

Table S5. FMECA table: List of all the identified failure modes for the different components of the system under study (WWTP+Reclamation Facility), the corresponding causes, existing corrective actions and consequences for the equipment, final effluent quality, environment and human health; the scores assigned for the likelihood of occurrence S_O , the ease of detection S_D , and the magnitude of the consequences S_M ; the hazard for the environment and the human health

(Micro= microbiological hazard; Chem = chemical hazard; Phys = physical hazard); the risk R ($S_O \times S_M$) and the RPN ($S_O \times S_D \times S_M$) values.

(Number of subsystems: 13; number of compartments: 3 in the biological step; number of equipment: 2 in the chlorination step; number of identified components: 86; number of failure modes: 303).

Color legend:

maximum score
very high R
very high RPN

Subsystem	Compartment or Equipment	Component	Identifier	Failure mode	Causes	Likelihood of occurrence, S_L	Ease of detection, S_D	Existing corrective actions	Consequences	HAZARD for the environment		HAZARD for the human health			Magnitude of consequences, S_M	Risk R	RPN
										Micro	Chem	Micro	Chem	Phys			
INFLUENT (T1)		Flow rate	T1_1	Lower flow rate than the designed one	Daily and seasonal variability	3	1	The treatment steps adapt with respect to the (expected)daily/seasonal variations in the flow rate.	No significant effect occurs due to these deviations.						1	3	3
			T1_2	Higher flow rate than the designed one	Increment of the population due to local events, water infiltration in the sewer. In combined sewer, contribution of rainwater during intense rain events	3	1	The treatment steps may smooth out expected daily/seasonal variations in the flow rate. If extremely high flow rate are present, a combined sewage overflow outfall protects the WWTP.	If deviations are due to rainwater or unauthorized discharges, the plant may not be able to treat all the flow. Risk of flooding.	x	x	x	x		8	24	24
			T1_3	(Magnetic) Flow rate sensor malfunctioning	Air may have entered during maintenance operations, gases may have been released during spontaneous degradation processes	3	3	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding to the treatment train.	The measured flow rate value does not correspond to the real one and it is not possible to know the flow rate fed to the plant.	x	x	x	x		16	48	144
			T1_4	(Magnetic) Flow rate sensor breakage/malfunctioning	End-of-life, defective device	3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If a flow rate higher than the designed one is fed, the plant operates at a lower hydraulic retention time and the reactions might be incomplete.	x	x	x	x		16	48	96
			T1_5			3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If a flow rate lower than the designed one is fed, no relevant effect on the system performance occurs.						1	3	6
			T1_6	(Magnetic) Flow rate sensor does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Chemical composition and load	T1_7	Higher concentration of a regulated substance	Daily expected variation, unauthorized discharge in the sewer network	3	2	Multiparametric sensors can give a warning in the case of unexpected values. The multibarrier treatment system may be able to remove the regulated substances at the desired level.	Daily peak concentrations of regulated contaminants do not have serious effects as the treatment plant has a buffer capacity. If the deviation is due to unauthorized discharges, the effects are related to their nature and load (see T1_9).						2	6	12
			T1_8	Lower concentration of a regulated substance	Daily expected variations, dilution due to infiltration water or rainwater	3	2	The treatment is able to cope with the expected daily/seasonal deviations of the concentrations.	The effects on the performance of the treatments are modest in the case of a reduction in the influent concentration of the regulated substances. They may depend on the reduced hydraulic retention time due to an increment in the flow rate (if there is rain water or infiltration contribution).						2	6	12
			T1_9	Higher load of a regulated substance	Daily expected variations, increment of the population (tourists, social events), unauthorized discharges in the sewer network	3	2	The treatment buffer capacity and its residual capacity may smooth out the deviations.	If the load deviation is relevant, the system may not be able to remove the substance at the desired level and meet its corresponding legal limit in the discharge.	x	x	x	x		8	24	48
			T1_10	Lower load of a regulated substance	Daily expected variations, dilution due to infiltration water or rain water	3	2	The treatment buffer capacity and its residual capacity may smooth out the deviations.	Chemical, physical, and biological treatments are not seriously affected by a lower pollutant load.						2	6	12
			T1_11	Presence of new and recalcitrant substances (unexpected)	Unauthorized discharges in the sewer network, urban runoff, major industrial accidents leading to a release	2	5	Multiparametric sensors may give a warning in the case of unexpected values (of the surrogates).	The effects are strongly related to the substances and their ecotoxicological characteristics.	x	x	x	x		16	32	160
			T1_12	Multiparametric sensor fouling	Substances present in the influent	2	4	Periodic maintenance.	Unreliable measurements.	x	x	x	x		16	32	128
			T1_13	Multiparametric sensor breakage	Debris and bulky materials in the influent	1	1	Periodic maintenance/replacement.	Measurements are not available and the control of the influent is not possible.	x	x	x	x		4	4	4
			T1_14	Multiparametric sensor does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
			T1_15	Exceptional occurrence of coarse materials in the influent (debris, gravel, twigs, sand)	Urban runoff	2	3	To avoid damage to the equipment, efforts must guarantee their retainment through pre-treatments: degritting, screens, primary sedimentation.	Deterioration of the influent quality. Due to the multibarrier system, the effects on the final effluent are marginal. The treatment steps will probably not be damaged, the coarse screen will receive wastewater with debris and bulk materials and will be able to retain the raw material. The fine material will be retained in the following pretreatments.						4	8	24
COARSE SCREENING (T2)		Screen	T2_1	Screen clogging	Debris and bulky materials in the influent	2	3	Manual activation of the cleaning system.	Accumulation of the screenings on the bars, reduction of the section available for the flow.			x	x		4	8	24
		Automatic cleaning system	T2_2	Cleaning system breakage	Mechanical stress	2	3	Periodic maintenance with a timely replacement of components.	Clogging, reduction of section available for the flow.			x	x		4	8	24
		Screening conveyor belt	T2_3	Screening conveyor belt breakage	Mechanical stress	2	1	Periodic maintenance.	Screened material accumulates and is not removed			x	x		2	4	4
			T2_4	Screening conveyor belt does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the belt can work properly.			x	x		1	2	2
		Cleaning system timer	T2_5	Timer breakage	Shorter lifetime	1	3	Periodic maintenance.	Inactivation of the cleaning system.			x	x		2	2	6
			T2_6	Timer does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the timer can work properly.						1	2	2

