No.	Type of Hazard	Location of Hazard Where?	Origin of Hazard When?	Potential consequences What happens?	Measure No.	Recommended counter measures Possible reduction measures	Measure implemented (yes/no)
1	**Fire**						
		The whole plant	Fire caused by either an explosion, self-ignition, glowing particles, welding, etc.	Ignition source for explosion	1,1	Installation of fire detection/suppression equipment like: Portable systems: fire extinguishers Fixed systems: foam towers, large flow pumps, foam extinguishers, automatic or manuall operated fire protection systems	
					1,2	Make sure the gasification facilities comply with international standards for the prevention and control of fire and explosion hazards, including provisions for safe distances between tanks in the facility and between the facility and adjacent buildings	
					1,3	Install anti-back firing system	
				Damage or destruction of the gasifier plant and/or building	1,4	Locate fire systems in safe areas of the facility. Protect them from fire by distance or by fire walls	
				Physical injury to human being	1,5	Preparation of a formal fire response plan supported by the necessary resources and training, including training in the use of fire suppression equipment and evacuation. Procedures may include coordination with local authorities or neighbouring facilities and training in the use of fire supression equipment and evacuation	
		Fuel storage building		Undesired fuel combustion	1,6	The fuel should be stored in a closed container or in a separate room or building. A fire resistant separation (with a specified resistance time) between the fuel storage and the gasifier may be required according to local fire protection regulations	
					1,7	a humidification system at the ash removal in order to prevent fire hazard from glowing particles or nitrogen inerting on ash removal screws	
		Gasification facilities		Release of toxic fumes	1,8	the ventilation air intakes should prevent smoke from entering accommodation areas	
					1,9	ample ventilations, preferably natural ventilation with an air change of more than 6 h-1	
					1,1	Implement safety procedures for operation and maintenance, including use of fail safe control valves and emergency shutdown equipment	

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2	**Explosive atmosphere**						
		The whole plant	Technical or operational probem leadiing to: 1. Underpressure, 2. Overpressure, 3. Dust clouds	Air ingress Gas escape	2,1	Implement measures to avoid explosions including: - Flooding with inert gas - Avoid ignition source - Removal of dust deposits - Avoid dust clouds - Maintain clean working floor - Grounding of the plant sections	
				Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc	2,2	Gasification facilities should be designed, constructed, and operated according to international standards for the prevention and control of fire and explosion hazards, including provisions for safe distances between tanks in the facility and between the facility and adjacent buildings	
			When a mixture of combustible gases and oxygen meets an ignition source	Minor explosion or in German “Verpuffung”	2,3	Implementing safety procedures for operation and maintenance, including use of fail safe control valves and emergency shutdown and detection equipment	
				Damage or destruction of the gasifier plant and/or building	2,4	Define the maximum value of oxygen at sampling points Temperature sensors and pressure sensors should be installed before and after the main components Install oxygen sensors in the gas piping and monitor oxygen concentration, CO monitors around the plant	
			Spillage of flammable liquids	Explosion can intiate fire	2,5	Using a water seal acting as a flame arrestor Leak detection (gas sensors)	
		Plant sections where fine dust and particles are handled (fuel storage, ash or dust removal systems…)	Fine dust and particles	Explosion, fire	2,6	Organisational precautions to comply cleanliness, avoid dust depositions and contamination, avoid dust clouds and maintain clean working flours Good housekeeping is the key to avoid dust explosions Ban smooking, no smoking signs	
					2,7	Application of hazardous area zoning for electrical equipment in design. Ex-zoning will determine which type or category of equipment is allowed	
		Gas transportation sections	Poor gas quality		2,8	Unburnt gases should be flared Inertisizing the plant with nitrogen Apply anti-back firing systems The ventialtion must be ample, preferably natural ventilation with an air change of more than 6 times per hour	

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3	**Substance hazards**						
		The whole plant	Overpressure Leakages Operation and Maintenance	Gas escape leading to gas intoxication, CO poisoning some PAH are carcinogenic danger of suffocation (CO, PAH,…) irritation to eyes, inhalation	3,1	During operation and maintenance, operators should wear portable CO monitors	
					3,2	Construct the system to be gas tight Control rooms should have positive pressure ventilation	
				CO leakage outside the plant and environmental pollution	3,3	Installation of CO monitors in the plant	
		The whole plant, at start-ups and shut-downs	Flammable materials	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	3,4	Operators should be instructed not to stay unnecessarily close to system components (gasifier, cyclone bins, filters, etc.) with flammable materials during start-up, normal operation and shut-down	
		Storage buildings, gasifier building, and gas engine room	Overpressure	Gas escape leading to gas intoxication, CO poisoning some PAH are carcinogenic danger of suffocation (CO, PAH,…) irritation to eyes, inhalation	3,5	Install fixed online CO detectors in fuel storage buildings, gasifier building, and gas engine room giving an indication and alarm at 25/50 ppm	
					3,6	During operation, ample ventilation of gasification building with efficient air change of more than 6 times per hour	
		Water seals			3,7	Gas tight construction (apply good practices for COMAH (Seveso II) sites.	
		Ash removal section	Glowing carbon particles and high temperatures	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	3,8	Install a humidification sytem at the ash removal in order to prevent fire hazards from glowing particles	
					3,9	Water spraying at ash discharge	
			Foreign material	Damages to the ash removal system	3,10	Improve fuel pretreament section + Water spraying at ash discharge	
		Gas cleaning section	Glowing particles Leakages Storage or holding tanks	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	3,11	Install either: a water seal or a cyclone combined with a settling chamber in order to prevent glowing particles from entering the gas cleaning section.	
		Wet Scrubbing systems and Particle filter for fly-ash removal	Material toxicity + carcinogenicity resulting from tar removal/recycling	Environenmental pollution by scrubbing water	3,12	Installation of a bin/tank to collect and treat the toxic liquids (treatment by a certified company, prescribed in permit documents)	
				Operators intoxication, injuries Irritation	3,13	Avoid the production of unnecessary toxic materials; only toxic products like producergas and scrubbing water can not be avoided. Provide personnel protective measures like safety glasses, gloves, shoes, CO alarm	
					3,14	Wear protective cloths	
					3,15	Operators should wear hand gloves,glasses and safety shoes	
		Gas engine	High percentage of CO		3,16	CO can only be detected by sensors giving alarm. Then it should be described in the OM what to do when CO alarm	

