SASOL NATURAL GAS PROJECT
MOZAMBIQUE TO
SOUTH AFRICA

ENVIRONMENTAL IMPACT STUDY

SPECIALIST STUDY 1
ENVIRONMENTAL DESIGN REVIEW

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Introduction

SASOL intends to develop the Temane and Pande Gas Fields in Mozambique. The Central Processing Facilities (CPF) for the fields will produce gas and a small amount of associated condensate, and will be designed to produce, treat and transport 122 MGJ/annum (136 MGJ/annum peak) gas from the above fields. The stabilised condensate will be stored within the gas plant facility and exported by road tanker, while the dry gas will be transported via a 900 km 26" pipeline to Secunda in South Africa.

Study Approach

Project Development Africa have been contracted to perform a review of the current design basis information, waste inventory data and recommended disposal methods, thereby assisting in the Environmental Impact Study (EIS) for the CPF facilities. This has included investigating the compliance of the new facilities to applicable guidelines and regulations.

Recommendations: Proposed Actions During Final Design

From this review, some major recommendations and considerations requiring further work in the final design phase of the project can be made:

- Conduct an independent review of the design of the facility;
- The Pande gas field should be tested for heavy metals, and the sulphur content of this field should be confirmed;
- The maximum level of mercury allowable in the feed gas to Secunda should be determined. The variation in mercury concentrations in the reported samples should also be resolved;
- The heavy metal analyses should be improved, as the lower detection limits of present methods are significantly higher than the limits quoted in standards or technical specification;
- Some minor discrepancies in the Foster Wheeler Waste Inventories, such as the NOx/CO emission ratios from the turbines should be resolved;
- Standard Operating Procedures (SOP's) should be developed;
- Two landfill sites will be provided – one for hazardous waste, and the other for non-hazardous waste. It should be confirmed that the hazardous waste landfill site design basis caters for the amount of mercury in the gas;
- Confirm BAT (Best Available Technology) for NOx abatement from turbines,
- Confirm BAT for treatment of TEG unit emissions, and
- Consideration should be given to the design of an effective facility to treat large volumes of stormwater or firewater with high levels of organic contamination.

Recommendations: Proposed Actions for the Preparation of an Environmental Management Plan

The preparation of an Environmental Management Plan is the next major phase of work to be undertaken in terms of the Environmental Impact Assessment process for the project. Some of the major considerations requiring further work during the next phase are outlined below:

- Conduct a full Environmental Impact Assessment and develop an Environmental Management Plan for the assessment and suitability of the landfill sites for the waste disposal facilities;
- Develop Waste Management Plan for the CPF;
- Develop a Response Plan for routine & worst-case discharges;
- Develop a Procedure & Permit system for re-injection of any fluids;
- Develop a Plan for Road routing, design, construction & maintenance;
- Develop a Spill Prevention Control & Countermeasure (SPCC) plan;

- Develop a Construction Pollution Prevention Plan;
- Preparation of permit requirements for Venting & Flaring, which could involve further air pollution assessment including the use of atmospheric dispersion modeling;
- Preparation of permit requirements for the emergency condensate disposal facility;
- Preparation of permit requirements for the Hazardous and non-hazardous landfill sites;
- Preparation of permit requirements for the discharge of treated liquid effluent to environment;
- Preparation of permit requirements for the incinerator installation;
- Preparation of permit requirements for the discharge of stormwater;
- Develop a Procedure for Clean up & remediation after well –drilling; and
- Develop a Well abandonment procedure catering for plugging, restoration & maintenance.

Conclusions: Areas of Concern

The CPF has been designed in accordance with the latest international guidelines and standards (with the World Bank Standards as a predominant source). Emissions from the CPF have been assessed against South African and international standards. Several areas of concern exist where guidelines will not be met, such as:

- A sulphur-impregnated activated carbon filter may be necessary in the vapour outlet line downstream of the condensed overheads separator to control the release of mercury into the atmosphere
- High NOx emissions from gas turbines may need to be controlled
- Components such as BTEXs (benzene, toluene, ethyl benzene and xylene), ethylene glycol and n-hexane have not been accounted for in the glycol reboiler vent stream
- Consideration needs to be given to the incineration of medical wastes, and the resulting release of dioxins
- No facility has been made available for the treatment of stormwater or firewater with high levels of organic contaminants.

Overall Risk Assessment

With the current knowledge of the CPF and given the nature of the materials used on site and the nature of waste streams that are likely to be generated, the facility is considered to be a low to medium risk facility. Provided that certain recommendations and reservations are addressed, the overall risk of the CPF could possibly be reduced to that of a low risk facility.

1.0 INTRODUCTION

1.1 Project Background

SASOL has commissioned independent consultants to undertake an Environmental Impact Study (EIS) on the proposed development of the Temane and Pande Gas Fields in Mozambique. This Specialist Study forms a part of the EIS, and assesses the predicted gas composition and emissions from the Central Processing Facilities (CPF).

The CPF for the above fields will produce gas and a small amount of associated condensate, and will be designed to produce, treat and transport 122 MGJ/a (136 MGJ/a peak) gas from the above fields.

The CPF will include all processing units, utilities, offsites and infrastructure necessary to produce gas and stabilised condensate, and will comprise the following processing units:

- Receiving facilities
- LP Gas Compression (FUTURE)
- Gas dehydration
- Gas dew point control
- HP Gas booster compression
- Condensate Stabilisation
- Custody Transfer Metering

The stabilised condensate will be stored within the gas plant facility and exported by road tanker, while the dry gas will be transported via a 900 km 26" pipeline to Secunda in South Africa.

The scope of this study includes the gathering and flow lines from the wellheads and the CPF, but excludes the wells, the export pipeline, and the gas line from the CPF that feeds the local network distribution system for domestic use and power generation.

1.2 The Study Area

The study area focuses on the site of the CPF. The CPF is proposed approximately 40km from Vilanculos and will be accessed by an approximately 5km long sealed road from the EN-1 coastal highway.

2.0 STUDY APPROACH

2.1 Method of Investigation

Mark Wood Consultants approached Project Development Africa (PDA), to review the assumptions made by the engineering design team and, in particular, to comment on the following aspects:

- To verify the accuracy of the emission data for gases, solids and liquids produced by Foster Wheeler;
- To identify the range of emissions that could result in the case of a plant upset or an accident;
- To conduct a critical review of gas composition information from Sasol with particular attention to components such as sulphur (S) and mercury (Hg);
- To advise if the samples taken are sufficient to justify the conclusions made regarding toxic contaminants, and if inadequate to advise on requirements;
- To quantify the hazardous and toxic liquid and solid substances collected during construction and operation that require disposal, and to indicate the best means of disposal;
- To summarise the work requirements with respect to pollution management such as Environmental Management Planning, Construction Management and Monitoring, and Operational Management and Monitoring;
- To advise on odour creating Volatile Organic Compounds (VOCs) present in the gas;
- To investigate the feasibility of re-injection of water and condensate, and
- To compare the estimated emissions to water and air with WHO guidelines, SA standards and any other relevant standards and guidelines.

3.0 LEGAL AND POLICY REQUIREMENTS

3.1 Environmental Requirements

The Project must meet the requirements of the Mozambique Environmental Framework Law, Decree 76/98, Government Gazette December 1998, which addresses general principles regarding protection of the environment. Overall requirements are further stated in Articles 23 and 26 of Mozambique Ministry of Mineral Resources and Energy document "Regulations for Petroleum Operations", March 2001.

As far as can be currently ascertained, there are no Mozambique Regulations in place that specifically address requirements for treatment of wastes and quality standards thereof. Foster Wheeler has generated emission standards for the project by using the World Bank and other international guidelines as a basis. In this study, considerable use has been made of the following South African Standards, which present design principles and procedures in detail:

- Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.
- Minimum Requirements for Waste Disposal by Landfill.
- Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities.
- SABS 0228, 1995: The Identification and Classification of Dangerous Substances and Goods.
- Occupational Health and Safety Act of SA.

The use of these South African standards is unlikely to result in conclusions that conflict with international standards as South African standards have in any case been developed with the principle of international acceptability in mind.

While the above standards are sufficient to be able to assess the handling and treatment required for any waste, they do not address procedures and practices relating to consideration of the environment during design, construction and operation of an installation and pipeline such as the one proposed in this project. These aspects are excellently covered in the American Petroleum Institute publication API RP (Recommended Practice) 51, "Onshore Oil and Gas Production Practices for Protection of the Environment", 2nd Ed, Sept 1995.

Mozambique regulations specific to emission standards were not available for this study (if they exist). The project standards were compiled by comparing safety, health and environmental standards generally accepted in the oil and gas industry, to ensure that the best industry standards were used in the design. These included:

- World Bank Standards,
- EU Standards (both current and planned),
- WHO standards,
- UK standards, and
- US EPA standards.

With regard to atmospheric emissions, useful comparisons can be made by reference to the US EPA (Environmental Protection Agency) publication 40 CFR Part 63: "National Emission Standards for Hazardous Air Pollutants: Oil and Natural Gas Production and Natural Gas Transmission and Storage".