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PUMPING STATION (T3)		Valve in the pump feeding line	T3_1	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Wastewater outflow into the environment.	x	x	x	x		4	8	16
			T3_2	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Wastewater is not properly sent to the pump and potential outflow into the environment.	x	x	x	x		4	8	24
			T3_3	Valve blockage	Damage caused by coarse material, ageing	2	4	Periodic maintenance.	If the valve is blocked open, a flow higher than expected is fed to the pump. Higher energy consumption (higher costs).						8	16	64
			T3_4			2	4	Periodic maintenance.	If the valve is blocked closed, no flow goes to the pump. The system is fed with the flow provided by the other pumps in operation or by stand-by pumps.						4	8	32
			T3_5	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Pumps	T3_6	Pump blockage	Coarse material (debris, rocks, gravel or twigs) in the influent	3	3	Anti-clogging devices in the pumps.	Marginal consequences because the pumps are generally equipped with anti-clogging devices or shredders.						2	6	18
			T3_7	Worn out parts of the pump	Bad quality of the material	1	3	Periodic maintenance.	The pumps will not work or will not work as requested.						4	4	12
			T3_8	Pump overheating/Thermal blockage	Insufficient lubrication or foreign objects blocking the cooling fins	2	4	Periodic maintenance.	Pump malfunctioning, including noise; damage to the pump seals; pump life shortening; excess pump vibration; increase energy consumption and operating costs; safety hazards for the working staff.						16	32	128
			T3_9	Vibration of the pump	Alignment issues, incorrect installation, even overuse of pumps	1	2	Periodic maintenance.	Noise, increased wear on moving parts, damage to the internal parts.						4	4	8
			T3_10	Corrosion of some parts of the pump	Lack of regular clean-up	1	3	Periodic maintenance.	Leakage in the pumps and loss of water.	x	x	x	x		8	8	24
			T3_11	Pump out of order	Ageing/defective pump	2	1	Periodic maintenance, feeding is guaranteed by the stand-by pump.	Overwork for the other available pumps, stand-by pumps are requested to come into operation.						4	8	8
			T3_12	Leakage	Poor material	1	3	Periodic maintenance.	Loss of water into the surrounding environment.	x	x	x	x		8	8	24
			T3_13	Electrical issues	Sudden power surges	3	1	A generator is available to guarantee operation.	The pump would not work, but there is a generator to deal with these situations.						1	3	3
		Valve in the pump outlet line	T3_14	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Wastewater overflow into the environment.	x	x	x	x		4	8	16
			T3_15	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Wastewater is not sent properly to the following treatments and potential outflow into the surrounding environment may occur.	x	x	x	x		4	8	24
			T3_16	Valve blockage	Damage caused by coarse material, ageing	2	4	Periodic maintenance.	If the valve is blocked open, a higher than expected flow rate is fed to the following treatments. Potential reduction in the process performance due to a lower hydraulic retention time.	x	x	x	x		8	16	64
			T3_17			2	4	Periodic maintenance.	If the valve is blocked closed, no flow rate is fed to the following treatments from this line. The system is fed with the flow provided by the other pumps in operation or by stand-by pumps.						4	8	32
			T3_18	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
FINE SCREENING (T4)		Screen	T4_1	Screen clogging	Excess of material escaped from the coarse screen (e.g., plastics, papers, small rags)	2	3	Manual activation of the cleaning system.	Accumulation of the screenings on the bars, reduction of the section available for the flow, by-pass of the screenings and coarse material is fed to the next steps.			x	x		8	16	48
		Automatic cleaning system	T4_2	Cleaning system breakage	Mechanical stress	2	3	Periodic maintenance with a timely replacement of components.	Clogging, reduction of the section available for the flow.			x	x		4	8	24
		Screenings conveyor belt	T4_3	Screenings conveyor belt breakage	Mechanical stress	2	1	Periodic maintenance.	Screened material accumulates and is not removed			x	x		2	4	4
			T4_4	Screenings conveyor belt does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the belt can work properly.			x	x		1	2	2
		Timer	T4_5	Timer breakage	Shorter lifetime	1	3	Periodic maintenance.	Inactivation of the cleaning system.			x	x		2	2	6
			T4_6	Timer does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the timer can work properly.						1	2	2
GRITTING AND FOG REMOVAL (T5)		Blower	T5_1	Motor breakage	Bearing malfunctioning	1	1	Periodic maintenance.	Noise, malfunctioning, extraordinary maintenance.						8	8	8
			T5_2	Motor overheating	Friction between moving parts	1	3	Periodic maintenance.	Malfunctioning, extraordinary maintenance.						8	8	24
			T5_3	Motor out of order	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the blower can work properly.						1	2	2
			T5_4	Dirty air filter	Dirty air supplied, poor maintenance	2	2	Periodic maintenance.	Motor overheating.						8	16	32
			T5_5	Excess of the air supplied	Malfunctioning in the air flow rate measurement and control, human error	1	3	On-site inspection.	Sand resuspension and increment in the suspended solid load to the following treatment step.						8	8	24
			T5_6	Deficiency of the air supplied	Malfunctioning in the air flow rate measurement and control, human error	1	3	On-site inspection.	Deposition of the organic matter, collected sand contains organic matter.						8	8	24
		Air diffusers	T5_7	Clogging of the air outlet nozzles	Settled materials on the nozzles	2	4	Periodic maintenance.	Reduced air quantity supplied, sedimentation of the organic matter, collected sand contains organic matter.						8	16	64
			T5_8	Diffuser breakage	Ageing, poor material	1	4	Periodic maintenance.	Air is not uniformly supplied due to the breakage, scarce effect of aeration in gritting and FOG removal.						8	8	32
		Screw conveyor	T5_9	Conveyor components breakage	Poor material, scarce maintenance	1	3	Periodic maintenance.	Accumulation of the collected material, extraordinary maintenance.						8	8	24
			T5_10	Conveyor clogging	Malfunctioning of the coarse and fine screenings	1	3	Periodic maintenance.	Extraordinary maintenance.						8	8	24
		Sand washing system	T5_11	Excess of water supplied	Malfunctioning in the water flow rate measurement and control, human error	1	3	On-site inspection.	Marginal effects which do not affect the quality of the final effluent.						1	1	3
			T5_12	Deficiency of water supplied	Malfunctioning in the water flow rate measurement and control, human error	1	3	On-site inspection.	Sands are not well washed, still contain organic matter which could cause bad odors.			x			8	8	24
		Grease skimmer	T5_13	Grease skimmer breakage	Wear, end-of-life	2	2	Periodic maintenance.	Scum and FOG pass through the treatment and go to the following one.						8	16	32

