APPLICATION OF AIR STRIPPING IN REDUCTION OF AMMONIACAL NITROGEN FROM PIGMENT INDUSTRY EFFLUENT

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Abstract: Removal of ammoniacal nitrogen from pigment industry effluent by the air stripping process was studied. Air stripping was subjected to two different samples having ammoniacal nitrogen concentration in the range of 15000-16000 mg/L and 400-500 mg/L respectively. Air stripping was carried out using a lab scale aerator having a flow rate of 8 lpm. Effects of various operating parameters such as initial pH, stripping time and air flow on ammoniacal nitrogen removal were studied. pH optimizations had to be done as both the samples had different initial pH and ammonia/ammonium ratio shifts towards ammonia due to high pH. During the air striping, the stripping efficiency increased with increasing air flow and initial pH. The rate of decrease in concentration of ammoniacal nitrogen decreases with time.

Keywords: Ammoniacal nitrogen removal, Pigment industry effluent, Air stripping

Introduction

Nitrogen and its compounds are becoming increasingly important in wastewater management because of the many effects that nitrogenous material can have on the environment. Ammonia nitrogen is the main form of nitrogen in the water environment. Ammoniacal nitrogen (NH_3–N and NH_4^+-N) indicates the amount of nitrogenous organic matter that has been converted to ammonia. Ammoniacal nitrogen acts as a nutrient for aquatic plants and algae, and exerts oxygen demand in receiving waters leading to a poor water quality, eutrophication and toxicity to sensitive aquatic biota. [1] So, ammoniacal nitrogen (NH_3–N) has been selected as one of the indicators for assessing river quality, such as water quality and river pollution indices. [2] Moreover, environmental regulations regarding NH_3-N in municipal and industrial wastewaters that flow to nitrogen-sensitive receiving waters are becoming steadily more stringent in India. According to CPCB standards of effluent discharge, ammoniacal nitrogen (as N) concentration shall not be more than 50 mg/L. so, it is important to reduce the ammoniacal nitrogen concentration in order to meet the discharge standards.

Ammoniacal nitrogen can be removed from wastewater through both, biological and physico-chemical treatment methods such as biological nitrification-denitrification, ammonia stripping, breakpoint chlorination, ammonia precipitation [3], ion exchange, etc. Biological nitrification-denitrification is the most adopted method for removal of ammoniacal nitrogen from wastewater as it is energy efficient and does not require the addition of chemicals for the treatment. But, this method is very sensitive to toxic loading, shock loads, cold weather conditions. [4] Also, the nitrifiers are sensitive to pH and requires longer retention time. Another method, breakpoint chlorination, uses chlorine to oxidize ammoniacal nitrogen (NH_3-N) to nitrogen gas (N_2). To reach the chlorine breakpoint, sufficient chlorine (weight ratio of Cl_2:NH_3-N = 7.5:1) need to be added to satisfy all the demand in wastewater, resulting in high cost and formation of disinfection byproducts. [5]

As compared to above mentioned processes, air stripping is a simple process of physical-separation which is generally used for the wastewater with high ammonia concentrations. In addition ammonia removed by air stripping can be reabsorbed to acid absorption solution. There are various air stripping methods such as packed tower, bubble aeration [6], water-sparged aeroclone and micro-fabricated stripping column. [7]

Effluent from pigment industry is highly ammonia concentrated due to use of various chemicals like urea, phthalic anhydride, ammonium molybdate, etc. as raw materials. Both ammonia and carbon dioxide gas are evolved during manufacturing process due to decomposition of urea. Conventional ETP is generally installed for the treatment of wastewater generated during manufacturing process, which efficiently removes oil & grease and COD. But, reduction of TDS and ammoniacal nitrogen pose a great problem due to their higher concentrations. Concentration of ammonical nitrogen in the effluent stream is so high (i.e., 500 – 16000 mg/L) that biological treatment cannot be employed for its reduction as it hinders the growth of microbes.