The project design basis for environmental requirements specifies that the plant has been designed to the World Bank standards as a minimum. During this assessment the design has also been compared to several additional standards including:

- SA standards,
- Canadian standards, and
- US API standards.

3.2 Transboundary Movement of Hazardous Wastes

According to Foster Wheeler (e-mail from John Taylor dated 4/5/2001), provision is now being made for two landfill sites at the production facilities. One of these sites will be for non-hazardous waste, and the other will be a fully lined site for hazardous wastes.

If, however, provision is not made for a hazardous waste site in Mozambique, all hazardous wastes will need to be transported across the border into South Africa, where they can be disposed of into the existing Sasol hazardous waste site. The transboundary movements of hazardous wastes are controlled by the Basel Convention (1989) on Transboundary Movements of Hazardous Wastes, and by the Bamako Convention on the Ban of Import into Africa and the Control of Transboundary Movement of Hazardous Wastes within Africa (January 1991).

According to the Basel Convention, the Regulatory Authority (i.e. the Government) may only permit the exportation of hazardous wastes and other wastes after satisfying itself that the following conditions have been fulfilled:

- The Regulatory Authority has been provided with the relevant information;
- Packaging, labelling and transportation are in conformity with the recognised international rules, standards and practices;
- The exporter has formally applied for the transboundary movement of such wastes;
- Written consent of the Competent Authority of the State of Import;
- The existence of a movement document; and
- An adequate contract exists between the exporter and the disposer specifying environmentally sound management of the waste in question.

The Bamako Convention documents outline the stringent procedures that must be followed in the transboundary movement of the hazardous wastes.

4.0 IDENTIFICATION OF HAZARDS AND VERIFICATION OF EMISSIONS

The hazards in terms of wastes and emissions from the CPF are derived from three sources:

- The contaminants present in the natural gas, such as mercury;
- The contaminants from the various processes used in the CPF to render the gas suitable for downstream users, such as glycol; and
- The normal contaminants from a factory, such as lubricating oils.

4.1 Gas Chemistry

The natural gas from both the Temane and Pande gas fields has a similar composition, ranging from light to heavier hydrocarbons (up to C9's). The major hydrocarbon constituent is methane, with a mol% of about 92 to 95%. Other constituents of the gas include some inerts, carbon dioxide, water, and some contaminants (such as sulphur and heavy metals).

4.2 Hazardous and Toxic Components of Gas

Samples of natural gas were taken from four Temane field test wells. These samples were analysed by Arco (Core Lab) Oilphase was then contracted by Sasol to perform a full range of analyses (particularly for contaminants) on these results. Duplicate samples were also sent to Sasol laboratories for comparison purposes. In addition, Haldor-Topsoe (due to their expertise in reforming catalysts) was consulted by Sasol to verify the acceptable levels of heavy metals and other contaminants in the natural gas that could be tolerated by the catalysts in the downstream equipment. These values are quoted in Table 1 below.

Table 1 also summarises the results of the gas analyses, as reported in Sasol's Temane Field Gas Sampling Report.

TABLE 1: *Hazardous/toxic components of Temane gas*

Component	Quantity in Gas (according to sampling)	Max. Limit in Feed Gas to Secunda	Limit Source
Mercury	0.17 ppb** (=1.5 g/m^3)		
Arsenic	<0.15 ppmv (LDL)	0.2 ppbv	Haldor-Topsoe
Cyanide	<0.41 ppmv (LDL)	0.5 ppbv	Haldor-Topsoe
Sodium	<0.49 ppmv (LDL)	0.5 ppbv	Haldor-Topsoe
Potassium	<0.29 ppmv (LDL)	0.3 ppbv	Haldor-Topsoe
Vanadium	<0.22 ppmv (LDL)	0.3 ppbv	Haldor-Topsoe
Zinc	<0.17 ppmv (LDL)	0.2 ppbv	Haldor-Topsoe
Nickel	<0.19 ppmv (LDL)	0.2 ppbv	Haldor-Topsoe
Aluminium	<0.42 ppmv (LDL)	0.5 ppbv	Haldor-Topsoe
Sulphur	<150 ppmv – Pande Field <0.34 ppmv – Temane Field	15 ppmv total sulphur	Sasol Gas Sampling Report
H_2S	None	1 ppmv 3.8 ppmv (=5.7 mg/Nm^3)	Sasol Gas Sampling Report$^{)}$ EPA 42$^{)}$
Mercaptans	None		
COS	None		
Fluorine	<1.18 ppmv	0.2 ppbv	Haldor-Topsoe
Chlorine	<0.63 ppmv	0.2 ppbv	Haldor-Topsoe
BTEXs	Trace		
n-hexane	0.115 mol% (1150ppmv)		

Comments on the hazardous gas compositions quoted in Table 1 are as follows:

1. Mercury

The recommended maximum limit of mercury in the feed gas (to Secunda) should be specified and monitored on a regular basis. It is unlikely that the level of mercury in the natural gas has been underestimated, as typical levels of mercury in natural gas are lower (e.g. Mossgas natural gas shows levels of up to 0.00112 ppbv).

2. Heavy Metals

Haldor-Topsoe have recommended the maximum limits for the heavy metals in the natural gas to Secunda, above which there may be poisoning of the catalysts in the syngas units. These limits are a factor of 1000 times lower than the lower detection limits (LDL) of the heavy metals. It therefore cannot be assumed that there are no heavy metals present in the natural gas, particularly as trace amounts of aluminium and zinc were found (Sasol Gas Sampling Report). It is suggested that more accurate testing methods (with lower detection limits) be researched and employed in order to determine the actual quantities of the heavy metals in the natural gas. Several common methods of analysing these metals are available, however the detection limits of these tests are unlikely to be in the ppbv range. Such test methods may be uncommon, and may require specialised testing equipment/apparatus. It should therefore be determined whether the current process at Secunda utilises gas that adheres to these limits. If so, Sasol may have a practical means of determining the levels of heavy metals within the Mozambique gas.

3. Total Sulphur

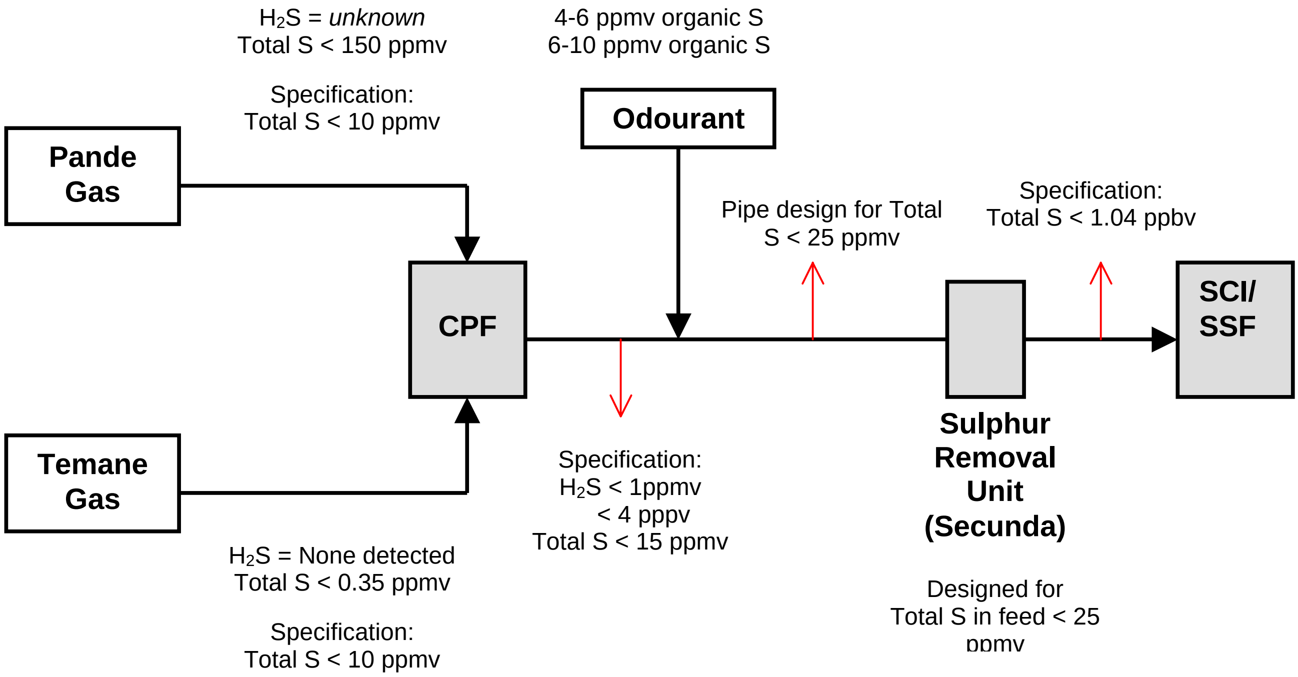
There is a possibility that the sulphur content of the Pande Gas may be higher than the specified limit. An analysis previously done by an engineering contracting company, John Brown (as mentioned in the Gas Sampling Report), only indicated that the sulphur content of the gas was below 150 ppm. Although there are no apparent reasons for the sulphur concentrations in the Pande and Temane Gas Fields to differ significantly, the sulphur content in the Pande Gas should be tested more rigorously in order to determine the actual sulphur present and thereby verify this assumption.

