High Efficiency Odour Control for Sludge Dryers, Sludge Pasteurizers and Sludge Stabilisation using Lime and Biogas Treatment

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ABSTRACT

This paper summarizes ERG’s experience of supplying odour control for sludge dryers, sludge pasteurizers, sludge lime stabilization and biogas treatment and indicates areas for improvement.

KEYWORDS

Odour control, chemical scrubbing, carbon filters, waste water, Odorgard^{TM}, sludge dryers, sludge pasteurizers, lime stabilization, biogas, V-tex^{TM}.

INTRODUCTION

Since the banning of sewage sludge disposal at sea in 1998 secondary treatment of sludge is now a vital part of waste water treatment. Initially many water companies opted for incineration, but over the last 10 years other options have been adopted such as producing stabilised sludge and pelletised dried sludge for use as fertiliser for agriculture. Currently over 62% of sludge is used in agriculture and only 19% goes for incineration to produce power. The recent increase in the price of fertilizer is causing an increase in demand for sewage sludge fertilizer. The generation of biogas from sludge is also becoming important due to the recent surge in natural gas prices.

ERG over the last 10 years has supplied a number of odour control systems for sludge dryers, sludge pasteurizers, sludge lime stabilisation plant and more recently biogas conditioning up-steam of engines.

These types of odour control and gas cleaning plants are more complex than other odour control equipment used in the waste water industry. This paper will explain how ERG has dealt with these complexities and review the performance of the equipment.

I. ODOUR CONTROL FOR SLUDGE DRYERS

Types of dryers

There are two main types of sludge dryer which ERG has been involved with: belt dryers and direct fired dryers.

Belt dryers operate at a lower temperature than direct fired dryers and therefore drive off slightly less contamination than direct fired dryers. The sludge is dried by passing heated air over the conveyor carrying the sludge. Operating with high volumes of air at lower temperatures on a single pass basis converts less H_2S to SO_2 and so the exhaust tends to be more odorous since H_2S is more odorous than SO_2, and the odour emission is greater because of the higher volume of exhaust gases.

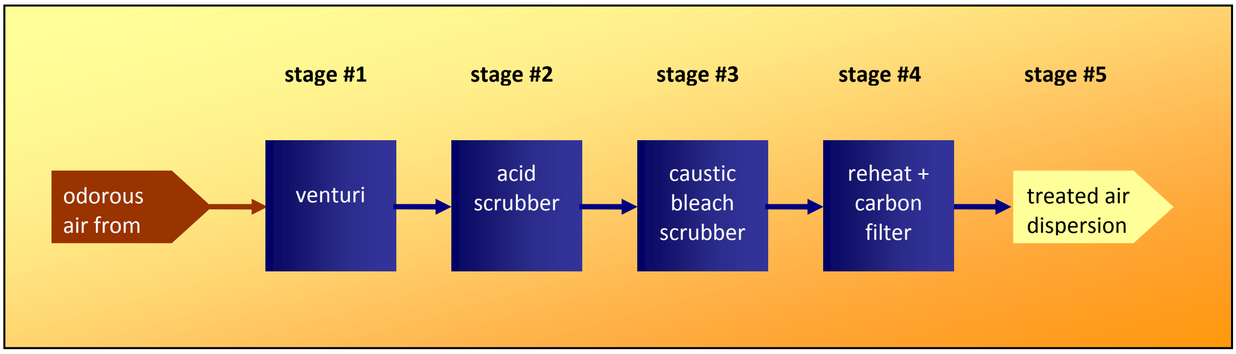
Direct fired dryers operate at higher temperatures and typically use a condenser loop to re-circulate the dryer exhaust back as combustion air for the burner. This re-circulated gas is sub-cooled in a condenser to reduce its water vapour content and temperature. A proportion of this cooled re-circulated gas is diverted to the odour control system in balance with the additional combustion air which is added to the dryer.

The table below is an example of the exhaust air to the odour control system from 2,000kg/hr water vapour sludge dryers.