Ammonia nitrogen exists in pigment industry effluent as either the ammonium ion (NH_4^+) or ammonia gas (NH_3), depending on the pH of the solution, in accordance with the following equilibrium reaction:

$NH_4^+ \leftrightarrow NH_3 + H^+$ ………………… (Eq. 1)

For effective air stripping, it is required to maximize the volatile ammonia component. Three major factors need to be considered i.e., temperature, pH and air flow-rate. Temperature of wastewater needs to be maintained high (25℃ – 28℃) as volatility of ammonia is temperature dependent. Higher pH (10.8 – 11.2) is also important for ammonia volatilization, which can be achieved by addition of lime or sodium hydroxide.

Bubble aeration can be used for removal of gaseous contaminators without any packing material. This method is advantageous over other air stripping methods, especially for lab scale experiments as it does not require any construction, is simple and generally inexpensive. [7]

In this study, bubble aeration method was applied for reduction of ammoniacal nitrogen from pigment industry effluent having very high ammonia concentration. The removal efficiency for ammoniacal nitrogen was studied for effects of initial pH, stripping time and air flow rate.

Characterization of Pigment Industry Effluent

Sample ID	pH	Initial Ammoniacal Nitrogen as N (in mg/L)
S-1 (Neutral sample)	9.78	450-600
S-2 (Alkaline sample)	10.56	14050-16200

The conversion factor is:

Ammonia (NH_3) multiplied by 0.8235 equals ammonia as N (NH_3-N).

For example: Ammonia concentration (NH_3) = 500 mg/L

But, Ammoniacal nitrogen concentration (NH_3-N) = 500 × 0.8235

= 411.75 mg/L

Experimental Setup

A glass flask with 500 mL of volume was used for bubble aeration experiments (Figure 1). Lab-scale aerator with flow rate of 8 lpm was used for providing aeration. The efficiency of ammonia removal, can be defined according to the equation;

$\eta = (C_{in} – C_t) / C_{in}$ ……………….. (Eq. 2)

where, C_{in} and C_t are ammonia concentrations (mg/L) in the wastewater at the beginning and at any time (t).

Figure 1: Lab-scale Batch Stripping System

Analytical Methods

Determination of ammonia concentration was carried out by Ammonia-Selective Electrode Method (4500-NH_3 D) as described by APHA. The ammonia-selective electrode uses a hydro-phobic gas permeable membrane to separate a sample solution from the electrode internal solution. Dissolved ammonia (NH_3 and NH_4^+) is converted to NH_3 by raising pH to above 11 with a strong base. Dissolved ammonia in the sample will pass through the membrane until the partial pressure of ammonia is equalized. The ammonia gas reacts with the internal filling solution creating an electrical current which will be proportional to the ammonia nitrogen (NH_3–N) concentration. HANNA HI 4222 pH/mV/ISE/temperature Bench Meter was used for measuring the ammonia concentration.

Experimental Procedure

Initial pH and ammoniacal nitrogen concentration of the sample were measured first. Then the pH of the sample was adjusted to > 11 by adding pallets or 1 molar solution of NaOH. Then the samples were aerated using lab-scale aerator for required time intervals (i.e., 10 minutes to 70 minutes) and various air flow-rates (i.e., 8 and 12 lpm). Then the reduction in ammoniacal nitrogen concentration was measured after every 10 minutes of aeration. The final pH of the sample and volume of the sample left after aeration was measured and removal efficiency was calculated using equation 2.

Results and Discussion

The influence of pH on ammoniacal nitrogen removal

During experiments, pH of the wastewater was changed for 9,10,11,12 and the influence of pH on air stripping experiment is shown in the figure 2 and 3.

As stated in equation 1, rising of pH will break ionization equilibrium and promote the formation of ammonia gas. Thus, it will improve the removal efficiency of ammoniacal nitrogen in wastewater.

