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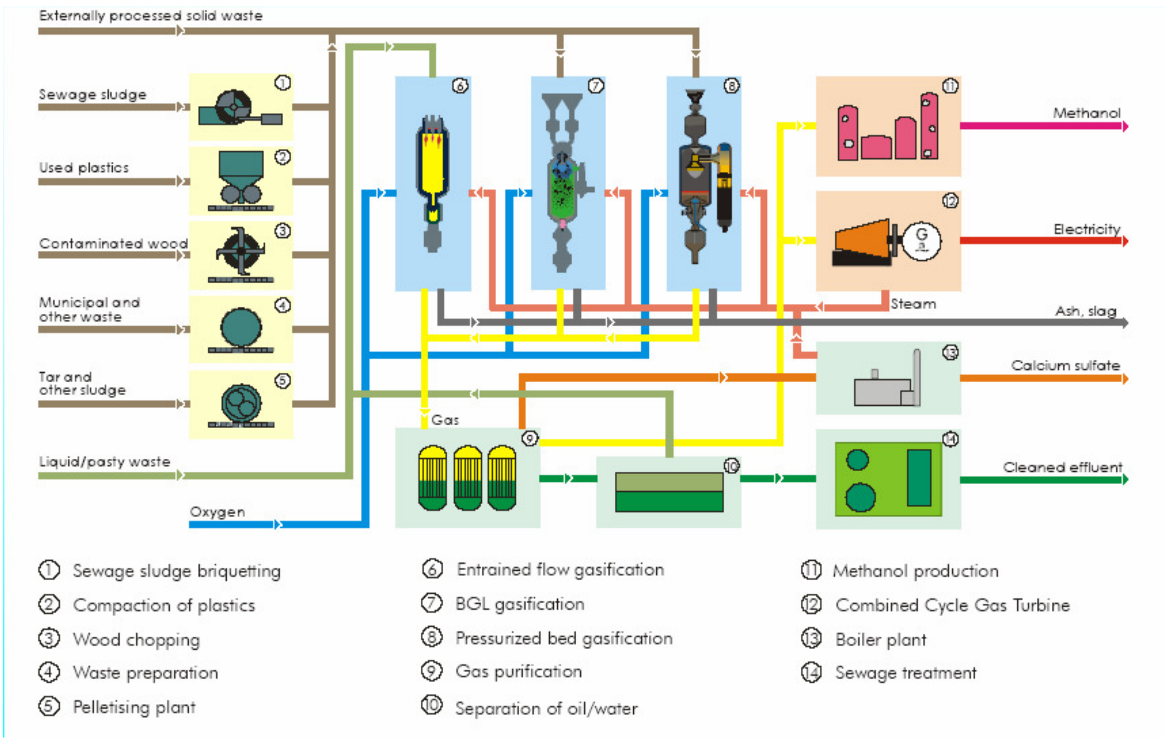
Name of Process:
Waste gasification Process

Applicable POPs wastes:
PCBs, PCDDs, PCDFs
Other high chlorinated products

Status: In 1992, at the Schwarze Pumpe Site, in Lausitz, in the federal states of Saxony and Brandenburg of Germany, a new concept for a gasification plant was made and waste gasification large scale tests had been performed
In 1995, investments were made for the methanol plant, power station, several preparation plants and a new gasifier. In 1998 approval has been received under the German Federal Immission Control Act.
Since 1992 waste treatment has started and the amounts have been continuously increased. From 2000 till 2006 yearly around 300.000 t of solid waste and 60.000 t of fluid waste have been processed to synthesis gas, gypsum, methanol, power and steam. In 2006 the production stopped. At present, 2008, the technology providers are under negotiation for new start up of the technology at other locations.
Commercial scale waste gasification is operated in Germany since 1992 in the Feed Stock Recycling Centre (Sekundärrohstoff-Verwertungszentrum) Schwarze Pumpe (SVZ). In total about **3.6 million tonnes** of waste has been treated in the gasification process.

