Sludge Dryer Wet Scrubber Used to Produce Renewable Energy

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Andrew C. Bartocci
Envitech, Inc.
2924 Emerson Street- Suite 320
San Diego, CA 92106

ABSTRACT

A new biosolids processing facility in Southern California produces cement kiln fuel from waste sludge to provide a renewable source of energy. The majority of the facility dryer exhaust is recycled while the balance is exhausted to atmosphere. The dryer exhaust contains ammonia, particulate, sulfur compounds, and moisture. The sludge dryer wet scrubber condenses the moisture and captures the pollutants through a combination of air pollution control system components which include a quencher, condenser/absorber, Venturi scrubber, and packed bed absorber. Simultaneous condensing of water vapor and pollutant removal enables the exhaust to be recycled to the dryer while at the same time enabling the plant to meet tough California regulatory requirements for SOx, NOx and particulate.

INTRODUCTION

A new biosolids processing facility located in Southern California converts approximately 883 wet tons per day of biosolids from five municipalities in the Los Angeles region into 167 dry tons per day of fuel. The result is a clean, renewable fuel that is used by a local cement kiln as an alternative to coal. The facility produces essentially zero net greenhouse gas emissions.

The facility uses an innovative process that consumes approximately two-thirds less energy than traditional drying methods. The dryer exhaust contains ammonia, particulate, sulfur compounds, and water vapor which must be treated to control emissions. The Envitech sludge dryer wet scrubber is a combination of air pollution control system components which include a quencher, condenser/absorber, Venturi scrubber and packed bed scrubber. The system condenses water vapor and captures the pollutants, enabling the plant to meet tough regulatory requirements for SOx, NOx, and particulate. The majority of the exhaust is recycled to the dryer. This reduces energy consumption and allows the downstream RTO to be smaller, resulting in both capital and operating cost savings.