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PRIMARY SEDIMENTATION (T6)		Feeding characteristics	T6_1	Higher flow rate	Rain events, infiltration contribution, wrong flow rate measurement by the sensors equipped in the systems upstream	3	2	Remote control alert.	Poor removal of settleable solids due to a high surface hydraulic load fed to the primary clarifier.						16	48	96
		Sludge level sensor	T6_2	Sludge level sensor breakage/malfunctioning	End-of-life, uncalibrated probe	3	2	Periodic maintenance.	Sludge may accumulate on the bottom, worse sedimentation performance.						8	24	48
			T6_3	Sludge level sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Sludge bottom scraper	T6_4	Sludge bottom scraper breakage/malfunctioning	End-of-life	2	4	Periodic maintenance.	Sludge may accumulate on the bottom, worse sedimentation performance.						8	16	64
			T6_5	Sludge bottom scraper does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Sludge draw off pipe	T6_6	Pipe leakage	Ageing/defective piping	1	4	Periodic maintenance.	Failure to transport the sludge to the sludge treatment train, sludge outflow into the environment.	x	x	x	x		8	8	32
			T6_7	Pipe obstruction	Obstacles in the pipe	2	2	Periodic maintenance.	Too low or no sludge flow in the pipe, failure to transport sludge to the sludge treatment train.						8	16	32
		Valve in the sludge draw off pipe	T6_8	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Sludge outflow into the environment.	x	x	x	x		4	8	16
			T6_9	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Sludge is not correctly drawn off.						8	16	48
			T6_10	Valve blockage	Damage caused by coarse material, ageing	2	4	Periodic maintenance.	If the valve is blocked open, a higher amount of sludge is conveyed to the sludge treatment. Potential reduction of the performance in the sludge treatments.						4	8	32
			T6_11			2	4	Periodic maintenance.	If the valve is blocked closed, no sludge is conveyed to the sludge treatments. Sludge accumulates on the settler bottom and a worse sedimentation performance occurs.						16	32	128
			T6_12	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Grease skimmer	T6_13	Grease skimmer breakage	Ageing	1	4	Periodic maintenance.	Residual scum and FOG pass through the treatment and go to the following one.						4	4	16

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BIOLOGICAL TREATMENT: P COPRECIPITANT + DENITRIFIC + NITRIFIC (T7)	P coprecip	Flow rate sensor	T7_1_1	Flow rate measurement malfunctioning	Air may have entered during maintenance operations, gases may have been released during spontaneous degradation processes	3	3	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	The values measured by the flow rate sensors are not correct. It is not possible to know the real flow rate fed to the biological step, but there is a flow rate sensor at the plant entrance and the working staff know the flow rate.							8	24	72
			T7_1_2	Flow rate sensor breakage/malfunctioning	End-of-life, defective device	3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If a flow rate higher than the designed one is fed, the reactor operates at a lower hydraulic retention time and oxidation reactions might be incomplete.		x					16	48	96
			T7_1_3			3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If a flow rate lower than the designed one is fed, no relevant effect on the biological treatment performance occurs.							1	3	6
			T7_1_4	Flow rate sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.							1	2	2
		Phosphate concentration sensor	T7_1_5	Sensor breakage/malfunctioning	End-of-life, uncalibrated probe	3	2	Periodic maintenance.	The automatic system does not detect the real phosphate concentration. If a higher dose of chemical is added, it will lead to higher costs due to an excess of precipitant and a higher amount of sludge to dispose of.							8	24	48
			T7_1_6			3	2	Periodic maintenance.	The automatic system does not detect the real phosphate concentration. In the case of a lower dose of chemical added, the removal of phosphate might be insufficient to meet the legal limit for the discharge.		x					16	48	96
			T7_1_7	Sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.							1	2	2
		Chemical tank (alum or iron salts)	T7_1_8	Different chemical	Different supplier, human error	2	5	Accurate control with the supplier and at the point of delivery.	Insufficient removal of phosphate, final effluent not complying with the legal limits.		x					16	32	160
			T7_1_9			2	5	Accurate control with the supplier and at the point of delivery.	Excess (waste) of chemical added. Higher sludge production, higher costs for the excess of chemical and of sludge to dispose of.							8	16	80
			T7_1_10	Different concentration of chemical in the supplied solution	Different supplier, human error	3	5	Accurate control with the supplier and at the point of delivery.	Insufficient removal of phosphate, final effluent not complying with the legal limits.		x					16	48	240
			T7_1_11			3	5	Accurate control with the supplier and at the point of delivery.	Excess (waste) of chemical added. Higher sludge production, higher costs for the excess of chemical and of sludge to dispose of.							8	24	120
			T7_1_12	Tank leakage/breakage	Ageing/defective tank	2	1	Remote control of the tank containing the chemical.	Loss of chemical, economic waste.		x		x			8	16	16
		Electrovalve for chemical dosage regulation (orthophosphate precipitation)	T7_1_13	Higher dosage of chemical	Uncalibrated valve, human error	3	4	Remote control of the tank containing the chemical.	Waste of chemicals, excessive operational costs.							8	24	96
			T7_1_14	Lower dosage of chemical	Uncalibrated valve, human error	3	4	Remote control of the tank containing the chemical.	Phosphorus concentration in the effluent exceeds the legal limits.		x					16	48	192
			T7_1_15	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Chemical release into the environment.		x		x			8	16	32
			T7_1_16	Valve breakage	End-of-life	3	1	Periodic maintenance.	Insufficient amount of chemical added to the bioreactor. Phosphorus concentration in the effluent exceeds the legal limits.		x					16	48	48
			T7_1_17	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, excess of chemical is added to the biological reactor. Waste of chemical.							8	16	64
			T7_1_18			2	4	Periodic maintenance.	If the valve is blocked closed, no chemical is added to the biological reactor. Phosphorus concentration in the effluent exceeds the legal limits.		x					16	32	128
			T7_1_19	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.							1	2	2
	denitrific step	Nitrate sensor	T7_2_1	Nitrate sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance.	Nitrate removal can be lower than that desired.		x					16	48	96
			T7_2_2	Nitrate sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.							1	2	2
		Mixer	T7_2_3	Too high mixing velocity	Failure to set the design velocity, human error	2	4	On-site inspection.	Floc breakage, lower denitrification efficiency.		x					16	32	128
			T7_2_4	Too low mixing velocity	Failure to set the design velocity, human error	2	4	On-site inspection.	Lower denitrification efficiency, poor aggregation among flocs.		x					16	32	128
			T7_2_5	Wrong position of the mixer	Variability in the hydraulic level of the tank	2	3	Periodic inspection.	If the mixer is located too deep in relation to the hydraulic level, the liquid is not adequately mixed and denitrification has a modest performance.		x					16	32	96
			T7_2_6			2	3		If the mixer is located too high in relation to the hydraulic level, the liquid is not adequately mixed and cavitation problems may occur.							16	32	96
			T7_2_7	Breakage of the internal components of the mixer	Failure to mix	2	3	Periodic maintenance.	Absence of mixing, very low denitrification efficiency.		x					16	32	96
			T7_2_8	Mixer does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the mixer can work properly.							1	2	2