	Units	**Belt Dryer**	**Direct Fired Dryer**	**Comment**
Gas Flow	m^3/hr	32,000	7,200	
Relative humidity	%RH	100	100	
Temperature	°C	40	70	Inlet temperature to odour control system
Peak Particulate	mg/m^3	1,000	2,000	Direct fired dryers have a bag filter so the 2,000mg/m^3 is the loading if a bag fails
Average Particulate	mg/m^3	25	2	
Peak H_2S	ppm	100	50	
Average H_2S	ppm	25	5	
Peak SO_2	ppm	25	100	
Average SO_2	ppm	5	10	If Biogas is used as the fuel SO_2 levels can be higher
Peak NH_3	ppm	50	300	
Average NH_3	ppm	25	100	
Peak VOCs	ppm	1	4	
Average VOCs	ppm	0.2	1	

Typical Gas Cleaning System for Dryer Exhaust Gases

A typical gas cleaning systems for treatment of dryer exhaust gases.



The treatment is typically divided into 5 stages:

The various odour sources and principally the dry exhaust are ducted to the odour control system.

Stage 1 – particulate removal by venturi scrubbing

The 1st stage is the removal of particulate and aerosols such as greasy siloxane deposits from the gas stream. ERG typically uses once through filtered final effluent (FFE) as the scrubbing liquor for the venturi. This FFE sprayed into the venturi throat captures the entrained particulate protecting the downstream scrubbers from fouling, cools the gas condensing out water vapour, captures about 80% to 90% of the ammonia depending on the pressure drop across the venturi throat, and removes about 20 to 30% of the H_2S and SO_2. ERG has used FFE on several sites and it is now proven to reduce maintenance and chemical consumption of down stream equipment.

Stage 2 – Alkaline gas scrubbing with acid

The 2nd stage is the removal of the alkali contamination such as ammonia and amines present in the gas by absorption into dilute sulphuric acid in a packed tower scrubber. The absorbed ammonia is converted into soluble ammonium sulphate.

Stage 3 – Caustic bleach scrubbing to remove H_2S, SO_2 and other sulphur compounds

The 3rd stage is the removal of the acidic contamination such as the H_2S, SO_2 and mercaptans present in the gas by absorption into dilute caustic bleach scrubbing liquor in a packed tower scrubber. The absorbed sulphur compounds are converted into soluble salts.

Stage 4 – Carbon Filtration

The 4th stage is the removal of VOCs from the gas. This involves reheating by about 7°C to reduce the relative humidity the gas and then adsorption onto pelletised activated carbon.

Stage 5 – Exhaust

The final stage is the exhausting of the gas at a suitable height and velocity so that effective dispersion is achieved.

From ERG's experience, a few of the key issues associated with effectively treating the odour from sludge dryers are highlighted below.

Ammonia emissions for Dryers

Ammonia emissions for sludge dryers dominate the exhaust contamination. On several sites that ERG has become involved with this fact has been overlooked and has resulted in malfunctioning of the odour control system.

This is because the alkali exhaust from the dryer has been combined with the odorous acidic extraction from the other areas of the site and fed to a single alkali bleach scrubber that has then failed to operate correctly because it has been swamped by the ammonia. This excess of alkali from the ammonia buffers the scrubbing liquor at about pH9 and thus prevents both sodium hydroxide (caustic) and sodium hypochlorite (bleach) from being dosed into the scrubbing liquor. Odour removal in these cases is very poor.

In certain cases this type of scrubber has been fitted with an Odorgard™ catalyst on the liquor recirculation system which enhances the oxidation process. This results in the absorbed ammonia being oxidised which in turn controls the build up of alkaline ammonium hydroxide in the scrubbing liquor. The draw back of this is that the ammonia is being inefficiently oxidised with expensive sodium hypochlorite instead of efficiently reacted with cheap sulphuric acid in an acidic pre-scrubber.

SO_2 and H_2S Emissions

ERG has been involved on sites where the impact of the SO_2 from the dryer exhaust has not been fully appreciated.

ERG has been involved with supplying wet chemical scrubbing systems for sludge dryers where H_2S levels as low as 5ppm have been specified with no mention of the 100ppm SO_2 that is also actually present. If sewage biogas is used as a fuel for the sludge dryer or for a thermal oxidiser (which can be used for odour control of the dryer off-gas as an alternative technology to the wet chemical scrubbing described above), then SO_2 levels in the exhaust can be significant. SO_2 is an acidic pollutant which will use high levels of caustic and bleach and so needs to be considered.

