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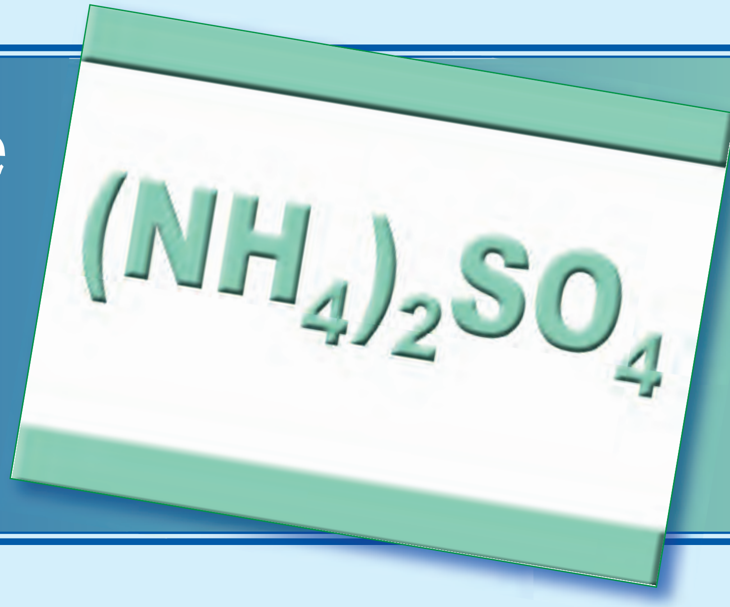
Calculating the Feed Rate for Ammonium Sulfate



An article on feeding ammonium sulfate to form combined chlorine residual can be found in the March 2016 issue of *The Kansas Lifeline* magazine and online at http://krwa.net/lifeline/1603/024.pdf. That article discusses the chemistry, the "chlorine to ammonia ratio", and gives an equation to use in feeding ammonium sulfate to the water being treated.

This article will review examples of determining how much ammonium sulfate (AS) solution to feed to form monochloroamine in the water being treated. The feed rate is dependent and proportional to the amount of monochloramine to be produced, the treated water flow rate, and the "extra", "free" ammonia desired; and dependent and inversely proportional to the strength of the AS solution.

General considerations

Ammonium sulfate (AS) is usually purchased in 25 pound bags. The Kansas Department of Health and Environment (KDHE) recommends that the chemical be NSF approved and chemical suppliers know such. Also, premixed ammonium sulfate solution can also be purchased in strengths of 35 percent, and 38 percent to 40 percent.

The first decision in setting up a feed system is determining the strength of the AS solution to be mixed. In addition, it is important to feed at a high enough rate that the operator can record the amount of solution pumped over a period of time to confirm and further monitor the ammonia dosage.

The solution tank should be large enough that replenishment is needed at least every four to five days; and the tank should be small enough that daily drawdowns can be measured to monitor and confirm the ammonia dosage. For instance, if the ammonia addition is operating 12 hours per day and the feed rate was 1.5 gallons per hour (gph), then a 50 solution tank would be good. That is, each day the drawdown of AS solution in the tank could be measured to monitored the ammonia dosage. Thus, 18 gallons of drawdown can be measured easier and more accurately than, for example, two gallons of drawdown for a 0.17 gph rate from the same tank.

The nearby table shows the different AS solution feed rates for different water treatment flow rates for different mixing strengths of AS solution to obtain 1.0 mg/l ammonium dosage. It is recommended as a general rule that the mixing strengths be in the range of 0.5 to 1.5 pound of AS per gallon of water (# / gal.) whenever possible. Also, the AS solution feed tank size should be selected to enable easily measured and accurate drawdown measurements.