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BIOLOGICAL TREATMENT: P COPRECIPITANT + DENITRIFIC + NITRIFIC (T7)	nitrification step	Suspended solids concentration sensor	T7 _{3_1}	Suspended solids sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance.	Failure to measure the real suspended solids concentration. If the measured one is higher than the real mixed liquor suspended solids concentration, the organic matter oxidation and nitrification will be lower than expected.	x					16	48	96
			T7 _{3_2}			3	2	Periodic maintenance.	Failure to measure the real suspended solids concentration. If the measured concentration of suspended solids in the mixed liquor is lower than the real ones, this may lead to an excessive return sludge flow rate and then to a higher solid loading to the secondary sedimentation unit.						8	24	48
			T7 _{3_3}	Suspended solids sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Ammonia sensor	T7 _{3_4}	Ammonia sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance.	Failure to provide the right concentration of ammonia. If it is lower than the real one, the supplied air is not sufficient to achieve the desired nitrification.	x					16	48	96
			T7 _{3_5}			3	2	Periodic maintenance.	Failure to provide the right concentration of ammonia. If it is higher than the real one, there is an excess of supplied air.						8	24	48
			T7 _{3_6}	Ammonia sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Redox potential sensor	T7 _{3_7}	Redox potential sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance.	Failure to provide the right measure of redox potential. If it is lower than the real one, an excess of air is supplied leading to a higher oxygen concentration, which is not necessary. Increment in operational costs.						8	24	48
			T7 _{3_8}			3	2	Periodic maintenance.	Failure to provide the right measure of redox potential. If it is higher than the real one, the amount of supplied air is insufficient for oxidation and nitrification. Limits at the discharge could not be respected.	x					16	48	96
			T7 _{3_9}	Redox potential sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately deal with this situation and the sensor can work properly.						1	2	2
		Orthophosphate sensor	T7 _{3_10}	Orthophosphate sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance.	Failure to provide the right concentration of ortophosphates. If it is lower than the real one, the amount of chemical added for their precipitation is not sufficient and the limits at the discharge might not be respected.	x					16	48	96
			T7 _{3_11}			3	2	Periodic maintenance.	Failure to provide the right concentration of ortophosphates. If it is higher than the real one, the amount of chemical added for their removal is in excess leading to higher costs (wasted chemical).						8	24	48
			T7 _{3_12}	Orthophosphate sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		pH sensor	T7 _{3_13}	pH sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	3	2	Periodic maintenance, remote control.	Failure to provide the right pH value. If the value is outside the expected range, an alarm will go on and onsite controls are requested. If the measured value is within the expected range, even if not the real one, the effects on the system and the final effluent quality are marginal.						2	6	12
			T7 _{3_14}	pH sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Blower	T7 _{3_15}	Motor breakage	Bearing malfunctioning	1	1	Periodic maintenance.	Noise, malfunctioning, extraordinary maintenance, failure to oxidize the organic and nitrogenous substances.	x					16	16	16
			T7 _{3_16}	Motor overheating	Friction between moving parts	2	3	Periodic maintenance.	Malfunctioning, extraordinary maintenance.						8	16	48
			T7 _{3_17}	Motor out of order	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the blower can work properly.						1	2	2
			T7 _{3_18}	Dirty air filter	Dirty air supplied	2	2	Periodic maintenance.	Motor overheating.						8	16	32
			T7 _{3_19}	Excess of the air supplied	Malfunctioning in the air flow rate measurement and control, human error	1	3	Remote control, on-site inspection.	Excess of energy consumption, higher costs.						8	8	24
			T7 _{3_20}	Deficiency of the air supplied	Malfunctioning in the air flow rate measurement and control, human error	1	3	Remote control, on-site inspection.	Poor oxidation and lower efficiency in carbonaceous and nitrogenous substance removal, potential foaming in the secondary sedimentation tank.	x					16	16	48
		Mixed liquor	T7 _{3_21}	Lower oxygen concentration	Extremely high ambient temperature	3	2	Remote control.	Insufficient oxygen concentration in the aerobic tank, insufficient oxidation of the organic compounds.	x					16	48	96
		Air diffusers	T7 _{3_22}	Clogging of the air outlet nozzles	Settled materials on the nozzles	3	4	Periodic maintenance.	Reduced air quantity supplied, lower oxidation rate, insufficient oxidation of the organic compounds.	x					16	48	192
			T7 _{3_23}	Diffuser breakage	End-of-life, poor material	2	4	Periodic maintenance.	Uneven air distribution, lower removal of carbonaceous and nitrogenous substances.	x					16	32	128
		Return mixed liquor pump	T7 _{3_24}	Pump blockage	Ageing, poor material, obstructions in the flow	3	1	Periodic maintenance.	Too high mixed liquor flow rate returned to the denitrification tank. The denitrification might be incomplete, an excess of suspended solids load might be sent to the secondary sedimentation unit.	x					16	48	48
			T7 _{3_25}			3	1	Periodic maintenance.	Too low mixed liquor flow rate returned to the denitrification tank, leading to a lower denitrification efficiency.	x					16	48	48
			T7 _{3_26}	Worn out parts of the pump	Bad quality of the material	1	3	Periodic maintenance.	The pumps will not work or will not work as requested. The return mixed liquor may be insufficient to guarantee the requested denitrification efficiency.	x					16	16	48
			T7 _{3_27}	Pump overheating/Thermal blockage	Insufficient lubrication or foreign objects blocking the cooling fins	2	4	Periodic maintenance.	Pump malfunctioning, including noise; damage to the pump seals; pump life shortening; excess pump vibration; increase energy consumption and operating costs; safety hazards for the working staff.						16	32	128
			T7 _{3_28}	Vibration of the pump	Alignment issues, incorrect installation, even overuse of pumps	1	2	Periodic maintenance.	Noise, increased wear on moving parts, damage to the internal parts.					x	4	4	8
			T7 _{3_29}	Corrosion of some parts of the pump	Poor material, ageing	1	3	Periodic maintenance.	Leakage in the pumps and spillage of the mixed liquor.	x	x	x	x		8	8	24
			T7 _{3_30}	Pump out of order	Ageing/defective pump	2	1	Periodic maintenance.	Mixed liquor is not recirculated into the denitrification tank, lower denitrification efficiency.		x				16	32	32
			T7 _{3_31}	Leakage	Poor material	1	3	Periodic maintenance.	Spillage of mixed liquor.	x	x	x	x		8	8	24
			T7 _{3_32}	Electrical issues	Sudden power surges	3	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the pump can work properly.						1	3	3