Technology description:

Figure 1: Treatment scheme of solid and liquid waste



SVZ operated a complex plant system for producing highly pure synthesis gas from hydrocarbon-containing waste and this system included downstream methanol production. Core units of the plant system were:

- slagging gasifier BGL (process of British Gas/Lurgi) for solid waste with liquid slag removal (the first plant of this kind in the world), see Figure 3
- 3 pressurised bed gasifiers for solid waste with revolving grate for removing the sintered slag, see Figure 2. In order to secure continuous availability of the 3 gasifiers, 7 gasifiers have been held available
- entrained flow gasifier for liquid and pasty waste, see Figure 4
- catalytic low pressure methanol synthesis plant

The gasification processes were operated at high process temperatures (1300 – 1600°C) and high pressure (about 25 bar). A feed mixture of high-pressure steam and pure oxygen was used for the gasification. There was a reducing atmosphere in the reactors. It was important that all oxygen was consumed during this step.

Under these chemical-physical reaction conditions the hydrocarbon molecules in the feed waste are irreversible cleaved into (small and vary small) gaseous molecules, namely into the components of synthesis gas (hydrogen (H_2) and carbon monoxide (CO) and also into methane (CH_4) and carbon dioxide (CO_2). The resulting gas is termed raw gas; the raw gas is a secondary raw material. Other products with a total of less than vol. 1% are: ethane (C_2H_4), propane (C_3H_6) and butane (C_4H_8). Persistent organic pollutants including PCBs contained in the waste are effectively destroyed. The resulting raw gas is subsequently converted in a multistage process to pure synthesis gas for the production of highest-grade methanol.

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Figure 2: Pressurized Solid Bed Gasification (Revolving Grate)