One of the advantages of using thermal oxidation to treat the exhaust from dryers is that in terms of odour control they are effective as they simply convert the highly odorous H_2S to almost odourless SO_2 and alkaline NH_3 to NO_x. It seems likely that in the future these SO_2 and NO_x emissions will have to be abated but for the present this is not the case.

Opportunity to manufacture ammonium sulphate

Currently large quantities of valuable ammonia are driven off sludge in the drying process. This ammonia can be easily captured and converted to >20%w/w ammonium sulphate solution which could then be used to enhance the quality of the sewage sludge fertiliser produced or sold separately.

Combining the direct fired dryer exhaust condenser and bag filter treatment with the odour control system

Currently the odour control systems for direct fired dryer are end of pipe solutions however there is an opportunity to integrate the odour control system into the exhaust conditioning system so that the odour control system becomes fully integrated with the dryer.

II. ODOUR CONTROL FOR SLUDGE PASTEURIZERS

Odour control for sludge pasteurisation systems present unique challenges as the exhaust gas flows are relatively small but highly contaminated. The odour control system ERG recently installed is only required to operate for 50% of the year, as during the winter months the sludge is cold enough not to require pasteurisation treatment. At low temperatures the bacteria the pasteurisation process treats does not form, so pasteurisation is not required.

Sludge pasteurisation involves holding the sludge at temperatures of approximately 70°C for about 2 hours. This operation destroys any harmful bacteria and makes the sludge suitable for conversion to fertiliser.

This process of heating the sludge for 2 hours drives off a cocktail of highly odorous contamination which requires treatment. As the process is batch as opposed to continuous the emissions to the gas cleaning package are highly variable, with peak loadings occurring as the batch reactors are vented down at the end of the 2 hour cycle and then refilled, expelling any residual gases in the reactors.

For a pasteurisation system comprising 8 pasteurizer vessels all operating in sequence the typical design extraction gas flow and contamination levels are as follows:

	Units	Average	Maximum
Gas Flow	m^3/hr	2,000	2,000
Relative humidity	%RH	100	100
Temperature	^oC	60	80
H_2S	ppm	400	800
Mercaptans	ppm	300	600
Sulphurous organic compounds	ppm	10	100
Various VOCs including low level chlorinated VOCs	ppm	10	100
Odour	ou_E/m^3	10,000,000	25,000,000

As the table indicates the contamination levels are highly odorous and variable.

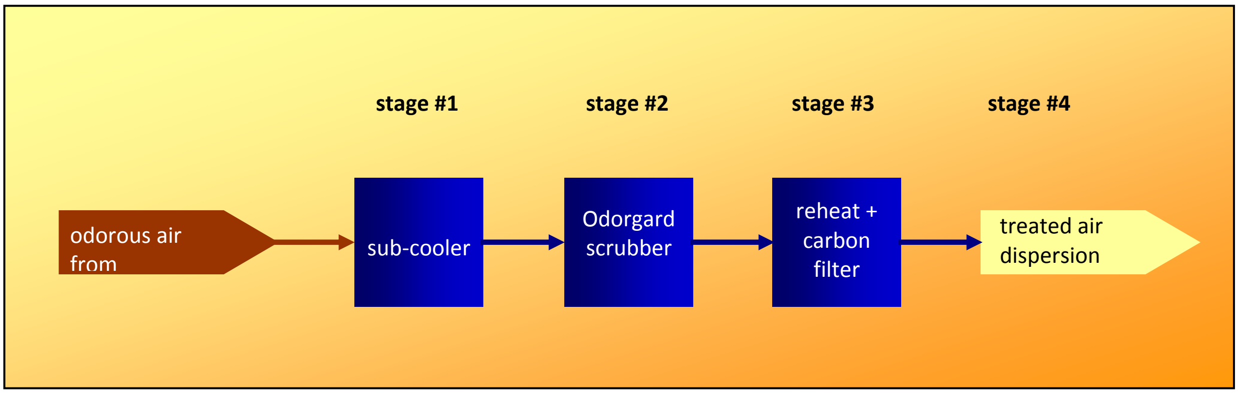
The 2 process solutions considered for the treatment of this exhaust stream were thermal oxidation and chemical scrubbing.