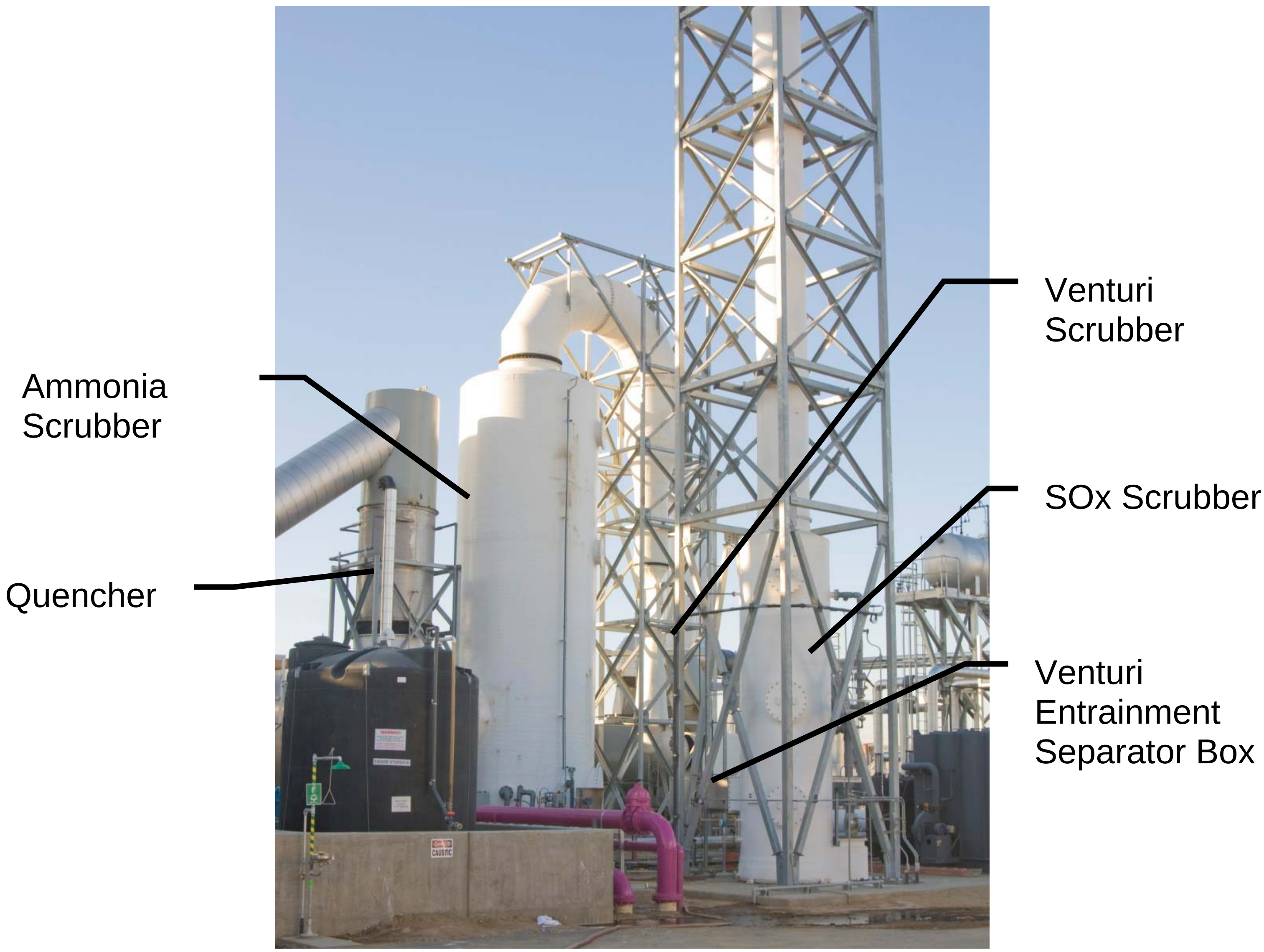
ENVITECH WET SCRUBBER SYSTEM DESIGN

The Envitech wet scrubber is designed as a multi-pollutant device using a combination of air pollution control system components. Figure 1 shows the overall system arrangement and major components. The system can be viewed as three principal sections as follows:

1. Ammonia Scrubber
2. Venturi Scrubber
3. SOx Scrubber

Each of these sections is discussed individually below.

Figure 1: Sludge Dryer Wet Scrubber System



AMMONIA SCRUBBER

The ammonia scrubber performs several key functions, including: 1) quenching the dryer exhaust gas to saturation, 2) collecting large particulate, 3) neutralizing and removing ammonia, and 4) condensing water vapor.

Flue gas from the sludge dryer enters the system at 93^{o}C (200^{o}F) and a flow rate of 90,047 m^3/hr (53,000 acfm). It is first cooled to a saturation temperature of 71^{o}C (160^{o}F) in an evaporative quencher. The quencher is a low pressure drop Venturi operating at 5.1 to 10.2 cm W.C. (2 to 4 inches W.C.). It is designed to remove particulate greater than 3 micron.

The gas then passes through a packed bed condenser/absorber. A 93% solution of sulfuric acid (H_2SO_4) is metered into the recirculation line to neutralize ammonia. The recirculation liquid is maintained at a pH below 3 to achieve greater than 99.9% ammonia removal. This suppresses NOx formation in a downstream regenerative thermal oxidizer (RTO) and is critical for the plant to meet NOx permit limits.

A liquid cooling circuit consisting of a plate and frame heat exchanger and a source of cooling water is used to sub-cool the gas to 49^{o}C (120 ^{o}F). This condenses approximately 70% of the water vapor. Condensing water vapor enables the majority of the gas to be recycled back to the sludge dryer, which reduces the energy consumption of the plant. Recycling the gas to the dryer also reduces the size of the downstream RTO resulting in both capital and operating cost savings.

A blowdown stream is taken from the condenser/absorber sump to purge condensed water vapor, particulate collected in the quencher, and ammonia sulfate.