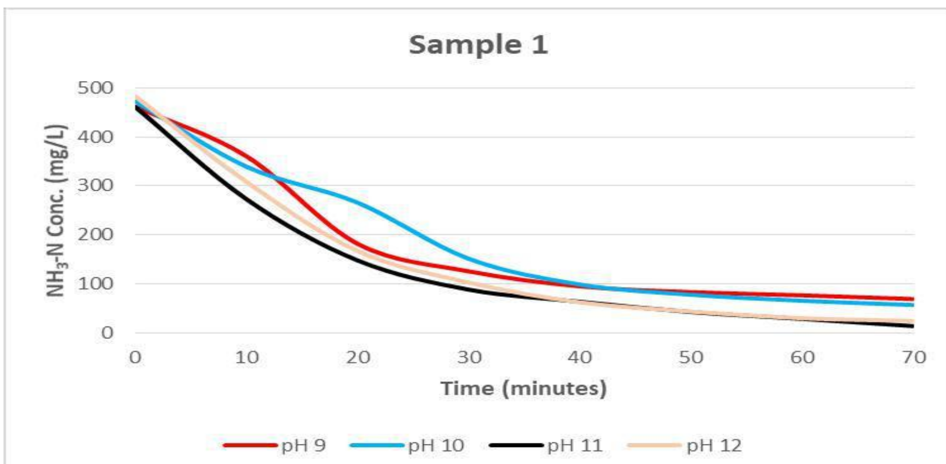

Figure 2: Effect of pH on removal of ammoniacal nitrogen for neutral sample

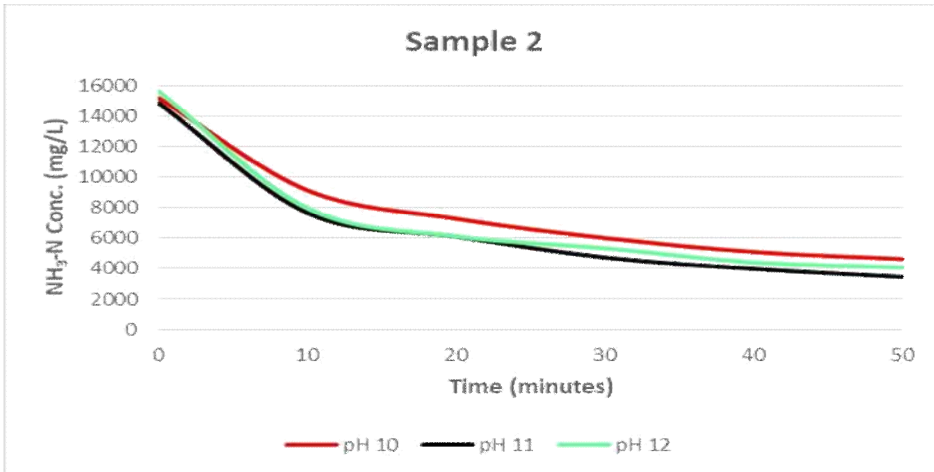

Figure 3: Effect of pH on removal of ammoniacal nitrogen for alkaline sample

Experiments were conducted at 8 L/min air flow and stripping time of 70 minutes and 50 minutes for sample 1 and sample 2 respectively. As seen in Fig. 2 and 3, as initial pH increased, removal of ammonia from wastewater increased. But there wasn't much difference in removal of ammonia between pH 11 and 12. The stripping rate remained constant when pH was higher than 11. So, pH was selected 11 to avoid increasing processing cost caused by NaOH required to increase pH. At this pH, removal efficiency of ammonia were 97.7 % and 79.35% respectively for sample 1 and sample 2.

The influence of aeration rate on ammoniacal nitrogen removal

Air flow was another important parameter on ammonia removal in air stripping. High air flow led to the increased rate of removal of ammonia in bubble aeration process. Figure 4 and 5 illustrates the effect of air flow on ammonia removal in air stripping (stripping time of 70 minutes and 50 minutes for sample 1 and sample 2 respectively and pH 11). The air flows were varied at 4, 8 & 12 L/min in the bubble aeration. Maximum ammonia removal efficiency at 8 L/min was 95% and 75% respectively for sample 1 (neutral) and sample 2 (alkaline).

Conclusions

I. Air stripping is feasible for the reduction of ammoniacal nitrogen from pigment industry effluent.

II. Removal efficiency and volume of air required is a function of initial concentrations of ammonia; higher the concentration, higher the efficiency and more volume of air is required for achieving the desired target.

III. In case of neutral sample, over 90% ammonia removal can be achieved and optimum operating conditions are pH 11, aeration rate 8 L/min and stripping time 70 minutes.