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4	**Operational & maintenance hazards**						
		The whole plant	Rotating parts	Injuries	4,1	Shielding, visual signs Emergency stop button	
			Welding	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	4,2	Implement permit systems and formal procedures for conducting any hot work during maintenance activities,including proper tank cleaning and venting Repairs like welding must be subjected to a permit to work system	
			Flammable material Explosive mixtures/atmospheres		4,3	When performing repairs such as welding, flammable material and explosive mixtures or atmospheres must be removed or prevented	
			Toxic/suffocating gases	Gas intoxication, CO poisoning Suffocation (CO, PAH,…) irritation to eyes, etc.	4,4	Operators should avoid contact and inhalation of either toxic or suffocating gases / liquids. This would obviously avoid most hazards that occur during maintenance. All plant maintenance procedures should be well documented while operators should routinely follow procedures.	
			Bad operational/ maintenance practices	Various consequences	4,5	Make sure only skilled and qualified personnel are allowed to operate and maintain the plant. Provide training to the personnel	
				Grounding connections deterioration and malfunction	4,6	Include formal procedures for the use and the maintenance of grounding connections	
			Inadequate control system programming	Wrong settings and malfunction leading to various consequences	4,7	Make sure safety related-changes to the process control system are only performed by trained personnel and that the procedure is well documented (operation manual)	
					4,8	Make sure alarm settings are only re-programmed after the problem is solved	

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		Reactor	Malfunctioning	Pressures build-ups leading to backfiring in the previous section, to gas escape and its consequences (please refer to section 3)	4,10	Install anti backfiring system at reactor	
		Gas flare	Bad weather associated to poor gas quality		4,11	Install anti back firing system: Flame arrestor or water seal (reference to EN 12874) Automatic ignition	
					4,12	The cross section area of the pressure relieve channel to the flare should be about double the area compared to the pressure relieve valve cross sectionnal area	
		Gas inlet	Improper ignition timing		4,13	Install anti backfiring system at air inlet to the engine according to national regulation	
		At valves location	Overpressure		4,14	Implementation of safety procedures for operation and maintenance including use of fail safe control valves and emergency shutdown and detection equipment of the pressure	
		In the gasifier reactor	Locally higher oxygen levels may occur	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	4,15	Make sur there are two escape routes to an open air from the gasifier building	
		At start up	Explosive athmosphere Ignition sources		4,16	Flaring the gas or purging the whole system with nitrogen	
		After shutdown	Explosive athmosphere Ignition sources		4,17	Purging with nitrogen Purging with air is also applied in practice. When purging with air, explosive atmosphere is not prevented - ignition sources have to be eliminated (secondary explosion protection)	
5	**Thermal hazards**						
		Fuel storage, transport and feeding	Temperature rise	Feedstock self-ignition	5,1	Monitor temperature in big piles of feedstock, Install CO monitors, Install Sprinkler installation	
		Hot surfaces of gas cooler	Chemincal reactions	Malfunctioning of the process due to overheating of materials like refractory lining, valve settings, etc. which may cause all sorts of dangers in particular gas escape	5,3	Water spraying at ash discharge, Set maintenance intervals, Corrosion resistant steel material, Detect leakages by indication of temperature increase in case auto-ignition temperature exceed set limits	
		Hot surfaces of reactor, cyclone	High Temperature	Thermal stress and corrossion	5,4	Regular inspection and maintenance	
				Operators injuries	5,5	Proper insulation and shielding Wear heat resistant hand gloves	

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6	**Electrical Hazards**						
		The whole plant	Power failure	Pressures build-up leading to gas escape and its consequences (please refer to section 3)	6,1	Safety emergency stop	
			Static electricity build up	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	6,2	Use proper grounding to avoid static electricity build up and lightning hazards	
			Sparks		6,3	Use of intrinsically safe electrical installations and non sparking tools Screw conveyors should have shaft speed monitor and speed control	
		Where explosive athmosphere can happen	Bad zoning practices		6,4	Instrumentation and electrical equipment should be for Zone 1, otherwise the equipment should be secured; in the gasifier itself equipment should be for Zone 2	
		Gas conducting part	Sparks	Fire ignition Explosion, which can lead to more explosions (a.o. dust explosions), plant destruction, fire, etc.	6,5	All gas conducting part should be electrically grounded	
		PLC Programmable Logic Controller	Static electricity	Malfunction of the PLC	6,6	Galvanic separation of measurement devices, PLC should be properly grounded to earth	
			Power failure		6,7	PLCs have to be supplied by an uninterrupted power supply unit (UPS)	
		Inlet to the engine	Electrical breakdown	Backfiring in the inlet system	6,8	Shielded cables should be used in order to avoid electrical breakdowns that could cause backfiring in the inlet system.	
7	**Mechanical hazards**						
		Conveyors, Electromotors	Sharp edges, sharp parts	Operator injuries	7,1	Shielding, visual signs, emergency stop button	
					7,2	Safety switches and local circuit breakers on rotating parts and switches, on access panels, on pressure relieve equipment, on critical valves with access to gas containing equipment such as feeders, cyclones and ash outlets	