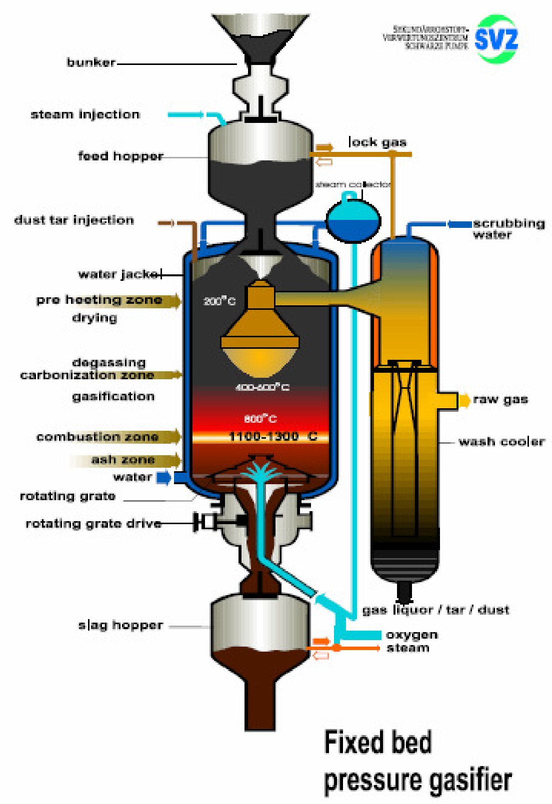


Figure 3: Slagging Gasifier BGL

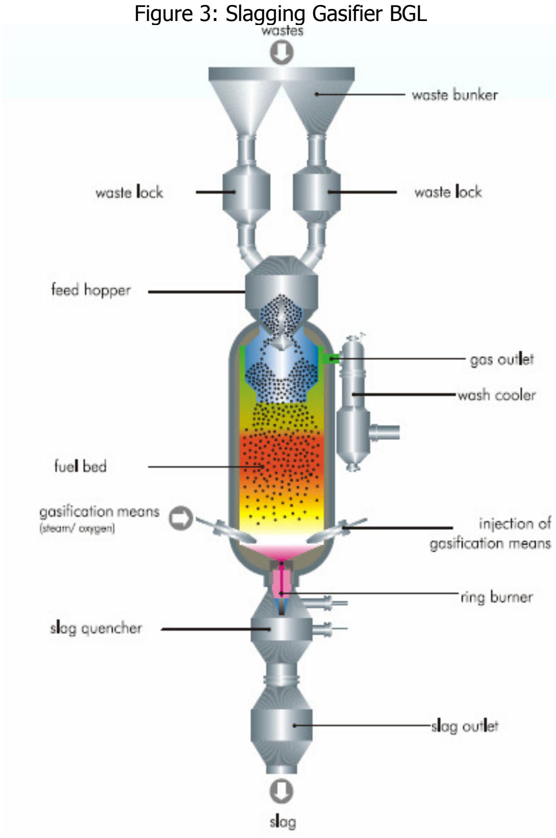
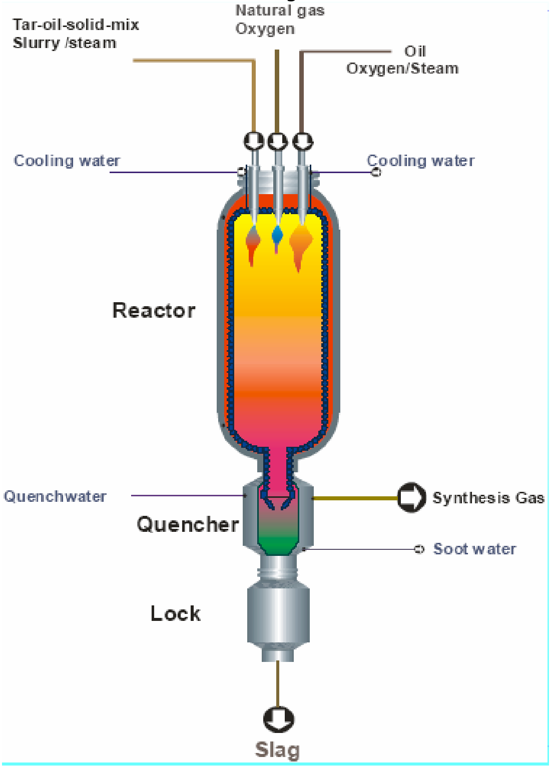


Figure 4: Entrained Flow Gasification System with Cooling Screen



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The special feature of the waste treatment process is that during the waste pre-treatment process (which produces secondary raw material gas) in the pressurised bed gasifiers, slagging gasifier and entrained flow gasifier and before subsequent recycling of the raw gas (to produce pure synthesis gas), the persistent organic pollutants that are present in the waste such as PCBs, dioxins, furans and polycyclic aromatic hydrocarbons are irreversibly transformed. They are cleaved (as mentioned before) into a variety of gaseous molecules – mainly hydrogen (H_2), carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2) – and so are effectively destroyed.

PCBs (present in amounts up to 500 mg/kg waste[1]) are cleaved just as effectively in the pre-treatment process as are all other persistent organic pollutants; no additional energy input is required from outside. The residual waste and emissions no longer show persistent organic pollutants.[2]

The destruction of the persistent organic pollutants in the waste in the pre-treatment process means that in accordance with Article 3 Paragraph 1 of the Waste Framework Directive all conditions are fulfilled for subsequent recycling of the raw gas to pure synthesis gas and for downstream methanol production in the plant system. The process has been demonstrated on an industrial scale and is state-of-the-art (BAT). Each year about 360,000 tonnes of solid, liquid and pasteous waste have been recycled.

Overview of chemical reactions:

Chemical Reactions of Gasification

$$2C + O_2 \rightleftharpoons 2CO$$

$$H_2O + C \rightleftharpoons CO + H_2$$

$$2H_2O + C \rightleftharpoons CO_2 + 2H_2$$

$$C + 2H_2 \rightleftharpoons CH_4$$

Composition of Syngas
(after Gas Cleaning)

H_2	64,1	Vol.-%
CO	19,6	Vol.-%
CO_2	6,3	Vol.-%
CH_4	8,4	Vol.-%
N_2	1,4	Vol.-%
O_2	0,06	Vol.-%
C_nHm	0,12	Vol.-%
H_2S	<0,05	mg/Nm3