Thermal oxidation at temperatures above 850°C was ruled out as once the gas stream was thermally oxidised the sulphurous contamination would form high levels of SO_2 which would then require further complex treatment involving high temperature quenching and multiple stage chemical scrubbing. This solution would also generate greenhouse gases.

So direct chemical scrubbing of the pasteurizer exhaust was considered to be the more reliable and effective solution and with a lower carbon footprint.

Typical Gas Cleaning System for Sludge Pasteurizer Off-Gases

A typical gas cleaning system for the treatment of pasteurizer off-gases.



The system installed involves 3 treatment stages of the odorous air ducted from the pasteurizers as follows:

Stage 1 – Cooling the gas to <30°C

The hot, wet exhaust gas from the pasteurizers is drawn under negative pressure to a water sub-cooler scrubber vessel which scrubs the gas with water and cools the gas to <30°C by transferring the heat energy of the gas into the soft water which is heated up by about 10°C. The build up of heat and contamination in the soft water is controlled by continually blowing-down contaminated liquor to a neutralisation tank and then to drain.

Stage 2 – Catalytically enhanced scrubbing using Odorgard™

The cooled gas which now has about 50% of its H_2S contamination removed enters a large alkali scrubbing tower. The gas is scrubbed using dilute sodium hydroxide and sodium hypochlorite liquor which absorb the soluble contamination. The readily absorbed H_2S is easily captured and rapidly oxidised to soluble sodium sulphate. The less soluble but highly odorous contamination such as the mercaptans and sulphurous contaminants, for example, dimethyl sulphide (DMS) and dimethyl disulphide (DMDS) are also absorbed as the scrubbing tower has a high residence time and a high liquor rate. This contamination is then re-circulated through a bed of nickel based catalyst called Odorgard™. This catalysts bed hold millions of microscopic bubbles of oxygen on its surface which aggressively oxidise the absorbed contamination as it passes though the bed. This introduction of microscopic oxygen bubbles into the liquor speeds up the rate of oxidation and enhances the efficiency of removal of less soluble contamination.

The performance of the system was assessed using concurrent GCMS measured over an 8 hour period at the inlet and outlet of the scrubbing system and the results are tabulated below:

Compounds	**Inlet**		**Outlet**		**Removal**
	mg/m^3	**ppm**	**mg/m^3**	**ppm**	**%**
Organic Sulphur Compounds					
Methyl mercaptan (Methanethiol)	21.641	10.82	0.018	0.009	99.92
Ethyl mercaptan (Ethanethiol)	0.047	0.02	0	0	100.00

Dimethyl sulphide (DMS)	1.076	0.42	0.014	0.005	98.70
Carbon Disulphide	0.321	0.10	0.128	0.040	60.12
Allyl mercaptan	0.1	0.03	0	0	100.00
Methyl ethanethionate	0.758		0		100.00
Allyl methyl sulphide	0.018	0.00	0	0	100.00
Dimethyl disulphide (DMDS)	10.057	2.57	0.081	0.021	99.19
2-Methyl-2-(methio)-propane	0.184	0.04	0	0	100.00
Dimethyl trisulphide	4.219	0.80	0	0	100.00
Sub-total of sulphur compounds	**38.421**		**0.241**		**99.37**
Insoluble or low solubility VOCs					
Aromatic hydrocarbons	1.8		1.5		17.00
Cyclic hydrocarbons	2.4		0.6		75.00
Aliphatic hydrocarbons	3.3		2.8		15.00
Esters	0.6		0.4		33.00
Ketones	0.6		0.6		00.00
Aldehydes	0.8		0.8		00.00
Chlorinated compounds	0.5		0.5		00.00
Sub-total of insoluble VOCs	**10.0**		**7.2**		**28.00**
Soluble VOCs					
Alcohols	84.7		3.3		96.10
Terpenes	1.0		0.1		90.00
Sub Total of soluble VOCs	**85.7**		**3.4**		**96.00**

The table above shows that the combination of washing the gas with soft water and catalytically enhanced alkali scrubbing captures a high proportion of the highly odorous sulphurous compounds and removes 89% of the VOC.