Subsystem	Compartment or Equipment	Component	Identifier	Failure mode	Causes	Likelihood of occurrence, S _L	Ease of detection, S _D	Existing corrective actions	Consequences	HAZARD for the environment		HAZARD for the human health		Magnitude of consequences, S _M	Risk R	RPN	
BIOLOGICAL TREATMENT: P COPRECIPITANT + DENITRIFIC + NITRIFIC (T7)	nitrification step	Valve in the return mixed liquor pipe, after the pump	T7 _{3_33}	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Mixed liquor overflow into the environment.	x	x	x	x		4	8	16
			T7 _{3_34}	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	The mixed liquor is not properly sent to the denitrification tank leading to an insufficient removal of nitrates.		x				16	32	96
			T7 _{3_35}	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, a higher than expected mixed liquor flow rate is fed into the denitrification tank, which might lead to insufficient denitrification efficiency and also an excess of suspended solid load into the secondary sedimentation unit.		x				16	32	128
			T7 _{3_36}			2	4	Periodic maintenance.	If the valve is blocked closed, then the mixed liquor is not recirculated into the denitrification tank, causing an insufficient removal of nitrates.		x				16	32	128
			T7 _{3_37}	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.							1	2
		Valve in the return sludge pipe, before the pump	T7 _{3_38}	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Sludge outflow into the surrounding environment.	x	x	x	x		4	8	16
			T7 _{3_39}	Valve breakage	Ageing/defective valve	2	2	Periodic maintenance.	Sludge is not properly sent to the pump leading to an insufficient removal of the organic matter in the bioreactor.		x				16	32	64
			T7 _{3_40}	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, a higher than expected sludge flow rate is fed to the pump. Higher energy consumption (higher costs).						8	16	64
			T7 _{3_41}			2	4	Periodic maintenance.	If the valve is blocked closed, no sludge is fed to the pump causing an insufficient removal of carbonaceous and nitrogenous substances in the bioreactor.		x				16	32	128
			T7 _{3_42}	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.							1	2
		Return sludge pump	T7 _{3_43}	Pump blockage	Ageing, poor material, obstructions in the flow	3	1	Periodic maintenance.	Too high sludge flow rate returned to the bioreactor which could lead to excessive suspended loads to the sedimentation unit.		x				16	48	48
			T7 _{3_44}			3	1	Periodic maintenance.	Too low sludge flow rate returned to the bioreactor, causing an insufficient removal of carbonaceous and nitrogenous substances.						16	48	48
			T7 _{3_45}	Worn out parts of the pump	Bad quality of the material	1	3	Periodic maintenance.	The pumps will not work or will not work as requested. The returned sludge may be insufficient to guarantee the requested oxidation of the organic matter.		x				16	16	48
			T7 _{3_46}	Pump overheating/Thermal blockage	Insufficient lubrication or foreign objects blocking the cooling fins	2	4	Periodic maintenance.	Pump malfunctioning, including noise; damage to the pump seals; pump life shortening; excess pump vibration; increase energy consumption and operating costs; safety hazards for the working staff.					x	16	32	128
			T7 _{3_47}	Vibration of the pump	Alignment issues, incorrect installation, even overuse of pumps	1	2	Periodic maintenance.	Noise, increased wear on moving parts, damage to the internal parts.					x	4	4	8
			T7 _{3_48}	Corrosion of some parts of the pump	Poor material, ageing	1	3	Periodic maintenance.	Leakage in the pumps and spillage of sludge.	x	x	x	x		8	8	24
			T7 _{3_49}	Pump out of order	Ageing/defective pump	2	1	Periodic maintenance.	Sludge recirculation does not occur.		x				16	32	32
			T7 _{3_50}	Leakage	Poor material	1	3	Periodic maintenance.	Spillage of sludge.	x	x	x	x		8	8	24
			T7 _{3_51}	Electrical issues	Sudden power surges	3	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the pump can work properly.						1	3	3
		Valve in the return sludge pipe, after the pump	T7 _{3_52}	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Sludge overflow into the environment.	x	x	x	x		4	8	16
			T7 _{3_53}	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Sludge is not properly sent to the bioreactor leading to an insufficient removal of the organic matter.		x				16	32	96
			T7 _{3_54}	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, a sludge flow rate higher than the expected one is fed to the bioreactor which could lead to excessive suspended solids load to the secondary sedimentation unit.						16	32	128
			T7 _{3_55}			2	4	Periodic maintenance.	If the valve is blocked closed, then recirculation does not occur, causing an insufficient removal of carbonaceous and nitrogenous substances.		x				16	32	128
			T7 _{3_56}	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Suspended solids sensor in the recirculation pipe	T7 _{3_57}	Suspended solids sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	4	2	Periodic maintenance.	Failure to measure suspended solids concentration. If the measured suspended solids concentration in the return sludge is higher than the real one, insufficient removal of the organic matter might occur.						16	64	128
			T7 _{3_58}			4	2	Periodic maintenance.	Failure to measure suspended solids concentration. If the measured concentration of suspended solids in the return sludge is lower than the real one, a higher secondary sludge flow rate is returned to the bioreactor, and an excessive suspended solids load might be fed to the secondary clarifier.						16	64	128
			T7 _{3_59}	Suspended solids sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Return sludge flow rate measurement device	T7 _{3_60}	Flow rate measurement malfunctioning	Air entered during maintenance operations or gases produced during degradation processes in the bioreactor	3	3	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	The values measured by the flow rate sensors are not correct. It is not possible to know the real flow rate fed to the biological step, but there is a flow rate sensor at the plant entrance and the working staff know the flow rate.						8	24	72
			T7 _{3_61}	Flow rate measurement device breakage and malfunctioning	End-of-life, defective device	3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If it is higher than the desired value, there is a higher biomass concentration in the bioreactor with a potentially higher solid loading rate to the secondary clarifier.						16	48	96
			T7 _{3_62}			3	2	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding.	Failure to provide the right flow rate. If it is lower, there is a lower oxidation rate and lower removal of organic and nitrogenous matter.		x				16	48	96
			T7 _{3_63}	Flow rate measurement device does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2

