, Liu J, Zhang J, Li J, Gui Z. Cyclonic state micro-bubble flotation column in oil-in-water emulsion separation. Sep Purif Technol. 2016;165:101-6.
24- Tansel B, Pascual B. Removal of emulsified fuel oils from brackish and pond water by dissolved air flotation with and without polyelectrolyte use: Pilot-scale investigation for estuarine and near shore applications. Chemosphere. 2011;85(7):1182-6.
25- Zheng T, Wang Q, Shi Z, Huang P, Li J, Zhang J, et al. Separation of pollutants from oil-containing restaurant wastewater by novel microbubble air flotation and traditional dissolved air flotation. Sep Sci Technol. 2015;50(16):2568-77.
26- Bahadori A, Zahedi G, Zendehboudi S, Bahadori M. Estimation of air concentration in dissolved air flotation (DAF) systems using a simple predictive tool. Chem Eng Res Des. 2013;91(1):184-90.
27- Adlan MN, Palaniandy P, Aziz HA. Optimization of coagulation and dissolved air flotation (DAF) treatment of semi-aerobic landfill leachate using response surface methodology (RSM). Desalination. 2011;277(1-3):74-82.
28- Zhang Q, Liu S, Yang C, Chen F, Lu S. Bioreactor consisting of pressurized aeration and dissolved air flotation for domestic wastewater treatment. Sep Purif Technol. 2014;138:186-90
29- Hosseinzadeh H, Shayegan J, Jalali M. Performance enhancement of dissolved air flotation column in removing low concentrations of heavy fuel oil by adding powdered activated carbon. J Desalination Water Treat. 2013;51(16-18):3353-60.