Stage 3 – VOC removal using carbon filtration

The treated gas is then reheated by about 7^{o}C to reduce the relative humidity of the gas to about 70% so that the gas is correctly conditioned. This dry gas is then drawn into an activated carbon filter which adsorbs any insoluble odorous VOCs ensuring the gas emitted to atmosphere is free of odour

Removing 89% of the VOCs and >99% of the low solubility sulphur compounds in the stage 2 Odorgard^{TM} scrubber means that the final stage of carbon filtration is only required to polish out any residual odours. As carbon filtration is a batch operation this is desirable and it means the carbon bed can last for several years without requiring change out.

Particular challenges

Sulphur formation

Care is needed in the design of the scrubbing system to ensure that elemental sulphur precipitation is prevented as this can result in fouling of packing and pump blockage. Due to the large peak loadings it is essential the system is highly responsive so that the scrubbing liquor does not become swamped with contamination resulting in sulphur precipitation. This is achieved using fast reaction sampling of the liquor and rapid dosing techniques. This ensures the scrubbing liquor does not become acidic, and sulphur precipitation is prevented.

Sodium carbonate formation

The off gases can on occasions contain high levels of CO_2. This excess of CO_2 can then reacts with the caustic scrubbing liquor to form sodium carbonate. This can be prevented by careful design.

III. ODOUR CONTROL FOR SLUDGE STABILISATION USING LIME

Lime stabilisation is a popular method of treating sludge and producing an alkali fertiliser. When lime dust is mixed with the acidic sludge it generates an exothermic reaction which heats up the sludge destroying any unwanted bacteria. This heating up of the sludge drives off high levels of ammonia and a cocktail of odorous sulphurous compounds. Where possible this lime stabilisation process is carried out in remote areas where the odour release does not cause a public nuisance.

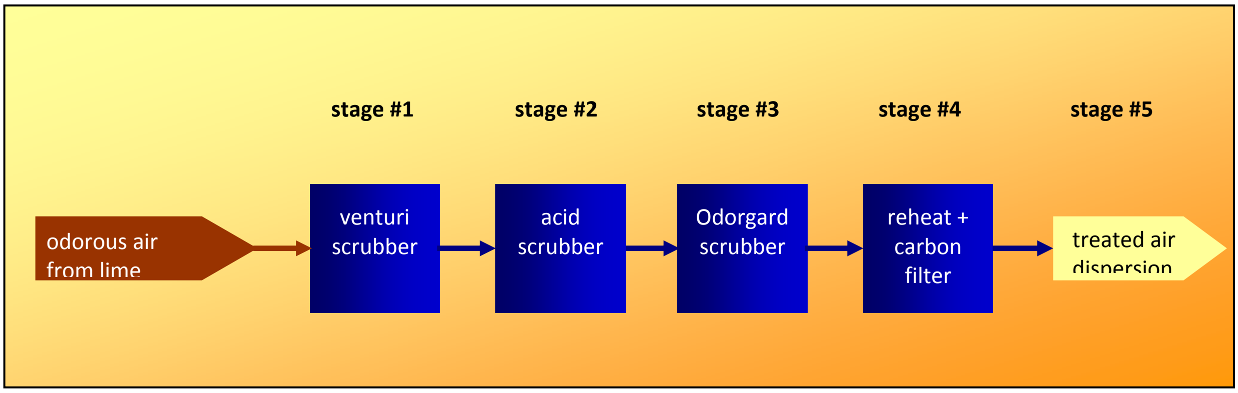
This is not always the case and odour control abatement systems are becoming increasingly necessary for this type of process.

Typical gas flow and contamination levels are as follows:

	Units	Average	Maximum
Gas Flow	m^3/hr	15,000	15,000
Relative humidity	%RH	100	100
Temperature	°C	20	30
H_2S	ppm	25	50
Mercaptans	ppm	5	20
Sulphurous compounds (DMS)	ppm	5	10
Various VOCs	ppm	2	4
Particulate (lime dust)	mg/m^3	<5	<20

Typical Gas Cleaning System for Lime Stabilisation of Sludge Off-Gases

A typical gas cleaning system for treatment of lime stabilization off-gases.