Subsystem	Compartment or Equipment	Component	Identifier	Failure mode	Causes	Likelihood of occurrence, S _L	Ease of detection, S _D	Existing corrective actions	Consequences	HAZARD for the environment		HAZARD for the human health			Magnitude of consequences, S _M	Risk R	RPN
SECONDARY SEDIMENTATION (T8)		Feeding characteristics	T8_1	Bad settling sludge (light sludge) in the feeding	Lower nutrients or oxygen supplied in the aerobic tank, development of voluminous sludge flocs due to filamentous bacteria	3	2	Addition of chemicals toxic for the filamentous bacteria, addition of flocculants to make the sludge flocs heavier.	Bulking.						8	24	48
			T8_2		Lower nutrients supplied in the bioreactor, particularly in low-load plants	3	2	Check supplied air to reduce the generation of foam, break down foam with sprayed water, remove foam by addition of flocculant, chlorine spray.	Foaming.						8	24	48
			T8_3	Lower sludge flow rate withdrawn from the secondary sedimentation tank	Prolonged residence time of the settled sludge in the tank	3	2	The return sludge flow rate may be incremented, the oxygen concentration in the aerobic tank must be lowered, the denitrification process in the tank must be checked.	Rising, possible higher concentration of suspended solids in the secondary effluent.						8	24	48
			T8_4	Very light and small sludge flocs	Lower nutrients supplied in the bioreactor, particularly in low-load plants	3	2	A filtration step is able to retain them.	Pin point.						4	12	24
			T8_5	Higher suspended solids load fed	Higher suspended solids concentrations in the aeration tank and/or higher flow rate sent to the secondary settler	3	2	Remote control alert.	If the solid flow exceeds the maximum allowed for the sedimentation, the sludge will not settle and the final effluent will contain a high(er) concentration of suspended solids.						16	48	96
			T8_6	Higher flow rate	Rain events, infiltration contribution, wrong flow rate measurement by the sensors equipped in the systems upstream	3	2	Remote control alert.	Sludge escapes with the secondary effluent (higher suspended solids concentrations in the effluent).						16	48	96
		Sludge level sensor	T8_7	Sludge level sensor breakage/malfunctioning	End-of-life, uncalibrated probe	3	2	Periodic maintenance.	Sludge may accumulate on the bottom, worse sedimentation performance.						8	24	48
			T8_8	Sludge level sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Sludge bottom scraper	T8_9	Sludge bottom scraper breakage/malfunctioning	End-of-life	2	4	Periodic maintenance.	Sludge may accumulate on the bottom, worse sedimentation performance.						8	16	64
			T8_10	Sludge bottom scraper does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the scraper can work properly.						1	2	2
		Secondary, excess return sludge draw off pipes	T8_11	Pipe leakage	Ageing/defective piping	1	4	Periodic maintenance.	Failure to transport the sludge to the bioreactor or to the sludge treatment train. Sludge outflow into the environment.	x	x	x	x		8	8	32
			T8_12	Pipe obstruction	Obstacles in the pipe	2	2	Periodic maintenance.	Too low or no sludge flow in the pipe, failure to transport the sludge to the bioreactor or the sludge treatment train.						8	16	32
		Valve in the secondary sludge draw off	T8_13	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Sludge outflow into the environment.	x	x	x	x		4	8	16
			T8_14	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Sludge is not correctly drawn off.						8	16	48
			T8_15	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance regulation of the valves in the return sludge pipe and in the excess sludge pipe.	If the valve is blocked open, a higher amount of sludge is drawn off. Potential insufficient amount of return sludge to the bioreactor.		x				16	32	128
			T8_16			2	4	Periodic maintenance.	If the valve is blocked closed then no sludge is drawn off. Longer residence time in the tank, potential bulking, insufficient returned sludge flow rate.		x				16	32	128
			T8_17	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Valve in the excess sludge pipe	T8_18	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Secondary sludge outflow into the environment.	x	x	x	x		4	8	16
			T8_19	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Sludge is not correctly drawn off.						8	16	48
			T8_20	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open then a higher amount of sludge is sent to the sludge treatment train.						8	16	64
			T8_21			2	4	Periodic maintenance.	If the valve is blocked closed then, no sludge is sent to the sludge treatment.						8	16	64
			T8_22	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Grease skimmer	T8_23	Grease skimmer breakage	Ageing	1	4	Periodic maintenance.	If foam is present, it may pass through the treatment and go to the following one.						8	8	32