Heating value
12.000 - 15.000 kJ/Nm^3

Chemical Reactions of Methanol Synthesis

$$2H_2 + CO \rightleftharpoons CH_3OH$$

$$3H_2 + CO_2 \rightleftharpoons CH_3OH + H_2O$$

In total the following quantities of materials have been treated:

Solids	Fluids
Used plastics 925,000 t Sewage sludge 120,000 t Contaminated wood 240,000 t Treated domestic waste (RDF) 400,000 t Pellets from tar, sewage sludge 160,000 t Shredder residues and others 315,000 t	Contaminated oils, Oil-/water mixtures 1,440,000 t Mixtures from solvents

[1] Limited to 500 mg/kg in accordance with the approval granted to the company; the technological process permits even higher PCB levels.

[2] The raw gas contains many inorganic sulphur and nitrogen compounds as pollutants and has not ceased being waste.

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PART I: Criteria on the Adaptation of the Technology to the Country

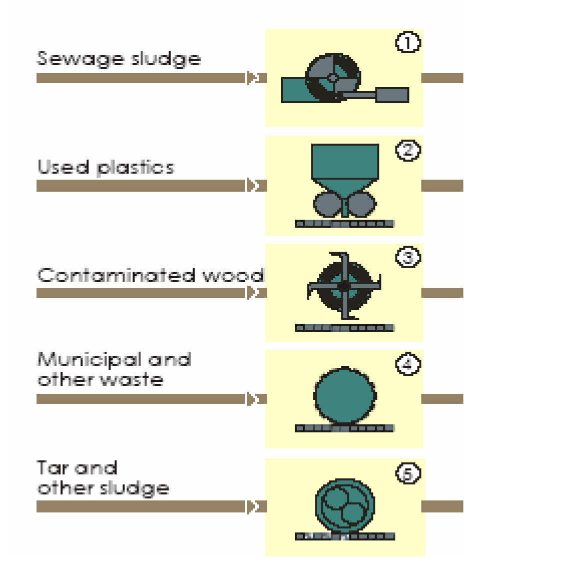
A. Performance:

1. Minimum pre-treatment: See also Figure 1
Two major steps can be distinguished:

Step I: Size reduction is required for solid waste particles with seizes bigger than 80 x 140 mm. Solid waste with seizes smaller than 80 x 140 mm directly undergoes step II. The various materials needed different pre-treatment. For example was for plastics the reduction to 80-140mm not sufficient. Here additional size reduction plus a compaction or pelletizing step had to be made. Pelletizing leads to material in the size of about 20 x 60-80 mm, compaction to material of about 60 x 100-120 mm. Depending on type of gasifier and waste type different fractions of pelletized and compact waste material are fed into the gasifier. In general a higher part of pelletized than compact material is needed for the gasification process in the Pressurized Solid Bed Gasifier and Slagging Gasifier BGL.

For municipal waste for example, reduction plus drying and pelletizing had to be performed. Ferrous and non ferrous metals are removed from solid wastes. After pelletizing, the waste undergoes step II. In the case of liquid and pasteous waste, sludge, solids and water are separated by sedimentation and density separation. The pre-purified oil is distilled in order to reach water content of < 1% and serves as main energy supplier. After the level< 1% of water content has been achieved, it is possible to add large amounts of slurry. There is no water content restriction for slurry products to be fed into the entrained flow gasifier. Depending on the influx of different materials, the appropriate mix for gasification had to be prepared. Therefore, often certain materials to be kept in stock in order to secure that this mix could be obtained. The use of a socalled menu catalogue ensured the optimal gasification.

Step II: Gasification of waste (including drying and degassing) generates raw gas for further processing.