Equation and definitions

$$gph = \frac{(mg/l) \times (GPM) \times 1.9}{(\#/gal) \times 1{,}000}$$

gph = gallons per hour (pumping rate of ammonium sulfate solution feed pump)

GPM = gallons per minute (water flow to which ammonia is being added)

mg/l = ammonia dosage in milligrams of ammonia per liter (ammonia as NH_4^+ or NH_3)

#/gal = pounds of ammonium sulfate per gallon (ammonium sulfate solution)

1.9 is a conversion factor

1,000 is a conversion factor

These two conversion factors are chosen for simplicity and are a combination of the following four factors: molecular weights ratio, grams per pound, minutes per hour, and liters per gallons.

Recommended Ammonium Sulfate Solution Feed Rates in gallons per hour (gph) To Obtain a 1.0 mg/l Ammonium Dosage		Treated Water Flow Rate in Gallons per Minute (GPM)										
		50	100	200	300	400	500	600	700	800	900	1000
Ammonium Sulfate Solution Mixing Rates in Pounds per Gallon	0.25	0.38	0.76	1.52	2.28							
	0.50	0.19	0.38	0.76	1.14	1.52	1.90	2.28				
	0.75		0.25	0.51	0.76	1.01	1.27	1.52	1.77	2.03	2.28	
	1.00			0.38	0.57	0.76	0.95	1.14	1.33	1.52	1.71	1.90
	1.25			0.30	0.46	0.61	0.76	0.91	1.06	1.22	1.37	1.52
	1.50			0.25	0.38	0.51	0.63	0.76	0.89	1.01	1.14	1.27

Notes: 1. Mixing rates of grandular, ammonium sulfate from bags
2. For different water flow rates, interpolate feed rate between the next lower and the next high feed rates.
3. Multiply gph feed rate by 63.08 to obtain feed rate in ml / min for feed pump calibrating.

The nearby table can also be used to determine maximum capacity of the AS solution feed pump. In general, the feed pump capacity should be about twice the required pumping rate so that the pump is operation around 40 percent to 60 percent if possible. There are many AS feed pumps being used that have a capacity of 1.0 gph to 4.0 gph.

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Small system rechlorination and ammonia addition

A small city has approximately 400 residents and buys water from another public water supply. During the warmer water temperature months from approximately June though October or November, the city needs to rechlorinate the water to boost the monochloramine residual. In addition the city needs to add ammonia because there is not much, if any, free ammonia in the water and the free ammonia can vary if it is present.

The ammonia is added to the water as the water flows into the city's clearwell at the pumping station that pumps the water 12 miles to the city. The flow rate coming into the clearwell is 120 GPM. During much of the warmer water temperature months the incoming combined chlorine residual can vary widely but the residual is generally less than 0.5 mg/l. The city chooses at that time to add 4.0 mg/l of monochloramine so as to obtain a 3.5 mg/l residual entering the city.

Thus, to increase the combined chlorine residual by 4.0 mg/l, the amount of ammonia that needs to be added is 4.0 / 4.18 = 0.96 mg/l.

That is, it requires 0.96 mg/l of ammonia to react with 4.0 mg/l of free chlorine (added at rechlorination at the pumping station) to form 4.0 mg/l of monochloramine.

Looking at the table, one might choose an AS solution strength of 0.5 # AS / gallon. Thus, the AS solution pumping rate is:

(120 x 0.96 x 1.9) / (0.50 x 1,000) = 0.44 gph

The pumping station only operates around four to six hours per day. So a 10-gallon AS solution "tank" and a peristaltic or diaphragm pump with a maximum capacity of 1.0 gph would be good selections.

Process control: records and adjustments

There are two suggested ways to monitor the ammonia dosages to determine if the chemicals are being used effectively. It is recommend that BOTH methods be used. If both methods are used, determinations should agree. If only one method is used, errors can occur without the operators having information to know such.

The first method includes: 1) testing the water for free chlorine residual just before the ammonia is added; 2) testing the water for combined chlorine or

Example: smaller water treatment plant

A city is operating a treatment plant and was adding AS solution to change the free chlorine residual to combined chlorine residual that is monochloramine. The plant is operating fine but the operator wanted to know what the ammonia dosage was. That calculation can be made from operating data using the same equation but rearranged.