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RAPID SAND FILTRATION (T9)		Influent suspended solids concentrations sensors	T9_1	Suspended solids sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	4	2	Periodic maintenance.	Failure to measure suspended solids concentration. If the measured values are lower than the real ones, there may be more rapid clogging than expected.					4	16	32	
			T9_2			4	2	Periodic maintenance.	Failure to measure suspended solids concentration. If the measured values are higher than the real ones, there are no serious effects.					1	4	8	
			T9_3	Suspended solids sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.					1	2	2	
		Inlet line valve	T9_4	Valve leakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow into the environment.	x	x	x	x		4	4	8
			T9_5	Valve breakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow, if the filter is in operation is not correctly fed. Maintenance is required and during this phase, the other lines will receive the whole feeding.	x	x	x	x		8	8	16
			T9_6	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, the flow rate might be higher than the designed one. The effects are on the 1) effluent quality: deterioration due to erosion and dragging of filling particles, and 2) filling: compacting, rapid clogging, erosion and shortening of its lifetime.		x		x		16	32	128
			T9_7			2	4	Periodic maintenance.	If the valve is blocked closed, the flow is not fed to the filter. The other filters will receive the whole feeding.					8	16	64	
			T9_8	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.					1	2	2	
		Differential pressure transmitter	T9_9	Malfunctioning	Ageing/defective device	2	3	Periodic maintenance.	If the measured pressure differential is higher than the real one, the filter backwashing will start in advance and there may be more frequent backwashing, with higher energy costs and waste of (backwashing) water.					8	16	48	
			T9_10			2	3	Periodic maintenance.	If the measured differential pressure is lower than the real one, the backwashing will start later leading to accumulation of the feeding water on the filter surface, worsening of the effluent quality and filling material deterioration.		x		x		16	32	96
			T9_11	Breakage	Ageing/defective device	2	3	Periodic maintenance.	Accumulation of feeding water on the filter surface, filter clogging, worsening of the final effluent, filling material deterioration.		x		x		4	8	24
		Blower	T9_12	Motor breakage	Bearing malfunctioning	1	1	Periodic maintenance.	Noise, air is not supplied for the cleaning phase, extraordinary maintenance.				x	8	8	8	
			T9_13	Motor overheating	Friction between moving parts	2	3	Periodic maintenance.	Malfunctioning, extraordinary maintenance.					8	16	48	
			T9_14	Motor out of order	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the blower can work properly.					1	2	2	
			T9_15	Dirty air filter	Dirty air supplied	2	2	Periodic maintenance.	Motor overheating.					8	16	32	
			T9_16	Excess of the air supplied	Malfunctioning in air flow rate measurement and control, human error	2	3	On-site inspection, remote control.	Dragging of the filling material (with the retained solids).					8	16	48	
			T9_17	Deficiency of the air supplied	Malfunctioning in air flow rate measurement and control, human error	2	3	On-site inspection, remote control.	Incomplete backwashing, rapid clogging requiring more frequent backwashing leading to higher energy costs and larger volume of water for the backwashing.					8	16	48	
		Backwash timer	T9_18	Timer breakage	Ageing/defective timer	2	2	Periodic maintenance.	The filter is not backwashed as planned. It will clog and water fed will accumulate on the filter surface.					16	32	64	
			T9_19	Timer out of order	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the timer can work properly.					1	2	2	
		Backwash pipe	T9_20	Flow rate sensor breakage/malfunctioning	End-of-life, uncalibrated sensor	3	2	Periodic maintenance.	Failure to measure the real flow rate. If the measured flow rate is higher then the real one, an excessive expansion of the filter and medium loss may happen.					8	24	48	
			T9_21			3	2	Periodic maintenance.	Failure to measure the real flow rate. If the measured flow rate is lower then the real one, the filling material will not be cleaned as required and more frequent backwashing will be necessary with increasing energy costs and waste of (backwashing) water.					8	24	48	
			T9_22	Flow rate sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a. generator which can immediately cope with this situation and the sensor can work properly.					1	2	2	
			T9_23	Pipe obstruction	Obstacles in the pipe	2	2	Periodic maintenance.	Too low or no backwashing water is fed to the filter. The backwashing is not complete/does not occur.					16	32	64	
			T9_24	Pipe leakage	Ageing/poor material	2	1	Periodic maintenance.	Loss of backwashing water. Backwashing is incomplete or does not occur.					16	32	32	
		Valve in the backwash pipe, before the pump	T9_25	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Water outflow into the environment.					4	8	16	
			T9_26	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Water is not properly sent to the backwash pump.					4	8	24	
			T9_27	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, too high a flow is fed to the backwash pump. Higher energy consumption (higher costs).					8	16	64	
			T9_28			2	4	Periodic maintenance.	If the valve is blocked closed, no flow goes to the backwash pump. The filter will not be cleaned and more frequent backwashing will be necessary with increasing energy costs and waste of (backwashing) water.					16	32	128	
			T9_29	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.					1	2	2	

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RAPID SAND FILTRATION (T9)		Backwash pump	T9_30	Pump blockage	Ageing, poor material, obstructions in the flow	3	1	Periodic maintenance.	Too high water flow rate fed for the backwashing will cause an excessive expansion of the filter and medium loss.						16	48	48
			T9_31			3	1	Periodic maintenance.	Too low backwash water flow rate to the filter will not clean the filling material and more frequent backwashing will be necessary with increasing energy costs.						16	48	48
			T9_32	Worn out parts of the pump	Bad quality of the material	1	3	Periodic maintenance.	The pumps will not work or will not work as requested.						8	8	24
			T9_33	Pump overheating/Thermal blockage	Insufficient lubrication or foreign objects blocking the cooling fins	2	4	Periodic maintenance.	Pump malfunctioning, including noise; damage to the pump seals; pump life shortening; excess pump vibration; increase energy consumption and operating costs; safety hazards for the working staff.					x	16	32	128
			T9_34	Vibration of the pump	Alignment issues, incorrect installation, even overuse of pumps	1	2	Periodic maintenance.	Noise, increased wear on moving parts, damage to the internal parts.					x	4	4	8
			T9_35	Corrosion of some parts of the pump	Poor material, ageing	1	3	Periodic maintenance.	Leakage in the pump and spillage of water.						8	8	24
			T9_36	Pump out of order	Ageing/defective pump	2	1	Periodic maintenance.	Backwashing water is not supplied to the filter, backwashing does not occur.						16	32	32
			T9_37	Leakage	Poor material	1	3	Periodic maintenance.	Spillage of water.						8	8	24
			T9_38	Electrical issues	Sudden power surges	3	1	A generator is available to guarantee operation.	The pump would not work, but generally there is a generator to deal with these situations.						1	3	3
		Valve in the backwash pipe, after the pump	T9_39	Valve leakage	Ageing/defective valve	2	2	Periodic maintenance.	Water overflow into the environment.						4	8	16
			T9_40	Valve breakage	Ageing/defective valve	2	3	Periodic maintenance.	Water is not properly sent to the backwashing, water outflows into the environment.						8	16	48
			T9_41	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, too high flow is fed for the backwashing causing an excessive expansion of the filter and medium loss.						16	32	128
			T9_42			2	4	Periodic maintenance.	If the valve is blocked closed, no flow is fed for the backwashing. The filter will not be cleaned and more frequent backwashing will be necessary with increasing energy costs and amount of (backwashing) water.						16	32	128
			T9_43	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Nozzles	T9_44	Clogging of the outlet nozzles	Obstruction due to small particles of the filling material	2	5	Periodic maintenance.	Too low backwashing water is fed to the filter. An uneven distribution of the water and air occurs and the backwashing is not efficient.						8	16	80
			T9_45	Breakage	Ageing/poor material	1	3	Periodic maintenance.	Uneven distribution of water and air during the backwashing phase. Broken nozzles must be replaced.						16	16	48
		Outlet line valve	T9_46	Valve leakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Effluent outflow into the environment.	x	x	x	x		4	4	8
			T9_47	Valve breakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Effluent outflow, the following disinfection unit is not correctly fed.	x	x	x	x		8	8	16
			T9_48	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, the flow rate might be higher than the designed one. The following disinfection might not be completed.	x	x	x	x		16	32	128
			T9_49			2	4	Periodic maintenance.	If the valve is blocked closed, the flow is not fed to the disinfection unit and disinfection does not occur.	x	x	x	x		16	32	128
			T9_50	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Filling material	T9_51	Saturated filling material	Higher content than expected in the influent	3	3	Scheduled backwashing can clean the filter.	The effluent does not fulfill the standards for release or reuse.	x	x	x	x		16	48	144