1 = Sewage sludge briquetting

2 = Compaction of plastics

3 = Wood chopping

4 = Waste preparation

5 = Pelletizing plant

Pellitizer

pelletized plastics

2. Destruction efficiency (DE):
DEs of 99.974 per cent have been reported for PCDDs and PCDFs. Reported DE mainly depends on low PCDD/F-concentration of 34.08 ng TEQ/kg in treated waste. It should be mentioned specifically that a much higher DE of 99.99143 is achieved when PCDD/F-concentration in waste reaches 50.000 ng TEQ/kg or more. (See B. Buttker et al., 2006). In case of high PCDDs and PCDFs conventrations, the DE can be increased accordingly. During the permitting and the following production, no efforts had been made to reach higher concentrations, because there was no commercial market available at that time.

3. Toxic by-products:
none

4. Uncontrolled releases:
Not applicable

5. Capacity to treat all POPs:

6. Throughput:
The total waste throughput is 360 000 t/y.

6.1 Quantity [tons/day, L/day]

6.2 POPs throughput : [POPs waste/total waste in %]
Based on a total waste throughput of 360 000 t/y, and using the maximum allowable concentration of 50.000 ng TEQ/kg, around 175 t of pure PCDDs and PCDFs per year can be treated.

7. Wastes/Residuals:

7.1 Secondary waste stream volumes:

Slags about 15%. This slag is vitrified slag and may contain heavy metal compounds. The slag is capable of being recycled e.g., into insulating materials. It has been used for dike filling materials and filling for brown coal mines and for the various large-scale landscaping projects in former Eastern Germany.

PCBs, PCDDs and PCDFs have not been detected by analytic means in the methanol produced and in water, slag and gypsum. The vitrified slag may contain heavy metal compounds; that slag is capable of being recycled e.g., into insulating materials.

7.2 Off gas treatment:

Sulphur and nitrogen compounds contained in the raw gas are removed in the gas processing facilities emission-free, in a sealed pressure system. Traces of POPs (0.0034 ng TEQ/Nm^3) (see B. Buttker et. al., 2006) are dissolved in the tar and oil constituents that condensate out and are subsequently fed to the gasification process in the entrained-flow gasifier. Here any residual POP traces which may be still present are finally destroyed at temperatures of 2000°C.

The waste-to-gas conversion process takes place in a reducing atmosphere with high temperature and high pressure. The possibility of the formation of PCDDs and PCDFs is avoided due to the shock wise cooling off from 2000 °C to 180 -200°C.

7.3 Complete elimination:

Detailed information and treatment examples:
It is not possible to supply detailed lists of projects as the plant is not running at present and such data are not available for assessment.

PART II: Criteria on the Adaptation of the Country to the Technology

Part II is not applicable for Waste to Gas Plants. This system is not specifically designed for POPs, but for a large volume of other wastes. Under normal circumstances such a plant will be established for other main reasons than POPs waste in a country. Its presence is based on national or regional waste and energy management plans and deals with the issue of domestic waste and hazardous waste management and only marginally with POPs. Therefore the data given in this Annex cannot simply be compared with the data for technologies which are specifically designed to treat POPs! The Waste to Gas Plant is able to dispose of continuously all kinds of hazardous waste: solid, liquid, pasteous and materials in drums. The total part of pesticides or other POPs waste like PCB, packed in drums for treatment by gasification, in relation to the entire waste input is normally less than 1 %. Questions on energy use in relation to POPs destruction are not relevant, as the plant has energy recovery and delivers energy to the public network. Therefore only a limited number of issues have been dealt with in this part.

Note: This part has to be filled in every time the "suitability" of the technology has to be examined for a certain country situation!!

A. Resource needs:

Three different types of gasifiers are used: slagging gasifier BGL for solid waste with liquid slag removal, pressurised bed gasifiers (3) for solid waste with revolving grate for removing the sintered slag, and an entrained flow gasifier for liquid and pasty waste. The total capacity of the plant is 360 000 t per year.

1. Power requirements :

2. Water requirements:

Water has been recycled within the plant, as a number of products enter with considerable water contents.

3. Fuel volumes:
The waste is treated with a gasification mixture containing at least 15 wt. % coals in order to ensure stable process conditions. No additional energy in the form of electricity or steam is necessary.