The sulphur content of the Temane Gas has been determined to be negligible. It has however been suggested in a Sasol Email, dated 1 July 1999, that the sulphur content of the gas is expected to increase with the life of the gas field.

The current assumed sulphur content of the gas should therefore be reconsidered, as higher sulphur levels may have a major impact on the future operations of the production facility and may even require Sulphur removal facilities.

See Figure 1 below for a representation of all of the limits specified for the involved processes.

FIGURE 1: *Schematic Showing Sulphur Specifications and Measured Concentrations*



4. Hydrogen Sulphide

A large fraction of the sulphur present in the gas may be in the form of hydrogen sulphide. If further testing of the Pande gas (see Note 3 above) yields that there is high sulphur content in the gas, the total H_2S content of the gas will also be higher. Note that there are some minor discrepancies in the H_2S specifications and also in the amounts of odourant added to the gas in various reports, but these have no significant environmental implications.

5. Odorous components

H_2S and mercaptans would be the primary source of odours at the production facilities. The on-site analysis for sulphur from the Temane Field indicated no H_2S at a Lower Detection Level (LDL) of 0 ± 0.3 ppmv and no mercaptans have been measured in the gas to date. These components should therefore not cause any significant odour problem. The Pande Gas field may be more problematic in this regard, depending on the total quantities of sulphur detected in the gas (see Note 1).

6. Fluorine and Chlorine

The detection levels of the Fluorine and Chlorine concentrations in the gas are considerably higher than the limit recommended by Haldor-Topsoe for downstream users. Although these components do not normally occur in natural gas, these are considered to be hazardous chemicals, with Chlorine having an Occupational Exposure Limit (Time-Weighted Average) of 0.5ppmv. Therefore, although it is unlikely that Chlorine or Fluorine will be present in the gas, these components should be tested for at lower detection limits.

7. Hazardous Air Pollutants (as defined by the Code of Federal Regulations)

The Code of Federal Regulations provides a list of compounds considered to be Hazardous Air Pollutants (HAPs). These have been reviewed in order to determine whether there is a possibility of them occurring in the natural gas. All of the expected relevant HAPs (such as benzene, toluene, ethyl-benzene, xylene (BTEXs) and n-hexane) have already been accounted for in the analyses of the gas, and it is unlikely that any of the other HAPs (such as acetaldehyde, formaldehyde and naphthalene) will be present in the natural gas.

4.3 Gas Emissions from the Plant under normal operating conditions (continuous and intermittent)

Table 2 below indicates the continuous gas/vapour emissions to air during plant operation. Table 3 indicates the emissions that are emitted intermittently during normal plant operation. Foster Wheeler has determined these values, which have been commented on where appropriate. The component quantities given are for the hazardous/harmful emissions only, whereas the total quantity refers to the total quantity of the emission stream, which will be predominantly made up of CO_2 in the exhaust cases. Note that the Foster Wheeler figures are based on 365 operating days per annum.

The following notation is used in the tables:

NOx	NO_2, NO, N_2O, etc. emissions
UHC	Unburned Hydrocarbons
SOx	SO_2, SO_3 etc. emissions
VOCs	Volatile Organic Compounds
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene Compounds
HAPs	Hazardous Air Pollutants

TABLE 2: *Continuous Gas Emissions to Air during Normal Operation*

Emission Source	Hazardous components of emission	Total Quantity [te/yr]	Component Quantities [te/yr]					Comments
			NOx	SOx	UHC	CO	VOCs	
LP Compression – turbine exhaust	NOx, UHC, CO	1434765	196.2	0	8.18	28.57	0	Possible underestimate of CO in the exhaust gas (See Note 1).
TEG Package – Glycol Reboiler Exhaust	NOx, UHC, CO	4464	2.36	0	0	1.48	0	There may be some UHC present in the exhaust gas, which has not been accounted for in the FW Waste Inventory. This will, however, be a negligible amount (See Note 1).
TEG Package – Glycol Reboiler Vent	BTEX, n-hexane, ethylene glycol							This item has been excluded from Foster Wheeler's Waste Inventory (See Note 4).
Dewpoint Control – Propane Losses 2x Refrigeration Compressors	-	Neglig-ible	0	0	0	0	0	
HP Compression – Turbine Exhaust	NOx, UHC, CO	2680560	494.6	0	2.98	16.49	0	Possible underestimate of CO in the exhaust gas (See Note 1).
Condensate Stabilisation – Reboiler Exhaust	NOx, UHC, CO	8177	4.32	0	0	2.7	0	
Electric Power Generation – Turbine Exhaust	NOx, UHC, CO	1040320	96.65	0	6.29	21.95	0	(See Note 1)
Diesel Fuel System – Tank Vents	VOCs	24 te/yr	0	0	0	0	0.2	FW quantity appears to be too high – the 0.2 te/yr quoted in the VOC column is in the right order of magnitude for this emission.

Emission Source	Hazardous components of emission	Total Quantity [te/yr]	Component Quantities [te/yr]					Comments
			NOx	SOx	UHC	CO	VOCs	
								Discrepancy between these two results (24 and 0.2 te/yr) should be resolved (these numbers should be the same).
Medical Centre	-	None	0	0	0	0	0	
Pilot light etc. – Pilot gas to flare	NOx, CO	48655	25.25	0	0	15.78	0	
Fugitive Emissions from Leaking Process Equipment	BTEXs, n-hexane							This has not been included in the FW Waste Inventory, however this is a major source of emissions (See Note 4)

Notes:

1. EPA AP-42 provides guidelines for the typical ratios of NOx and CO in the exhaust gas of both controlled and uncontrolled turbines, making use of natural gas as the source fuel. The Foster Wheeler Design Basis states that the turbines used will be low NOx turbines. The typical ratio for uncontrolled turbines should be in the region of NOx:CO = 1:0.24. The ratios of the figures provided by the vendors to Foster Wheeler for the gas turbines are considerably higher than this, particularly in the case of the HP Compressor. It would therefore appear that either the NOx figures are too high, or otherwise the CO figures quoted may be too low. With such high NOx emissions, it is recommended that the turbines be controlled in such a way to reduce these emissions.

2. Foster Wheeler has not accounted for the glycol reboiler vent stream in their waste inventory. Several HAPs may be emitted here on a continuous basis and this stream therefore requires careful consideration.

3. As mentioned in the Sasol Document on Design Gas Composition and Properties, BTEXs have been disregarded as possible Hazardous Air Pollutants (HAPs). These are, however, present in a ppmv level, and, while the concentrations are low, this is still substantial in terms of absolute quantities released into the atmosphere.

One of the main sources of HAPs in the oil and gas production industry are those released through the reboiler vent of the glycol dehydration unit. Components such as BTEXs (benzene, toluene, ethyl benzene and xylene), ethylene glycol and n-hexane need to be accounted for. These are estimated to be present in ppmv levels in the natural gas, which may result in significant quantities of these being released to atmosphere. It is therefore recommended that the quantities of BTEXs in the natural gas be more thoroughly investigated.

4. According to the EPA Standards, another major source of emissions in the natural gas industry is the fugitive emissions from leaking process equipment. The Foster Wheeler emissions inventory has not included any estimate of fugitive emissions. Methods for estimating the emission quantities from different equipment types are detailed in EPA-453/R-93-0206, *Protocol for Equipment Leak Emission Estimates*, June 1993. The air pollution assessment needs to include an estimate of the fugitive emissions.

TABLE 3: *Intermittent Gas Emissions to Air during Normal Operation*

Emission Source	Main hazardous components of emission	Frequency	Total Quantity [te/yr]	Comments
Inlet Facilities – Hydrocarbons on system depressurising	BTEXs, n-hexane	2-3 years		When maintenance is required on equipment, the system will be vented to the flare and gas freed by nitrogen purge to the flare before being opened to atmosphere.
Diesel Fuel System – Re-Fuelling Operations	VOCs	2/week	0.1	
Effluent System – Solids Incinerator Exhaust	NOx, CO, Dioxins	1 per week		
Condensate Storage/ Loading – Loading Operations	VOCs	-	226	Loading Operations will not be a continuous process, and the emissions lost to atmosphere should be significant less than that quoted by FW.
Condensate Storage/Loading – Tank Roof Seals	VOCs	-	85	These are Floating Roof Tanks, which substantially reduce the expected emissions. The quantity presented by FW should be at least one order of magnitude lower if the tanks are built and fitted with the latest EPA recommendations – this value should be recalculated.

4.4 Solid and Liquid Waste Inventory under Normal Operating Conditions (continuous and intermittent)

The following Tables 4 and 5 summarise the solid and liquid effluents produced by the plant on both a continuous and an intermittent basis. The waste inventory produced by Foster Wheeler comprehensively summarises all of the expected emission streams. Where appropriate, this waste inventory and the quantities given have been commented on by PDA.