Stage 1 – Lime dust and ammonia removal

Typically the gas is drawn into a low pressure drop venturi which washes out any entrained lime dust and captures a proportion of the ammonia into the dilute sulphuric acid scrubbing liquor. This captured lime forms calcium sulphate particulate which is washed away or can be settled out in a settler vessel for disposal as sludge.

Stage 2 – Ammonia removal to high efficiency

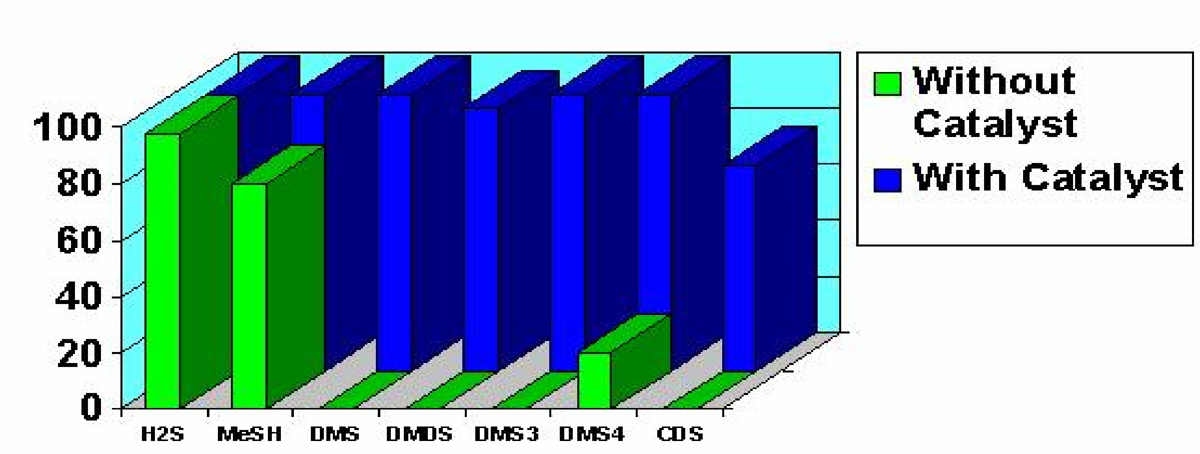
The gas free of dust is then scrubbed using either a cyclonic scrubber or a packed tower scrubber to capture all the ammonia ensuring only trace levels are allowed to proceed to the next stage of gas cleaning. Removing all the ammonia is important as low levels of alkali contamination can disrupt the efficiency of the down stream alkali scrubbing system.

Stage 3 – H_2S and sulphur compound removal to high efficiency

The gas then enters an alkali scrubbing tower which absorbs and stabilises the acidic contamination such as the H_2S, mercaptans and DMS.

If this stage is enhanced with the Odorgard™ catalyst then it is not necessary in most cases to have a final carbon filtration stage. A key advantage of Odorgard™ is its ability to remove dimethyl sulphide (DMS) which is highly odorous. DMS is 4 times more odorous than H_2S.

Below is a chart published by ICI Synetics (now owned by Johnson Matthey) showing removal efficiency in % for a variety of organic sulphur compounds.



The chart shows the dramatic improvement in DMS removal achieved by using the Odorgard™ catalyst.

Stage 4 – VOC and DMS removal using carbon filtration

The gas is reheated to reduce the relative humidity and then treated by carbon filtration to remove any residual odorous VOCs.

IV. BIOGAS TREATMENT UPSTREAM OF POWER GENERATION EQUIPMENT

Gasification

Gasification of biological sludge is used to generate power and has a relatively low carbon foot print when compared to fossil fuel power generation. Biological sludges however can be contaminated with pollutants which required capture prior to combustion and tars which require capture as they foul power generation engines.

Typical gas flows are relatively small and are different from odour control exhaust streams as they are composed mainly of methane, carbon monoxide and inert gases and have minimal oxygen present.