4. Reagents volumes:
There is a need for a gasification agent (steam and oxygen) for the gasification technologies used. Other material requirements include calcium carbonate (limestone) to influence viscosity of slag.

5. Weather tight buildings
Parts have been covered by roof, but sides are open. Other parts like water treatment have been without any cover in the open.

6. Hazardous waste personnel requirement:
Plant workers have been required to be trained in hazardous waste operations. Annual certificates to work with hazardous waste, including safety and health and hazardous waste management training have been regularly followed.

7. Sampling requirements/facilities:

8. Peer sampling:
At SVZ a special company was established for Peer review activities, Lausitzer Analytik GmbH
Additionally specific investigations and controls have been made by a number of certified and recognised independent laboratories.

9. Laboratory requirements:
A special daily routine controls have been developed for acceptance controls of all ingoing waste. All procedures had been established and applied accordingly for the companies own process control.

Equipment such as GC and GCMS is applied.

On site requirements:

10. Communication systems:
A specific central Programmable Logic Controller (PLC) called Protocontrol P which is frequently applied in the power sector and has been developed for the plant and implemented for preparation of waste stream and gasification and others.

Mobile network:
All operators have mobile phones to act in case of problems or emergencies.

Fixed network:
Standard telecommunication facilities.

11. Number of personnel required: in Germany the plant has been run with around 300 persons that worked continuously with 3 shifts.

11.1 Number of Technicians required (skilled labour):
Only skilled persons are employed. A third of the skilled persons are engineers.

11.2 Number of Labourers required (unskilled labour):
none

B. Costs: Costs are based on the present situation that the plant is not running impossible to indicate

1. Installation and commissioning costs [US Dollars]:

2. Site preparation costs [US Dollars]:

3. Energy & Telecom installation costs:

4. Monitoring costs:

5. Complying costs:

6. Reporting costs:

7. Running costs with no waste:
Process is based on running with waste only

8. running costs with waste:

9. Decommissioning costs:

10. Landfill costs:

11. Transport costs of residues:
Depending on the local situation

C. Impact:

Sulphur and nitrogen compounds contained in the raw gas are removed in the gas processing facilities emission-free, in a sealed pressure system. Traces of POPs (0.0034 ng TEQ/Nm^3) (see B. Buttker et. al., 2006) are finally destroyed in the entrained-flow gasifier at temperatures of 2000°C. PCBs, PCDDs and PCDFs have not been detected by analytic means in the methanol produced and in water, slag and gypsum. The vitrified slag may contain heavy metal compounds; that slag is capable of being recycled e.g., into insulating materials. Since the waste-to-gas conversion process takes place in a reducing atmosphere the possibility of the formation of PCDDs and PCDFs is limited. PCDDs and PCDFs emissions to air are reported as follows: Desulphurization plant 0.0006 ng TEQ/Nm^3; boiler plant 0.0029 ng TEQ/Nm^3. The reported DE mainly depends on low PCDD/F-concentration of 34.08 ng TEQ/kg in treated waste. DE is 99.99143 when PCDD/F-concentration in waste reaches 50.000 ng TEQ/kg (see B. Buttker et. al., 2006). It is recommended for future users to look into higher POPs concentrations due to reasons as described in Part I under 2. Destruction efficiency (DE).

1. Discharges to air:
.

2. Discharges to water:
None

3. Discharges to land:

4. Soil impact (noise etc):

D. Risks

A detailed HAZOP has been conducted showing the possible risks and actions to be undertaken.

1. Risks of reagents applied:

Standard safety precautions were taken dealing with preheated oxygen under pressure and superheated steam. The plant was equipped with automatic emergency shut down system.
The classical safety standards were applied dealing with coal, reactive lignite and hazardous waste. Emission of solids was well within the EU regulations. Bunker and hoppers were equipped with dedusting and venting systems. Nitrogen purges kept the oxygen of the bunker atmospheres below the explosion limit for gas. Carbon monoxide was additionally monitored in the vent gas.