TABLE 4: *Solid Wastes*

Emission Source	Emission state/phase	Worst Case Emission Classification	Quantity discharged in normal operation (FW schedule)	Comments
Inlet Facilities Pig Receiver residues	Sludge	Hazardous	1-2 te/yr	
Inlet Facilities Production Filter	Sludge	Hazardous	<1 te/yr	
LP Compression Cartridge Filters	Solid	Hazardous	<3 kg/yr	
TEG Package Sock Filters	Solid	Hazardous	2 kg/yr	
TEG Package Activated Carbon Filters	Solid	Hazardous	2 kg/yr	
Dewpoint control Filters	Solid	Hazardous	<1 te/yr	
HP Compression Cartridge Filters	Solid	Hazardous	<3 kg/yr	
Electric Power Generation – Filters		Hazardous	<1 te/yr	
Instrument & Utility Air Desiccant	Solid	Non Hazardous	1 -2 te/yr	
Potable/Utility Water - Filters	Solid	Non Hazardous	<1 te/yr	
Vent & Flare System – Emergency Condensate Disposal Facility Residues	Ash	Hazardous		Only on simultaneous failure of Condensate Stabilisation
Diesel Fuel System Tank Bottoms	Sludge	Hazardous	<1 te/yr	
Drain Systems – Sumps	Sludge	Hazardous	<1 te/yr	
Effluent System Solids Incinerator Exhaust	Ash	Hazardous		Incinerated sludges from digester
Canteen – Catering Waste	Solid	Non Hazardous	20-40 te/yr	
Chemical store – Office Waste	Solid	Non Hazardous	20-30 te/yr	
Medical Centre – Medical Sharps	Solid	Hazardous	1-2 te/yr	
Miscellaneous – Packaging	Solid	Non Hazardous	100-250 te/yr	

TABLE 5: *Sources of Liquid Effluent*

Emission Source	Intermittent/ Continuous	Worst Case Emission Classification	Quantity discharged in normal operation (FW schedule)	Comments
Effluent System – Treated Sewage	C	Non Hazardous	4563 te/yr	
Potable/Utility Water System Dosing chemicals - biocide/acid/caustic	I	Hazardous	<1 te/yr	The water quality is not known. Currently the water treatment scope does not include acid or caustic treatment, but this may be required in future
Fire Water System - water/foam	I	Non Hazardous	5-10 te/month	Normally there will be no foam except if there is a fire at the condensate tanks.
Effluent System – treated stormwater	I	Non Hazardous	6540 te/yr	
Effluent System – treated oily water	I	Non Hazardous	1359 te/yr	
Lab samples & reagents	I	Hazardous	<1 te/yr	
All Rotating Equipment – seals	I	Hazardous - Lube oils	20 te/yr	
Produced Water	C	Hazardous - Dissolved Hydrocarbons	464 te/yr (in Case 1) and will reach a max. of 3057 te/yr (in Case 4). (See Note 1)	This water has not been included in FW's waste inventory, as it will be reinjected into a well.

Notes:

1. The design compositions of the gas were predicted over four design cases, Cases 1 and 4 being:
Case 1: 100% Temane at initial pressure (7200 kPa at CPF inlet)
Case 4: 100% Pande at abandonment pressure (2240 kPa at CPF inlet)

In 1989, the API initiated a waste characterisation exercise, the results of which were published in API DR53. This study involved sampling and analysis of various wastes from numerous oil and gas facilities in the USA. Wastes tested which may be relevant to gas facilities included:

- Tank bottoms;
- Workover fluids;
- Produced sand;
- Glycol waste;
- Dehydration condensate water;
- Spent molecular sieve;
- Pit and sump samples; and
- Pigging materials

The analysis of these wastes showed the presence of several hazardous contaminants:

- Tank bottom samples generally yielded measurable levels of BTEX and fourteen metals, including aluminium, arsenic, barium, chromium, copper, lead, mercury, nickel;
- Only one sample of produced sand was tested, and showed measurable levels of BTEX and ten metals;
- In glycol waste, BTEX and seven metals were detected;
- In dehydration condensate water, BTEX and three metals, and;
- Pit and sump samples yielded BTEX and twelve metals.

From 120 samples (from all waste groups) analysed for benzene, 54% yielded detectable levels, with a range of concentrations from 0.01 to 6700 ppm. Only 12% of 33 samples yielded detectable mercury, varying from 0.1 to 1.4 ppm, while 45% yielded lead varying from 7 to 970 ppm.

Foster Wheeler has assumed that all mercury entering the CPF leaves either in the export gas, condensate or produced water and that there is no mercury-contaminated hazardous waste. Bearing in mind the above results and according to several other sources, for example Sasol Memorandum dated 27 October 2000 and Chemical Engineering Journal dated June 1998, the mercury will most likely accumulate in the gas treatment equipment, such as the glycol dehydrator unit and filters. Foster Wheeler's assumption should therefore be revised. Similarly most of the heavy metals will be present as solid particles, and these should mostly be removed by the activated carbon filters of the glycol dehydrator unit, which will therefore be contaminated with these heavy metals.

4.5 Gas Emissions from the Plant under Upset and Emergency Conditions

The values in Table 6 overleaf are supplied by Foster Wheeler, and are commented on as appropriate.

Notation used:

NOx	NO_2, NO, N_2O, etc. emissions
VOCs	Volatile Organic Compounds
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene Compounds
NNF	Not normally flowing

TABLE 6: *Intermittent Gas Emissions to Air due to Upset Conditions*

Emission Source	Main hazardous components of emission	Frequency	Total Quantity [te/yr]	Comments
Inlet Facilities - PSV on line between Temane Inlet Manifold and Production Separators	BTEXs, n-hexane	Only under process upset conditions	NNF	
Inlet Facilities – Production Separator	BTEXs, n-hexane	Only under process upset conditions	NNF	
Inlet Facilities – Liquid Separator	BTEXs, n-hexane	Only under process upset conditions	NNF	
TEG Dehydration – TEG Contactor	BTEXs, n-hexane, ethylene glycol	Only under process upset conditions	NNF	
TEG Dehydration – Glycol Reboiler, Glycol/Gas Separator	BTEXs, n-hexane, ethylene glycol	Only under process upset conditions	NNF	This stream has been assumed to be the glycol surge drum vent to flare. The gas vent from the glycol reboiler is a continuous stream and has been included.
HC Dewpoint Control - Drums and Chiller in Unit 50	BTEXs, n-hexane	Only under process upset conditions	NNF	
HP Gas Compression – HP Suction Scrubber	BTEXs, n-hexane	Only under process upset conditions	NNF	
Condensate Stabilisation - Stabiliser Flash Drum	BTEXs, n-hexane	Only under process upset conditions	NNF	
Condensate Stabilisation – Stabilisation Tower	BTEXs, n-hexane	Only under process upset conditions	NNF	
Emergency Elec. Gen. System – Emergency Diesel Generation	NOx (0.13 te/yr)	1/month	149	
Vent and Flare System - Flare Stack Main Startup	BTEXs, n-hexane, other HC's	Every 2 years	2214	Experience at Mossgas has shown that the frequency of this event is likely to be higher than proposed.
Vent and Flare System - Flare Stack Design Rate	BTEXs, n-hexane, other HC's	Every 10 years	69.2	Experience at Mossgas has shown that the frequency of this event is likely to be significantly higher than proposed
Vent and Flare System – Emergency Condensate Disposal Facility	VOCs	Every 10 years	69.2	

4.6 Liquid Emissions from the Plant under Upset and Emergency Conditions

There are four possible major sources of liquid emissions under emergency or upset plant conditions, which have not been included in the emissions inventory:

- During fire fighting there will normally only be firewater, but in the case of a fire in the condensate storage tank bunded area the firewater will also contain foam. This runoff from fire fighting could also be contaminated with hydrocarbons;
- Large volumes of stormwater contaminated with hydrocarbons (This is highly unlikely as the total volume of contaminated stormwater is relatively small at 140 m^3 per incident and most of the stormwater runoff will be from clean areas or paved areas, and the design caters for storage and processing of this volume of 140 m^3 of potentially contaminated water);
- Spills due to the failure of the Diesel or Condensate Tanks. Provided that the design of the bunded areas adheres to standard engineering practice, the bund volume will exceed the tank volume. There should therefore not be a surface liquid emission; and

- Spills due to the failure of other equipment. Should these occur where an adequate bund has not been provided, a surface liquid emission will occur.

4.7 Emissions during Construction of the Plant

Construction wastes for the CPF are listed generally in Table 7 below (reproduced from Foster Wheeler's Waste Inventory. It is understood at this stage that the CPF construction waste facilities will not be converted into permanent facilities for the operating plant.