The plant operates at 756 GPM. The AS solution strength is 0.5 # / gallon and 40 gallons of AS solution are used in 22 hours. The AS feed rate is: (40.8 gal) / 22.3 hours = 1.83 gph.

Using the rearranged AS feed equation, the ammonia dosage is (1.83 x 0.5 x 1,000) / (756 x 1.9) = 0.64 mg/l ammonia.

Thus, the maximum amount of monochloramine or combined chlorine that can be formed for the same amount of free chlorine is 0.64 x 4.14 = 2.6 mg/l.

If the operators wanted a higher combined, monochloramine residual leaving the plant, the ammonia dosage would have to be increased also.

Example: larger water treatment plant

A larger treatment plant operates at 1.7 MGD (1,180 GPM) in the winter and 3.5 MGD (2,430 GPM) in the summer. AS solution strength is 1.0 # / gallon. What are the AS solution pump feed rates in the winter and summer for feeding 0.9 mg/l ammonia?

Winter: (1,180 x 0.9 x 1.9) / (1.0 x 1,000) = 2.0 gph

Summer: (2,430 x 0.9 1.9) / (1.x 1,000) = 4.2 gph

The ammonia dosage of 0.9 mg/l will allow a maximum combined residual leaving the plant of 3.76 mg/l with no free ammonia. Operating at no free ammonia is very difficult to accomplish and maintain and any “extra’ free chlorine residual at the location of ammonia addition will cause the combined chlorine residual to decrease. The ammonia dosage of 0.9 mg/l with a 0.1 mg/l free ammonia will allow a maximum monochloramine or combined residual leaving the plant of 0.8 x 4.18 = 3.3 mg/l.

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monochloramine after the ammonia is added’ and 3) testing for the free ammonia after ammonia additions.

If all is going well, then the combined chlorine residual after ammonia addition should be about equal to the free chlorine residual before ammonia addition.

Also, the monochloramine after ammonia addition should be about 95 percent or more of the free chlorine residual before ammonia addition.

The free ammonia after ammonia addition and after the combined / monochloramine reaction is completed should be in the range of 0.1 to 0.2

mg/l with lower values being difficult to consistently maintain.

The second method is calculating the amount of ammonia dosage from ammonium sulfate solution monitoring data. The calculated dosage should be from the amount of AS solution used on a daily, weekly, and monthly basis. The calculated dosage should agree with the ammonia of the combined chlorine residual and the desired or measured amount of free, un-reacted ammonia in the water.

The calculated dosage in the second method should be very close to the free ammonia values plus the ammonia in the combined chlorine / monochloramine in the first method. If the methods agree, then all is well.

A hand-held DPD colorimetric tester such as this Hach unit with digital readout is one of the most commonly used monitoring devices in Kansas.

Testing equipment

A hand-held DPD colorimetric tester with digital readout for free chlorine or total chlorine is necessary if careful attention is also given to monitoring the usage of the ammonium sulfate solution and calculating the dosage. The monochloramine and free ammonia testers can give an added assurance of the data.

Automatic monitoring and recording equipment may also be used but should not be totally substituted for the hand-held testers and solution monitoring. Automatic equipment is more likely to monitor incorrectly and thus should be checked often with a hand-held tester. Also, be sure to regularly perform maintenance and cleaning on automatic equipment as recommended by the manufacturer.

Once the ammonia addition and rechlorination are set up and operating, both chemical feeds can be further "fine tuned" so as to obtain the desired monochloramine residual and "extra", "free" ammonia in the water. A good performance would be maintaining the "free" ammonia in the range of 0.1 to 0.2 mg/l but that can be difficult unless both chlorine and ammonia dosage are correct and do not vary.

Please contact KRWA if you wish any assistance or help in trouble-shooting problems with ammonia addition or chlorine residuals. KRWA staff are also available to check your feed rates that help ensure that proper amounts of ammonia and chlorine are being added. If any reader would like assistance with water treatment, call KRWA at 785-336-3760 or email to krwa@krwa.net.

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