2. Risks of technology:

Risk of gas (carbon monoxide, hydrogen, methane, hydrocarbons) emissions is the main possible hazard. Exposed areas of the gasifier surrounding where potential leakage could occur were classified as Ex-zone 1. The plant was built to the technical standard of technically tight flange connections. Additional personal protection was applied monitoring the carbon monoxide around the gasifier at strategical positions. Fugitive and start up emissions were contained and safely and any reminder was co-incinerated in a steam raising boiler equipped with $DeSO_X$ and $DeNO_X$.
The fixed bed technology has a large inventory of fuel/carbon inside the reactor which represents a safety reservoir for the inflowing gasification agent (Steam/oxygen). The control system is therefore reliable, easy/simple and therefore very safe.

3. Operational risks:

POPs are effectively destroyed by the process in a closed loop system without endangering human health or the environment. Use of carbon monoxide/hydrogen gas under pressure requires suitable controls and safeguards to ensure that explosive air/oxygen-carbon monoxide/hydrogen mixtures are not formed. Operating experience gained from 1992 to date has indicated that the process can be undertaken safely. As a matter of fact the BGL Slagger has a lot in common with Lurgi Fixed Bed Dry Bottom Gasification which has a good record of safe operation at the Sasol Synfuels plant South Africa with operating record from the 1950's onward, DGC in North Dakota, USA and plants in China. Additional measures were taken to the safety standards of these plants. Oxygen in the gas and gas quality (carbon monoxide and carbon dioxide) was constantly monitored (2 out of 3) to ensure always a safe operation linked to an automatic shut down system for the gasifier. This allowed for a safe start up routing the gas as early to the production gas header thus minimizing start up gases/emissions to be flared off or incinerated.

As large quantities are handled, appropriate and environmentally compatible storage capacities and containments are required.

E. Constructability:

1. Ease of installation/construction of plant:
Installation of this plant is complex works which only can be done by real specialists, having in-depth experience in the construction and installation of such plants.

2. Ease of shipping/transit:
The gasification technology is available only in fixed configurations.

3. Ease of operation:
Complex plant requiring expertise of the staff to run

4. Ease of processing :
Easy as Protocol P-system is applied for process. See also under 10. Communication systems

F. Output/generation waste:

Sulphur and nitrogen compounds contained in the raw gas are removed in the gas processing facilities emission-free, in a sealed pressure system. Traces of POPs (0.0034 ng TEQ/Nm^3) (see B. Buttker et. al., 2006) in the raw gas are finally destroyed in the entrained-flow gasifier at temperatures of 2000°C. PCBs, PCDDs and PCDFs have not been detected by analytic means in the methanol produced and in water, slag and gypsum. The vitrified slag may contain heavy metal compounds; that slag is capable of being recycled e.g., into insulating materials. Since the waste-to-gas conversion process takes place in a reducing atmosphere the possibility of the formation of PCDDs and PCDFs is limited. PCDDs and PCDFs emissions to air are reported as follows: Desulphurization plant 0.0006 ng TEQ/Nm^3; boiler plant 0.0029 ng TEQ/Nm^3. The reported DE mainly depends on low PCDD/F-concentration of 34.08 ng TEQ/kg in treated waste. DE is 99.99143 when PCDD/F-concentration in waste reaches 50.000 ng TEQ/kg (see B. Buttker et. al., 2006).

1. Generated waste (% of input waste)
No waste. All products are re-used. About 15% of total waste input is recycled.
All metals are vitrified. Materials have been used based on specific permit for filling works in browncoal mining area in combination with large-scale landscaping works

2. Deposited waste at landfill (% of input waste)
No deposit at landfills

3. Waste quality properties (pH, TCLP):
Solid effluents met criteria for TCLP. Test results are not available anymore.

**Note: This Technology Specification and Data Sheet (TSDS) does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the companies or other sources, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts below listed technology suppliers it would not have been possible to set up this TSDS. Date:09.08.2008*

Technology suppliers that have contributed to this TSDS: :

Dr. B. Buttker
Dr. Matthias Zender
Osman Turna, Lurgi GmbH

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