TABLE 7: *Construction Wastes for CPF*

Source	Quantity	Unit
NON-HAZARDOUS MATERIALS		
Excavation Spoil	5700	t
Concrete	750	t
Bricks/blockwork	250	t
Timber	300	t
Plastic (bottles/containers)	10	t
Glass	2	t
Scrap Metal (rebar/pipe off-cuts)	300	t
Insulation materials	20	t
Cable scrap (elec./inst. cable cut-offs)	50	t
Grit (blasting material)	10	t
Food waste	150	t
Office waste	30	t
Cable drums	300	No.
HAZARDOUS WASTE FROM UTILITIES		
Engine oil	10000	Litres
Waste fuel	1200	Litres
Oil filters	600	No.
Empty chemical drums	500	No.
HAZARDOUS WASTE		
Waste oil	30000	Litres
Cooking oil	2000	Litres
Batteries	50	No.
Contaminated waste	100	Drums
Medical waste	15	Boxes
Oil filters	350	No.
Toner (from copiers)	150	No.
Tyres	30	No.
Battery acid	20	Litres
Solvents/paints	300	Litres
Sealants/mastic	500	Litres

Note that Foster Wheeler have not included sewage in the above table of wastes, however they have identified in the effluent design basis that the construction phase sewage treatment plant will be designed for about 1000 people.

5.0 METHODS OF WASTE HANDLING AND DISPOSAL

In terms of the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, wastes (including gaseous wastes) are classified as either general or hazardous according to the nature of the components of the waste. This classification is based on properties such as flammability, corrosivity, toxicity, etc. from SABS Code 0228. Hazardous wastes are further divided into one of four classes using a Hazard Rating system. Pre-treatment and disposal requirements are then set in accordance with this Rating.

Fundamental pre-requisites emerging from consideration of the wastes from the proposed facility are:

- The presence of solid wastes possibly containing flammable substances and/or mercury imply the need for a Hazardous Waste Landfill as well as a General Waste Landfill, of appropriate design and construction, with appropriate segregation and management of the wastes, and possibly requiring further treatment of the wastes before dumping, and
- Flammable gaseous wastes must be thermally destroyed.

5.1 Solid Waste

The US EPA, in a 1988 regulatory determination, decided that oil and gas exploration and production wastes were high volume and low toxicity wastes which should be exempt under Subtitle C of the US Resource Conservation and Recovery Act, under which Hazardous Waste is regulated in the US. These wastes include:

- Basic sediment and other tank bottoms,
- Accumulated materials from separators and fluid treating vessels and production impoundments,
- Pit sludges,
- Workover wastes,
- Glycol compounds from gas dehydration units,
- Spent filters/media,
- Packing fluids,
- Produced sand,
- Pipe scale,
- Hydrocarbon-bearing soil, and
- Pigging wastes.

Application of the SA DWAF standard to the above wastes would not necessarily lead to the conclusion that they are Non-Hazardous, depending on the nature and concentrations of hazardous components in the waste. In any event, inevitable generation of ancillary wastes which would unquestionably be classified as hazardous, such as batteries, solvents, paints, etc., lead to the necessity for segregation, control, possible further treatment and distribution of solid waste to separate land-fill sites. One of the sites should be designed and constructed to accept Hazardous Waste. The bulk of solid wastes would be segregated and dumped accordingly. On this basis, the Foster Wheeler proposal, which provides for two appropriately designed landfill sites (one lined for hazardous waste, and the other for non-hazardous waste), meets the requirements of the standard.

Foster Wheeler has estimated solid wastes from the facilities to be 300-350 tpa. The sizing of the Hazardous Waste landfill site may need to take into account allowable disposal rates of specific hazardous components (e.g. mercury) in terms of g/ha/month, as required by the SA DWAF standard. Applying this, and assuming all mercury in the gas (1.5g/Nm^3) ends up on the landfill, would imply a landfill area of approximately 17Ha. Provided the sites are positioned, designed, constructed and operated in accordance with the standards, the risk to the surrounding environment and population will be negligible.

The possibility of transporting the hazardous waste to the proposed new hazardous waste site for the Mozal development in Maputo has also been raised. It is suggested, however, that this possibility be discounted at this stage. These proposed facilities are still in the investigative phase, and there could be a substantial delay before they would be available. Transport of the waste to a third party site would present a further disadvantage.

Foster Wheeler proposes provision of an incinerator to burn sludges (mainly biomass, but also recovered oily waste from the oily water treatment facilities) accumulating in the effluent and sewage treatment facilities. Consideration should be given to treating medical and laboratory wastes here, to enable compliance with the SA DWAF requirement for potentially infectious wastes and flammable liquid wastes to be incinerated and not land-filled. Export of these wastes to SA as suggested is potentially onerous and expensive. The design of this incinerator is critical in terms of temperature of combustion zone and residence time, and the outlet of this incinerator may have to be processed through a scrubber or some other suitable device to ensure the destruction of dioxins.

5.2 Liquid Waste

Foster Wheeler proposes that a standard package Biological Aerated Flooded Filter (BAFF) be provided for the CPF construction camp sewage treatment. This would be modified and integrated into the ETU design.

The Foster Wheeler design allows for provision of liquid effluent treatment facilities for domestic sewage and gas plant effluent including drainage from the site area. Wastewater treatment systems to treat oil-contaminated water comprise one or more of the following operations:

- Gravity separators;
- Advanced treatment, including flocculation, air flotation, filtration; and
- Biological treatment.

Sasol are retaining the option to use septic tanks located close to the sources of domestic effluent and discharging into soak-pits, should these be found to be practical during the detailed design phase of the project.

Sanitary sewers feed into a biological aerobic treatment process. The treated water passes through final polishing, filtering and UV sterilisation operations prior to discharge via outfall to bush. The nature of this discharge is not clear, but FW have pointed out that care will be taken to avoid potential soil erosion by uncontrolled discharge of effluent.

Gas plant effluent is segregated into Oily Water (OW) Drainage, Potentially Oil-Contaminated (POC) Drainage, and Potentially TEG-contaminated drainage. The latter is held for testing for TEG and released to the POC drain only if contamination is low. OW and POC drains feed to an Oily Water Treatment Plant, except in the case of high run-off flowrates, where the POC drain system will overflow to storm water. Foster Wheeler Process Flow Diagrams 8456-8110-20-0019, 20, and 21 indicate oily water treatment facilities comprising:

- Skimmer,
- Chemical de-emulsification and flocculation,
- Corrugated plate separator,
- Induced gas flotation, and
- Walnut-shell filter.

The de-oiled water passes through an optional biological treatment (Biological Aerated Flooded Filter), prior to polishing in a Polishing Trickling Filter followed by a sand filter and UV steriliser. The filtered and sterilised water is discharged via outfall to bush.

A second treatment option where water is treated to a “sufficient quality for discharge into a watercourse” is under consideration: “TPS (Tilted Plate Separator) Only For Oily Water Treatment”. This is a simplified process, the essential difference being the absence of:

- Oily water balancing tank,
- Induced gas flotation,
- Walnut shell filter,

- Polishing trickling filter, and
- Sand filter.

This option will have disadvantages in terms of an inability to cope with dissolved organics (dissolved condensate is expected to be only 1ppm), and poorer final effluent quality overall. "Typical normal values" for oil and grease in the final effluent for this option are quoted at 10mg/l, with short-term peaks up to 40mg/l. This peak figure of 40mg/l is somewhat close to the 42mg/l limit set by the US EPA – (note this was set for discharge from offshore rigs to the sea). This option would furthermore not satisfy the requirements set out in the Foster Wheeler Environmental Design Basis document, which sets the Project Standard at 5mg/l. Note that, in terms of this second treatment option, the Treated Sewage Effluent and Treated Oily Water Effluent are completely separate streams, the oil and grease in the former being given as less than 1 mg/l.

Foster Wheeler have warned on their mass balance drawing that:

- There is no effective facility to treat large volumes of stormwater or firewater with high levels of organic contamination,
- There is no facility to treat effluent/stormwater/firewater with a combination of organic and oily contamination unless a large de-oiled storage tank is added.

These considerations must be addressed, and if no practical measures exist to remove the potential risk they present, then a risk assessment should be undertaken for any situation that may lead to a degree of uncontrolled discharge to the environment, taking into account frequency and consequences. In this regard, consideration could be given to some sort of retention dam/basin before final discharge.

Table 8 below lists all expected solid and liquid effluents, with the proposed treatment method.