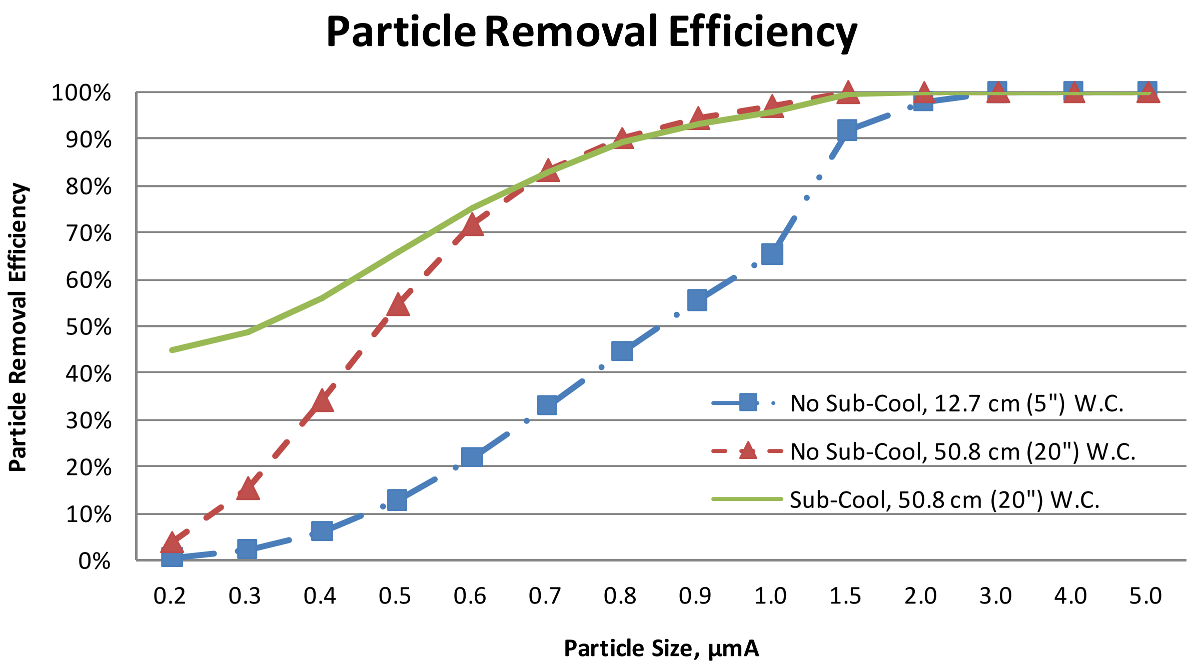
Before leaving the ammonia scrubber, the gas passes through a vertical, chevron style mist eliminator for water droplet removal. An interconnecting duct with a bifurcation directs 25% of the exhaust gas to the next section of the system, the Venturi scrubber.

VENTURI SCRUBBER

The Venturi scrubber removes the finer particulate remaining from the upstream quencher and packed bed scrubber. The Venturi takes advantage of water condensation effects from sub-cooling in the ammonia scrubber to enhance particle removal. Some of the water vapor from sub-cooling condenses on the particles causing their mass and diameter to increase. This allows the particles to be collected at a lower pressure drop. The Venturi operates at a pressure drop of 50.8 cm W.C. (20 inches W.C.).

Figure 2 shows a comparison of modeling results for particle removal efficiency versus particle size for 3 different cases based on pressure drop and sub-cooling. All three cases show that removal efficiency for small particulate is highly dependent on particle size. The removal efficiency begins to degrade as particle size decreases below 2 to 3 microns. Also be seen that greater removal efficiency is achieved with a higher pressure drop, i.e. removal efficiency is higher for 50.8 cm W.C. (20 inches W.C.) compared to 12.7 cm W.C. (5 inches W.C.).

Figure 2: Venturi scrubber particle removal efficiency comparison by pressure drop and sub-cooling



The case of no sub-cooling at a pressure drop of 12.7 cm W.C. (5 inches W.C.) (dashed blue line with dots) represents the upstream ammonia scrubber quencher. It can be seen that nearly all particles greater than 3 microns are removed. However, a significant amount of sub-micron particulate will pass through to the downstream Venturi scrubber. The Venturi scrubber is needed as a polishing step for the finer particulate < 3 microns.