IV. In case of alkaline sample, over 75% of ammonia can be removed efficiently and optimum operating conditions are pH 11, aeration rate 8 L/min and stripping time 50 minutes.

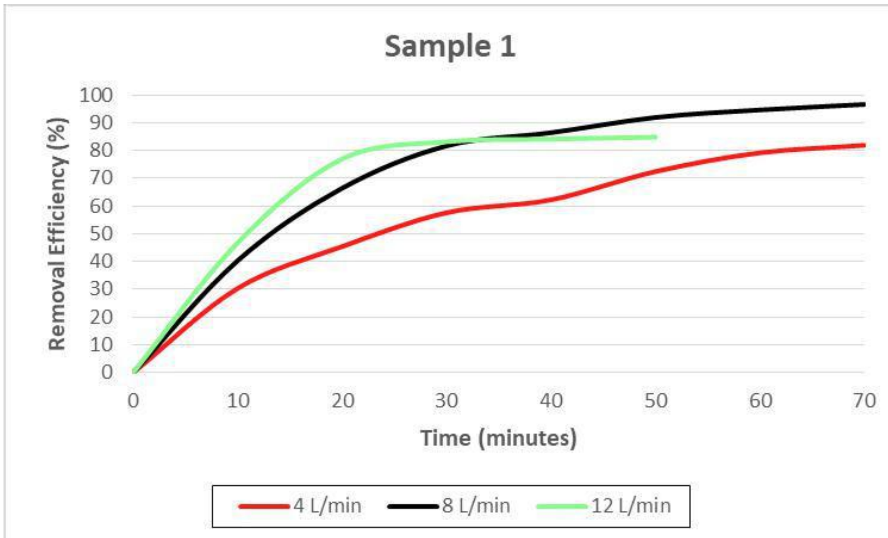

Figure 4: Effect of air flow-rate on removal of ammoniacal nitrogen from neutral sample

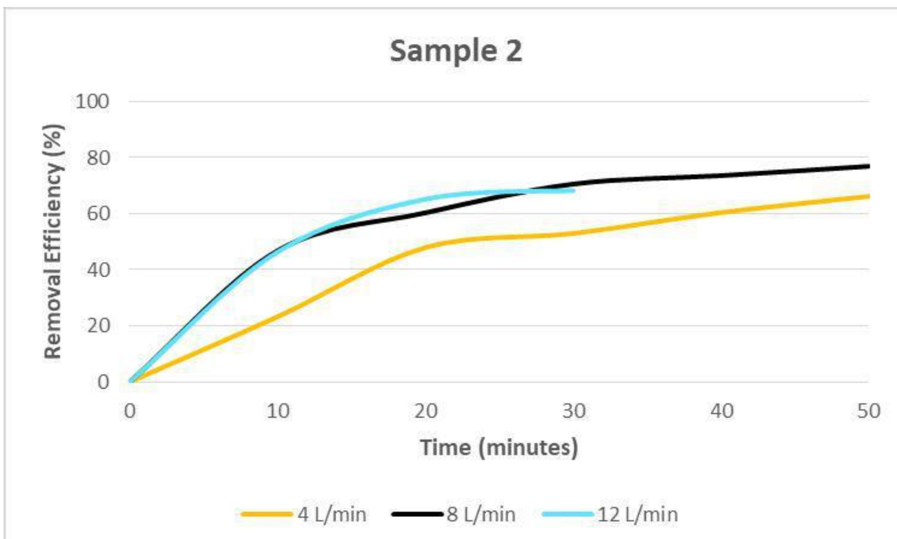

Figure 5: Effect of air flow-rate on removal of ammoniacal nitrogen from alkaline sample

VI. Stripping experiments on alkaline sample were also performed at initial pH (pH of 10.3 because of large volume of NaOH required to raise pH to 12) and it is found that ammonia can be removed efficiently until the concentration reaches to 3300 mg/L. After that, the removal efficiency (ammonia removed per volume of air) decreased significantly.

VII. Due to high buffering capacity of alkaline sample, large quantity of NaOH and acid was required to adjust pH to 12 and then to 7. As a result, huge increase in TDS was observed in the treated sample.

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