TABLE 8: *Waste Disposal Methods*

Emission Source	Disposal method per FW PFD/Waste Schedule
CONSTRUCTION WASTES	
Drilling Fluids & Drilling Fluid contaminated cuttings	Not stated (not generated at CPF)
Excavation spoil, concrete, bricks	Re-use for landscaping, break & use as hardcore
Timber, plastic, glass, scrap metal	Recycle where practical, else non-hazardous waste landfill
Food waste, office waste	Non-hazardous waste landfill
Engine & other oil, filters, waste fuel	Hazardous waste landfill (NB SA DWAF require flammable material to be mixed with ash etc to lower flash point below 61 deg C)
Empty chemical drums	Hazardous waste landfill. Recycle?
Batteries	Hazardous waste landfill
Tyres	Hazardous waste landfill
Solvents, paints, sealants	Hazardous waste landfill
Medical wastes	Hazardous waste landfill (NB SA DWAF require infectious waste to be incinerated)
Domestic Sewage	To biological treatment plant
OPERATING WASTES	
Pig Receiver residues	Hazardous waste landfill
Emergency Condensate Disposal Facility Residues	Hazardous waste landfill
Strainers on liquid from production separators – sand/sludge	Hazardous waste landfill
Produced Water	Re-injection
LP & HP Compression filters	Hazardous waste landfill
TEG System activated carbon filters	Hazardous waste landfill
Glycol sock filters – sludge	Hazardous waste landfill
Instrument Air Compressor Desiccant Driers	Return exhausted/damaged desiccant to supplier (NB feasibility in SA needs to be confirmed – may need to be dumped)
Diesel Fuel Tank Bottoms	Hazardous waste landfill (NB: SA DWAF requires mixing with ash etc to reduce flash point below 61 deg C)
Potentially oil-contaminated run-off	Oily water treatment plant
Recovered oil from oily water treatment	Removed by tanker to incinerator or emergency condensate disposal

Emission Source	Disposal method per FW PFD/Waste Schedule
plant	facilities
Sludge from oily sludge settlement pond	Hazardous waste landfill
Sludge from ETP	Incineration
Domestic sewage	To biological treatment plant
Treated effluent (water) from ETP	Outfall to Bush
Spills from condensate loading arms/diesel filling	Contained in sump or released to POC (potentially oil contaminated) drain, depending on quantity
Drain Systems – Sumps	Hazardous waste landfill
Emergency Condensate Disposal Facility	Hazardous waste landfill
Medical Centre - Medical Sharps & infectious wastes	Drum & export to RSA (NB SA DWAF requirement for incineration)
Potable/Utility Water System Dosing chemicals - biocide/acid/caustic	Hazardous waste landfill
Fire Water System - water/foam	To ETP
Lab samples & reagents – solvents	Dedicated sink to drum – (NB SA DWAF requirement for incineration if available)
All Rotating Equipment – seal oils & lubes	Hazardous waste landfill
Engine & other oil, filters, waste fuel	Hazardous waste landfill
Empty chemical drums	Hazardous waste landfill
Batteries	Hazardous waste landfill
Tyres	Hazardous waste landfill
Solvents, paints, sealants	Hazardous waste landfill (NB SA DWAF requirement for incineration if available)
Food waste	Hazardous waste landfill
Office waste	Non-hazardous waste landfill

5.3 Re-Injection of Produced Water and Condensate

Deepwell disposal of oilfield wastewaters is a safe and viable disposal option where wells are properly constructed, operated and monitored. A system of classifying injection and disposal wells has been developed on the basis of the fluid to be injected such that design, operating and monitoring requirements are consistent with the type of fluid injected. The classification of these wells and the requirements in terms of well completion, logging and testing are discussed in detail in Alberta Energy and Utilities Board Guide 51.

The location of the injection well should be carefully chosen with due consideration to factors such as well depth, geology of rock formations, and position in terms of vertical and horizontal distance relative to groundwater aquifers.

6.0 CONSEQUENCES OF EMISSIONS

6.1 Normal Operating Conditions

6.1.1 Wastes due to Hazardous and Toxic Components of Gas

For concentrations of contaminants above the maximum limit in the feed gas, the main risk is catalyst bed poisoning in the downstream processes. At present the design basis of the CPF does not include treating the gas to remove these contaminants. Should any of these contaminants prove to be problematic, a decision will have to be made regarding treatment either at the CPF or downstream at the applicable users. In the case of H_2S, there is also a risk of stress corrosion cracking (SCC).

Comments on the hazardous gas compositions quoted in Table 1, with recommended mitigation measures are as follows:

1. Mercury

There may be a small amount of mercury released into the atmosphere, but this should be well below the TWA limit specified. It may, however, be necessary to install a sulphur-impregnated activated carbon filter in the vapour outlet line downstream of the condensed overheads separator (which is common practice where the feed gas contains mercury). At present, only a Glycol Sock Filter and Activated Carbon filter have been provided for the rich TEG, downstream of the glycol surge drum.

Additionally, for feed gas containing mercury, the following steps should be taken regarding all of the filter elements in the glycol dehydration unit:

- Replaceable filter elements should be non-metallic to reduce the problem of disposal in case they become contaminated;
- Special provisions should be made for the handling, storage and disposal of used filter elements;
- There is a possibility of mercury accumulation in all connections to the filters. For this reason it is preferred that drainage points be vertical. Mercury migrates through gaskets and drip pans or pits should be constructed under the filters with a low point in which the mercury can be collected. Aluminium or copper alloys should not be used here.

2. Heavy Metals

Most of the heavy metals will be present as solid particles, and should mostly be removed through the activated carbon filters of the glycol dehydrator unit. Special provisions should be made for the handling, storage and disposal of used filter elements and sludges in order to protect personnel and to eliminate the possibility of contaminating the environment. These heavy metals will therefore be present in the landfill site, but are extremely unlikely to be present in the liquid effluent. It is also unlikely that significant amounts of heavy metals will be released into the atmosphere, and these concentrations will be well below the TWA limits recommended by the OHSA.

3. Total Sulphur

Although there are no apparent reasons for the sulphur concentrations in the Pande and Temane Gas Fields to be significantly different from each other, the sulphur content in the Pande Gas should be tested in order to verify this assumption. Should this assumption prove to be false, it may have significant consequences in terms of capital and operating costs, as well as an environmental impact.

4. Hydrogen Sulphide

High H_2S levels may cause stress corrosion cracking of pipes and equipment. The natural gas will be considered “sour” if hydrogen sulphide is present in amounts greater than 3.8 ppmv. If this is true (as is possible in the Pande gas fields), the gas will need to be “sweetened”, i.e. the hydrogen sulphide will have to be removed. This is normally achieved by the absorption of the H_2S in an amine solution.

Although amine plants are the most commonly used method of H_2S removal, other processes, such as the carbonate process, solid bed absorbents, and physical absorption may also be employed. The recovered H_2S may be vented, flared or incinerated.

5. Odorous components

H_2S and mercaptans would be the primary source of odours at the production facilities. Any possible increase in the H_2S content of the gas may result in increased odour problems. If H_2S becomes a problem due to operation or corrosion reasons, an H_2S removal step may be required, which will simultaneously reduce odour risk. There would also be a possibility of more mercaptans being present, which could also require removal in an absorption step.

6. Fluorine and Chlorine

These components would have to be removed in a separate catalyst absorber if present. The current design basis does not consider these contaminants and if any such facility is required, it may be located either at the CPF or at the downstream users.

7. Hazardous Air Pollutants (as defined by the Code of Federal Regulations)

The US EPA proposes that natural gas transmission and storage facilities have the potential to be major Hazardous Atmospheric Pollutant (HAP) sources. During normal operation, gaseous streams of significant flowrate released from the plant to the atmosphere are limited to combustion gases from turbines, the contaminated vapours driven off from the TEG regenerators, and combustion gases from TEG regenerator and stabiliser reboiler LP fuel gas burners. The quantities and compositions of these gases as proposed by Foster Wheeler are indicated in sections 4.3 and 4.5 of this document. No standards, as such, have been found which provide guideline emission quantities and compositions per stream that may be considered permissible. Rather, it will be the function of air pollution assessment including the use of atmospheric dispersion modelling to assess the concentration of HAPs around the facility, and ensure that these concentrations are within the OELs set by the OHS standard. Factors such as stack and flare height and positions relative to the facilities will play a part in determining these results.

EPA 40 specifies that for glycol dehydrators with a throughput of greater than 85000 Nm^3/day, or with a benzene emission rate of greater of 0.9 tpa, the emissions will need to be controlled and can not be released directly into the atmosphere. The TEG Unit at the CPF will have a throughput of approximately $4.5x10^6$ Nm^3/day, and the emissions will therefore need to be controlled i.e. they should be flared and not released directly into the atmosphere (as is specified in the current design). If combustion devices (such as a flare) are used for the control of the glycol dehydration unit emissions, the total HAPs from the outlet of this device should not exceed 20 ppmv.

The quantity of ethylene glycol released will, however, be in the region of 11 mg/m^3 (based on values in Sasol e-mail dated 4 May 2001), which is well below the maximum value 60 mg/m^3 (according to the SA Occupational Health and Safety Act).

The SA DWAF requires that flammable gas wastes be thermally destroyed. This requirement is met in the proposed design by routing all pressure control and pressure relief streams from the process to a flare. During normal operation these flows are negligible.

A further routine gaseous emission will be that from the effluent sludge incinerator. The quantity and quality of these emissions have not yet been specified. The possibility of dioxin formation and incomplete combustion should be considered in the specification of this unit, especially if ancillary wastes such as medical waste are disposed of here.

Additional gaseous discharges result from fugitive emissions from seals on rotating equipment, flanges, valves etc, which will occur along the pipeline to Sasol as well as at the CPF and wellheads. Estimates of these emissions may be made from the literature, and must be minimised by GMP (Good Manufacturing Practice) and adherence to good oil and gas industry standards in the EPC (Engineering, Procurement and Construction) of the project.

A non-routine gaseous emission would result from the emergency condensate disposal facility, which appears to be only for emergency condensate disposal. The specification of this unit should be such as to ensure efficient and total combustion of the hydrocarbons and other organic compounds.