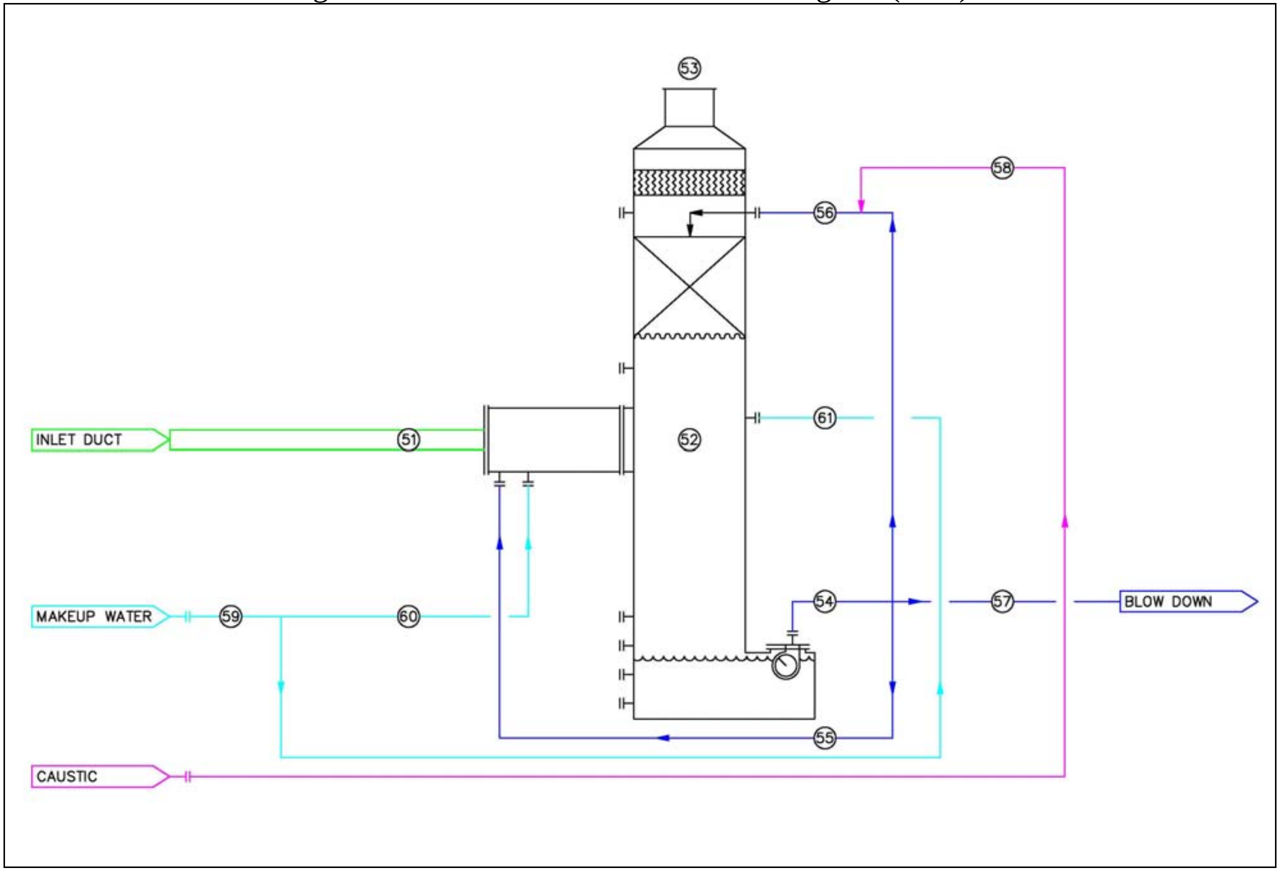
The remaining two cases (solid green line and dashed red line) show the benefit of sub-cooling for enhancing particle collection at a 50.8 cm W.C. (20 inch W.C.) pressure drop. For instance, the removal efficiency of a 0.3 micron particle without sub-cooling (dashed red line) is about 15%. However, sub-cooling increases the removal efficiency from 15% to just below 50% (solid green line). This is because sub-cooling grows the particle from 0.3 micron to 0.7 microns. The net effect of operating the Venturi at 50.8 cm W.C. (20 inches W.C.) with sub-cooling increases the overall particulate removal efficiency from 90% to 96%.