Sludge which is gasified in the waste water industry can have percentage levels of H_2S present and as well as siloxanes and tars.

Removal of the H_2S can be achieved by biological or chemical treatment and is relatively straight forward. Removal of the siloxanes and tars is more complex as these tars can form fine aerosols which are difficult to capture. These contaminants are detrimental to the power generating engines as they foul the pistons and cause engines to have to be taken off line for cleaning.

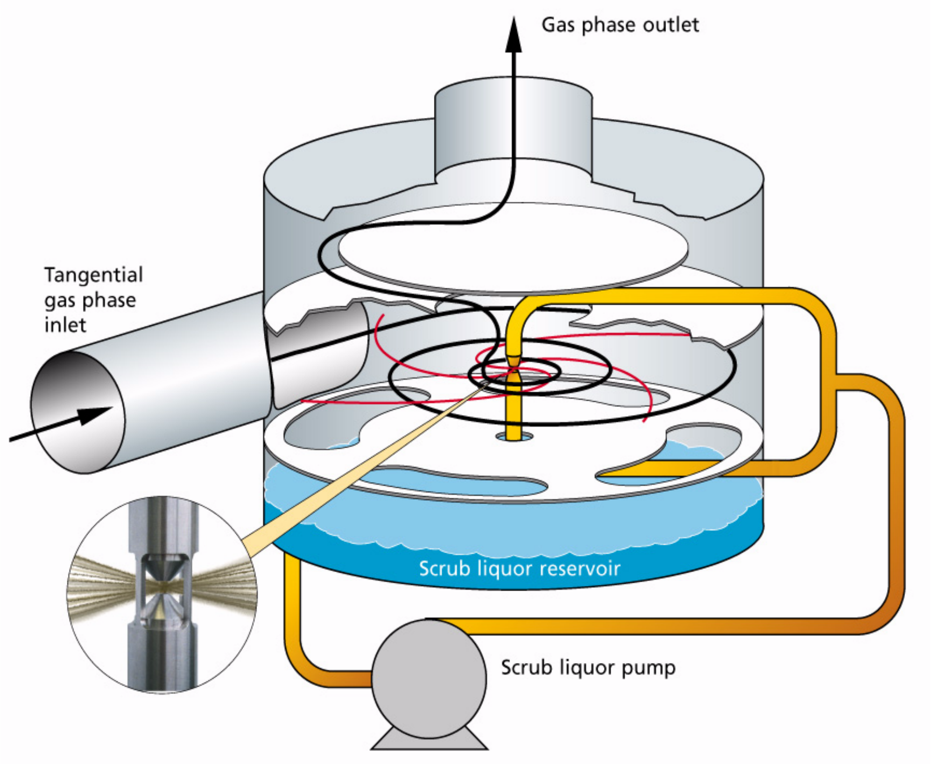
Prevention of Aerosol Formation

Care is required in cooling down the biogas stream leaving the gasifier so that the biogas is not sub-cooled in such a manner that sub-micron aerosols are formed which are then difficult to capture.

V-tex^{TM}

ERG has developed a unique patented method of scrubbing the gas with either biodiesel or water or caustic which captures the aerosols and in the case of bio-diesel scrubbing also absorbs the tars thus preventing fouling of the engine.

The patented technology employed is V-tex^{TM} scrubbing. This is explained by the diagram below. The gas is introduced into the specially designed vortex chamber and follows a spiral path to the centre of the chamber. The scrubbing liquor is sprayed out from the centre of the chamber using a unique opposed jet spray nozzle which generates a fine mist of rapidly moving droplets. These droplets capture the contamination and thus clean the gas. The gas leaves the vortex chamber via a mist eliminator and is then suitably conditioned for power generation.



CONCLUSION

Odour control systems and gas cleaning systems for secondary treatment sludge processing are more akin to air pollution control systems than typical end of pipe odour control systems. They are more complex and are generally cleaning gases of a toxic and hazardous nature as opposed to odorous air.

This paper has highlighted some of the issues facing air pollution control designers. The challenges of secondary sludge related air pollution are still relatively new and the air pollution control systems are often poorly integrated with the processed they are treating. No doubt this will change rapidly over the next few years.