The major hazardous air pollutant (HAP) of the unburned hydrocarbons (UHCs) is the n-hexane, which will be the UHC component present in the highest quantities. Based on the Foster Wheeler figures, these quantities will always be lower than the recommended TWA OEL Limit.

The NOx figures may be too high, or otherwise the CO figures quoted may be too low. With such high NOx emissions, it is recommended that the turbines be controlled in such a way as to reduce these emissions.

The associated concentrations of the main emissions are shown in Table 9 below: (Notation: OEL TWA = Time Weighted Average Occupational Exposure Limit)

TABLE 9: *Main Gas Emissions and their Associated Occupational Exposure Limits*

Emission Source	NOx Emissions		UHC Emissions		CO Emissions	
	Emission Conc. (mg/Nm^3)	OEL TWA* Limit (mg/Nm^3)	Emission Conc. (mg/Nm^3)	OEL TWA* Limit (mg/Nm^3)	Emission Conc. (mg/Nm^3)	OEL TWA* Limit (mg/Nm^3)
LP Compression – turbine exhaust	221.5	5 (As NO_2)	28.0 (0.16 mol% n-hexane)	70 (As n-hexane)	32.3	55
Reboiler Exhausts, Pilot Gas to Flare and Flare Stack Intermittent Emissions	320	5 (As NO_2)	-		200	55
HP Compression – turbine exhaust	300	5 (As NO_2)	1.8 (0.16 mol% n-hexane)	70 (As n-hexane)	10	55
Electric Power Generation – Turbine Exhaust	308	5 (As NO_2)	18.7 (0.16 mol% n-hexane)	70 (As n-hexane)	65.4	55

* The Occupational Exposure Limits (OEL) are limits of exposure, and are not the released limits. These emissions will be diluted and dispersed into the atmosphere, therefore the limits in the feed gas cannot be directly compared to these numbers – these emissions should firstly be dispersion-modelled.

An air pollution assessment including the use of atmospheric dispersion modelling is being undertaken in order to quantify the concentrations of NOx emissions to which personnel will be exposed. These quantities should be less than the Occupational Exposure Limit quoted in the table above (on a continuous basis). The short-term occupational exposure limit to NOx should not exceed 9 mg/m^3.

The short-term exposure limit for CO is 330 mg/m^3. In the case of the reboiler exhausts and electric power generation, an air pollution assessment including the use of atmospheric dispersion modelling, will be required for CO emissions to ensure that personnel are not exposed to high concentrations of this emission (i.e. higher than OEL TWA) on a continuous basis. The concentrations of the CO produced by the HP and LP Compressors will always be lower than the OEL TWA.

6.1.2 Other Solid and Liquid Wastes

In 1989, the API initiated a waste characterisation and groundwater modelling exercise, the results of which were published in API DR53. The API constructed a model to simulate common waste disposal scenarios in order to assess the risk of groundwater contamination at land-disposal sites. The model takes into account evaporation of VOCs, leaching, advective and dispersive transport, adsorption and microbial decay. The model runs conducted by the API yielded insignificant contamination (using parameters for BTEX) at receptor locations 500 and 1500 ft down-gradient from source, with a predicted maximum concentration order of magnitude less than the regulatory standards. Provided the landfill sites are positioned, designed, constructed and operated in accordance with the standards, the risk to the surrounding environment and population will be negligible.

Foster Wheeler has specified water quality discharged to the environment from the treatment facilities to meet industry standards that equal or exceed US EPA standards and World Bank guidelines for discharge to surface waters. The SA DWAF indicates a "general limit" (i.e. not requiring licence) for oil and grease in effluent discharged to "a water resource" of 2.5mg/l (i.e. even lower than the project standard). Should the process option that employs all three treatment methods as proposed by Foster Wheeler be adopted, the maximum flowrate of discharged water is stated as 7.7m^3/h. This is likely to dissipate into the existing ground and surface water systems of the area without significant impact on the surrounding environment or population, provided the discharge remains within the water quality standards specified.

6.2 Gas Emissions from the Plant under Upset and Emergency Conditions

The gaseous emissions under upset and emergency conditions are primarily due to:

- Pressure relief of certain process equipment;
- Emissions from the diesel driven emergency power generators; and
- Emissions from the emergency disposal of condensate

The pressure relief of certain process equipment will be for relatively short periods of time (of order of seconds to minutes). The design of the outlets of these PSVs should also ensure that they vent to a safe location. Bearing in the mind the relatively low frequency of these events, these emissions will in general have a minimal environmental impact.

The emissions from the diesel driven emergency power generators will be substantial in terms of rate of emission during each event. The air pollution assessment including the use of atmospheric modelling will confirm the impact of the emissions. Should the emissions lead to unacceptable exposure levels the facilities may require some design modifications, such as the provision of an outlet stack to which the exhausts of the diesel generators are coupled. The provision of such a stack would lead to a dispersion effect, thereby lowering the effective concentrations to which personnel would be exposed.

Similarly, the emissions due to the emergency disposal of condensate will be substantial in terms of rate of emission during each event and the air pollution assessment including the use of atmospheric modelling will confirm the impact of the emissions.

6.3 Liquid Emissions under Emergency and Upset Conditions

The current design has made provision for a facility to store and process 140m^3 of stormwater or firewater with high levels of organic contamination. The environmental impact due to liquid emissions under emergency and upset conditions depends on the probability of one of the scenarios identified in Section 4.6 occurring to a greater extent than the current design caters for, as well as the extent to which this event will then impact the surrounding groundwater systems.

Although it is not currently allowed for in the design, firewater is usually treated with a biocide and is therefore not potable water. The foam that will be present in the firewater during a fire in the condensate storage tank bunded area is also not suitable for potable water. It is also highly probable that the firewater runoff will be contaminated with hydrocarbons, either from a leaking or ruptured vessel or from contamination within the bunded area due to previous leakage and sampling. In addition, the rate of firewater application to an affected area could typically be of the order of 750 m^3/h to 1500 m^3/h, and will generally be substantially higher than the maximum rainfall rate. All of the above therefore point to the possibility that the firewater and foam runoff will have an environmental impact if not collected and processed.

It is highly unlikely that the rainwater runoff would be higher than the current design caters for, and this is therefore not a likely scenario for an environmental impact during emergency or upset conditions.

Should there be any leak from a major tank rupture or failure, at least the bunded area of the applicable vessel will be contaminated, and there will be a potential subsurface contamination plume.

There is also a possibility that if the operational procedures have not been followed, the storm water system will also be contaminated. Depending on the size of the leak, it may be contained in the system or may be larger than the system can cope with.

In view of the above, it is likely that there will be contaminated discharges from the facility either during a fire or if a vessel ruptures. The current design should therefore be reviewed, as it would be beneficial to ensure that facilities for treating large volumes of contaminated water runoff are provided. A more detailed study will be required to assess the probable quantities and concentration ranges of these streams, and to investigate the feasibility of installing catchment ponds, which would allow for containment and reprocessing of this water. Such a catchment pond would also enable the recycling of firewater during a fire and could lead to either a smaller firewater tank storage requirement, or a greater capability to fight a fire for an extended period of time. Should such a facility not be constructed, a detailed assessment of the potential magnitude of such streams and the route that they would follow will have to be undertaken to determine the potential environmental impact of such incidents. In the case of contaminated firewater runoff, it is highly likely that the magnitude of these flows would be so large as to ensure that significant preferential flow paths would exist i.e. the runoff would form streams following the current runoff paths from the site.

6.4 Emissions during Construction of the Plant

It would make sense for the proposed landfill sites to be constructed at an early stage as well, to avoid the need for construction waste to be stored on-site. With these in place, environmental risk due to construction at the CPF should be small.

6.5 Re-Injection of Produced Water and Condensate

The re-injection of produced water and condensate is the preferred alternative and will have minimal environmental impact. This is provided that the wells are properly constructed, operated and monitored and that the location of the injection well has been carefully chosen considering factors such as well depth, geology of rock formations, and position in terms of vertical and horizontal distance relative to groundwater aquifers.

7.0 ALTERNATIVE WASTE MANAGEMENT METHODS

While the waste treatment facilities proposed are appropriate and in line with standard practice, Table 10 below identifies some points to note in relation to waste management during the project. These actions do not indicate major design flaws but are rather alternatives, modifications and mitigation measures that should be considered during the course of the detailed design phase of the project.