After the Venturi, the gas passes through a horizontal, chevron style mist eliminator for water droplet removal. The gas then goes to a downstream RTO (provided by others) for removal of volatile organic compounds (VOCs) before passing to the SOx scrubber.

SOx SCRUBBER

The final section of the Envitech sludge dryer wet scrubber is the SOx scrubber. Figure 3 shows the process flow diagram for this section. The SOx scrubber removes SOx in the gas stream resulting from the oxidation of sulfur compounds in the upstream RTO. The inlet gas to the scrubber is 204^{o}C (400^{o}F) at 40,776 m^3/hr (24,000 acfm) and contains about 8.6 kg.hr (19 lb/hr) of SOx.

Figure 3 SOx Scrubber Process Flow Diagram (PFD)



Hot flue gas from the RTO is first cooled to saturation in a horizontal quencher. It then passes through a packed bed absorber for acid gas removal. The pH of the scrubber recirculation liquid is maintained by adding 50 wt% caustic. Finally, the gas passes through vertical, chevron style entrainment separator at the top of the absorber tower for liquid drop removal. Recirculation liquid from both the packed bed absorber and the quencher is collected in the absorber sump. A blowdown stream is taken from the recirculation line to purge the system of the reaction products of SOx neutralization.

SUMMARY AND DISCUSSION OF RESULTS

The new biosolids processing facility posed many challenges to treating the sludge dryer exhaust. The scrubber system not only has to treat multiple pollutants: particulate, ammonia, SOx, but also has to condition the dryer exhaust for recycling the gas to the dryer. The facility relies on new technology so the inlet conditions used were based on material balances derived from pilot scale data. The preliminary design phase went through many iterations of material balances before the final system design was determined. The system design faced the additional challenge of integration with an RTO for VOC control. All of these factors required close collaboration with facility designers, upstream and downstream equipment suppliers, and plant contractors.

The system design makes use of well understood air pollution system components. A critical factor in meeting all of the design criteria as well as tough emission standards is the arrangement of the system components and process sequence. The system has been in operation since early 2008. Figure 4 below provides a summary of the key parameters that were achieved with the system design.

Figure 4: Summary of scrubber system performance

Parameter	**Inlet**	**Outlet**	**% Reduction**
Gas flow Rate, m^3/hr (acfm)	90,047 (53,000)	31,772 (18,700)	65%
Ammonia Scrubber Water Vapor[1], kg/hr (lb/hr)	16,874 (37,200)	4,990 (11,000)	70%
Particulate, kg/hr (lb/hr)	32.3 (71.3)	1.27 (< 2.8)	96%
Ammonia[2], kg/hr (lb/hr)	36.9 (81.4)	0.036 (< 0.08)	99.9%
SOx, kg/hr (lb/hr)	8.6 (19)	0.086 (< 0.19)	99%

[1]This shows inlet and outlet for the ammonia scrubber only.
[2]Ammonia reduction is critical to meet plant NOx permit limits.

CONCLUSION

Concern for global climate change coupled with high oil prices has generated a new interest in renewable energy sources. Harnessing these sources requires innovation and investment in new plants and technology. Air pollution control equipment is frequently a critical part of designing and building a new renewable energy facility. The design requirements often extend beyond single control system components. The air pollution control system can require a combination of system components working together to meet the demands of the facility design and increasingly tough regulatory standards. In the case of the new biosolids processing facility in Southern California, the Envitech sludge dryer scrubber was critical part in enabling a clean, renewable fuel source for a local cement kiln operation.

REFERENCES

1. Crawford, M. Air Pollution Control Theory, 1976.

2. Calvert, S.; Englund, M. Handbook of Air Pollution Technology, 1984

KEY WORDS

Sludge dryer scrubber, dryer scrubber, wet scrubber, ammonia scrubber, SOx Scrubber, packed bed absorber, packed bed scrubber, condenser/absorber, Venturi scrubber, multi-pollutant scrubber,