TABLE 10: *Alternative Waste Management Methods*

Emission	Treatment Proposed	Alternative Proposed
Hydrocarbon gases	Thermal destruction (flare)	None
Gaseous products of combustion (NOx, CO, SO_2)	None indicated	NOx abatement methods for gas turbines and fuel gas burners such as water/steam injection (which reduces NOx formation by reducing peak temperatures in the combustion zone) and selective catalytic reduction (whereby NOx is chemically reduced to N_2 and water in a catalysed reaction) are widely employed. Consideration can be given to specifying reasonable emission limits to suppliers.
Pig Receiver residues	Hazardous waste landfill	Encapsulation in drums may be necessary if mercury has accumulated to sufficient concentration
Emergency Condensate Disposal Facility Residues	Hazardous waste landfill	Encapsulation in drums may be necessary if mercury has accumulated to sufficient concentration
Strainers on liquid from production separators – sand/sludge	Hazardous waste landfill	Encapsulation in drums may be necessary if mercury has accumulated to sufficient concentration
Produced Water	Re-injection	Could possibly undergo biological treatment and be used elsewhere but re-injection in accordance with industry standards should present less risk to environment.
LP & HP Compression filters	Hazardous waste landfill	None
TEG System activated carbon filters	Hazardous waste landfill	Encapsulation in drums may be necessary if mercury has accumulated to sufficient concentration
Glycol sock filters - sludge	Hazardous waste landfill	Encapsulation in drums may be necessary if mercury has accumulated to sufficient concentration
Instrument Air Compressor Desiccant Driers	Return exhausted/damaged desiccant to supplier	Hazardous waste landfill. Encapsulation in drums may be necessary as requirements prohibit disposal of waste which ”reacts with water, air or components of other waste”
Diesel Fuel Tank Bottoms	Hazardous waste landfill (NB: SA DWAF requires mixing with ash etc to reduce flash point below 61 deg C)	Removal to process for recovery of useful hydrocarbons environmentally preferable but unlikely to be practical. Incineration
Potentially oil-contaminated run-off	Oily water treatment plant	None
Recovered oil from oily water treatment plant	Removed by tanker to incinerator or emergency condensate disposal facilities	Recycle for useful re-use environmentally preferable but unlikely to be practical in view of small quantities and remote location
Sludge from oily sludge settlement pond	Hazardous waste landfill	Incineration
Sludge from ETP	Incineration	Landfill
Domestic sewage	To biological treatment plant	None

Emission	Treatment Proposed	Alternative Proposed
Treated effluent (water) from ETP	Outfall to Bush	Consider holding dam, reeds
Spills from condensate loading arms/diesel filling	Contained in sump or released to POC (potentially oil contaminated) drain, depending on quantity	None
Drain Systems - Sumps	Hazardous waste landfill	Incineration
Emergency Condensate Disposal Facility	Hazardous waste landfill	None
Medical Centre - Medical Sharps & infectious wastes	Drum & export to RSA (NB SA DWAF requirement for incineration)	Incineration
Potable/Utility Water System Dosing chemicals – biocide/acid/caustic	Hazardous waste landfill NB standard requires neutralisation of acids/caustic prior to landfill)	None
Fire Water System - water/foam	To ETP	
Lab samples & reagents – solvents	Dedicated sink to drum – (NB SA DWAF requirement for incineration if available)	Incineration
All Rotating Equipment – seal oils & lubes	Hazardous waste landfill	None
Engine & other oil, filters, waste fuel	Hazardous waste landfill	Recycling preferable but not realistically feasible
Empty chemical drums	Hazardous waste landfill	Recycling preferable but not realistically feasible
Batteries	Hazardous waste landfill	None
Tyres	Hazardous waste landfill	Recycling preferable but not realistically feasible
Solvents, paints, sealants	Hazardous waste landfill (NB SA DWAF requirement for incineration if available)	Incineration
Food waste, office waste	Non-hazardous waste landfill	None

8.0 RECOMMENDATIONS FOR RISK MANAGEMENT

8.1 Proposed Actions during Final Design to Mitigate Concerns

Several points were raised during the review of available information and the investigation of the international regulations and guidelines applicable to this project. Some of the considerations requiring further work during the final design phase are outlined below:

- Conduct an independent review of the design of the facility with respect to environmental management;
- Sample and assess gas composition for the Pande gas field – the Pande gas field should be tested for heavy metals, and the sulphur content of this field should be confirmed;
- Determine the maximum level of mercury allowable in the feed gas to Secunda;
- Improve resolution of hazardous component (heavy metal) analyses where the LDL of present method is much higher than limits quoted in standards or technical specification;
- Resolve the variation in mercury concentrations in reported samples;
- Resolve the NOx:CO ratio differences between EPA and figures supplied by vendors to Foster Wheeler;
- Develop Standard Operating Procedures (SOPs);
- Confirm that the landfill site design basis caters for the amount of mercury in the gas;
- Confirm BAT (Best Available Technology) for NOx abatement from turbines, and
- Confirm BAT for treatment of TEG unit emissions

8.2 Proposed Actions for the Preparation of an EMP

The preparation of an Environmental Management Plan is the next major phase of work to be undertaken in terms of the Environmental Impact Assessment process for the project. Some of the major considerations requiring further work during the next phase are outlined below:

- Conduct a full Environmental Assessment and develop an Environmental Management Plan for the assessment and suitability of the landfill sites for the waste disposal facilities;
- Develop Waste Management Plan for CPF;
- Develop a Response Plan for routine & worst-case discharges;
- Develop a Procedure & Permit system for re-injection of any fluids;
- Develop a Plan for Road routing, design, construction & maintenance;
- Develop a Spill Prevention Control & Countermeasure (SPCC) plan;
- Develop a Construction Pollution Prevention Plan;
- Prepare permit requirements for Venting & Flaring, which could involve further air pollution assessment including the use of atmospheric dispersion modeling;
- Prepare permit requirements for the emergency condensate disposal facility;
- Prepare permit requirements for the Hazardous and non-hazardous landfill sites;
- Prepare permit requirements for the discharge of treated liquid effluent to environment;
- Prepare permit requirements for the incinerator installation;
- Prepare permit requirements for the discharge of stormwater;
- Develop a Procedure for Clean up & remediation after well –drilling; and
- Develop a Well abandonment procedure catering for plugging, restoration & maintenance.

9.0 CONCLUSIONS

The project standards were compiled by comparing safety, health and environmental standards generally accepted in the oil and gas industry such as the World Bank and other international guidelines, as a basis, to ensure that the best industry standards were used in the design. The project design basis for environmental requirements specifies that the plant has been designed to the World Bank standards as a minimum. Emissions from the CPF have been assessed against South African and international standards.

The design of the CPF has therefore followed modern practices and is, in general, in accordance with the latest international standards and guidelines. There are, however, some areas of concern which have not been considered or finalised, or where the latest international standards and guidelines will not be met. For more detail, reference should be made to the section of the report dealing with the particular area of concern. While the current information is adequate for the Environmental Impact Assessment, some of these matters will require further clarification or finalisation for the Environmental Management Plan, which is the next major phase of work to be undertaken in terms of the Environmental Impact Assessment process for the project.

The waste inventory produced by Foster Wheeler summarises the expected emission streams. A few errors and omissions have been identified which are listed and discussed in the relevant detailed sections of the report. The Foster Wheeler waste inventory is both comprehensive and credible.

The Foster Wheeler proposal, which provides for two appropriately designed landfill sites (one lined for hazardous waste, and the other for non-hazardous waste), meets the requirements of the standard and is the preferred alternative. The sizing of the Hazardous Waste landfill site may need to take into account allowable disposal rates of specific hazardous components (e.g. mercury) in terms of g/ha/month, as required by the SA DWAF standard. Provided the sites are positioned, designed, constructed and operated in accordance with the standards, the risk to the surrounding environment and population will be negligible. It would make sense for the proposed landfill sites to be constructed at an early stage as well, to avoid the need for construction waste to be stored on-site. With these in place, environmental risk due to construction at the CPF should be small.

Foster Wheeler has specified the water quality discharged to the environment from the treatment facilities to meet industry standards that equal or exceed US EPA standards and World Bank guidelines for discharge to surface waters. The maximum flowrate of discharged water is stated as $7.7m^3/h$. This is likely to dissipate into the existing ground and surface water systems of the area without significant impact on the surrounding environment or population, provided the discharge remains within the water quality standards specified.

There is no effective facility to treat large volumes of stormwater or firewater with high levels of organic contamination and there is no facility to treat effluent / stormwater / firewater with a combination of organic and oily contamination unless a large de-oiled storage tank is added. These considerations must be addressed, and if no practical measures exist to remove the potential risk they present, then a risk assessment should be undertaken for any situation that may lead to a degree of uncontrolled discharge to the environment, taking into account frequency and consequences. Consideration could be given to some sort of retention dam/basin before final discharge.

Deepwell disposal of oilfield wastewaters is a safe and viable disposal option where wells are properly constructed, operated and monitored. The location of the injection well should be carefully chosen with due consideration to factors such as well depth, geology of rock formations, and position in terms of vertical and horizontal distance relative to groundwater aquifers.

An incident within the complex could escalate to other parts of the complex and could even impact on the surrounding community if not managed properly. It is therefore recommended that a comprehensive quantitative risk assessment be made of the overall complex. The purpose of this risk assessment would be to identify the major potential hazards in terms of the number of possible fatalities per year.

Without having performed a comprehensive quantitative risk assessment, one can only offer an assessment of risk based on experience and judgement. With the current knowledge of the CPF and given the nature of the materials used on site and the nature of waste streams that are likely to be generated, the facility is probably a low to medium risk facility. Provided that the recommendations and reservations mentioned elsewhere in this report are addressed, the overall risk of the CPF could possibly be reduced to that of a low risk facility.

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