Subsystem	Compartment or Equipment	Component	Identifier	Failure mode	Causes	Likelihood of occurrence, S _L	Ease of detection, S _D	Existing corrective actions	Consequences	HAZARD for the environment		HAZARD for the human health			Magnitude of consequences, S _M	Risk R	RPN
UV DISINFECTION (T10)		Inlet line valve	T10_1	Valve leakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow into the environment.	x	x	x	x		4	4	8
			T10_2	Valve breakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow, the UV unit is not correctly fed.	x	x	x	x		8	8	16
			T10_3	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, the flow rate might be higher than the designed one. Disinfection might not be completed.	x		x			16	32	128
			T10_4			2	4	Periodic maintenance.	If the valve is blocked closed, the flow is not fed to the UV unit and UV disinfection does not occur.	x		x			16	32	128
			T10_5	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Influent flow characteristics	T10_6	Higher turbidity (=lower transmittance)	Lower removal efficiency of suspended solids in the filtration step, deterioration of the filling material	4	1	Periodic maintenance.	Increased lamp fouling, lower disinfection efficiency, potential formation of transformation products.		x		x		16	64	64
			T10_7	Higher flow rate than the designed one	Rain event, human error	2	1	The flow rate exceeding the max value must bypass the step.	Lower disinfection efficiency as the UV dose is kept constant (difficult to increase the UV intensity).	x		x			16	32	32
			T10_8	Lower flow rate than the designed one	Flow variability	4	1	Remote control.	No effect on disinfection. Overheating of the lamps if they are not completely submerged in the water.						8	32	32
		Flow rate sensor	T10_9	Flow rate sensor malfunctioning	Air may be entered during maintenance operations	3	3	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding to the treatment train.	The values measured by the flow rate sensors are not correct. It is not possible to know the real flow rate fed to the UV reactor, but there is a flow rate sensor at the biological treatment and the working staff know the flow rate.						8	24	72
			T10_10	Flow rate sensor breakage/malfunctioning	End-of-life, defective device	3	2	Periodic maintenance.	Failure to measure the real flow rate. 1) If real flow rate > designed flow rate > measured one or 2) If real flow rate > measured flow rate > designed flow rate --> insufficient disinfection.	x		x			16	48	96
			T10_11			3	2	Periodic maintenance.	Failure to measure the real flow rate. 1) If designed flow rate > real flow rate > measured one or 2) If designed flow rate > measured one > real flow rate --> no effect on disinfection.						1	3	6
			T10_12			3	2	Periodic maintenance.	Failure to measure the real flow rate. 1) If measured flow rate > designed flow rate > real flow rate economic issues due to bypassed water not necessary. 2) If measured flow rate > real flow rate > designed flow rate, economic issues due to an excess of bypassed water.						8	24	48
			T10_13	Flow rate sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Influent turbidity sensor	T10_14	Turbidity sensor breakage/malfunctioning	End-of-life, fouling, uncalibrated probe	4	2	Periodic maintenance.	Failure to measure the real turbidity. If the measured value is lower than the real one, the UV disinfection can produce an effluent which does not comply with the legal limits due to the shielding effect of suspended solids.	x		x			16	64	128
			T10_15			4	2	Periodic maintenance.	Failure to measure the real turbidity. If the measured value is higher than the real one, the operator might decide not to send the disinfected water for reuse, with economic losses as it is not necessary.	x	x	x	x		8	32	64
			T10_16	Turbidity sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Lamps	T10_17	Reduction in the lamp intensity	Lamp fouling	5	4	Periodic maintenance.	Lower disinfection efficiency.	x		x			16	80	320
			T10_18		Lamp ageing	4	4	Periodic maintenance.	Lower disinfection efficiency.	x		x			16	64	256
			T10_19	Lamp overheating	Lamp insulation due to deposit on its surface, increment in the supplied current, lower water flow rate to the UV unit	2	2	Periodic maintenance.	Lower disinfection efficiency, shortening of the lamp lifespan.	x		x			16	32	64
			T10_20	Lamp is off	Interruption of electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the lamp can work properly.						1	2	2
			T10_21	UV intensity sensor breakage/malfunctioning	End-of-life, uncalibrated device	3	2	Periodic maintenance.	Failure to measure the real UV intensity. 1) If real UV intensity > designed one > measured one or 2) If real UV intensity > measured one > designed one or 3) If measured one > real one > designed one --> disinfection is guaranteed.						1	3	6
			T10_22			3	2	Periodic maintenance.	Failure to measure the real UV intensity. 1) If designed one > real one > measured one or 2) If designed one > measured one > real one or 3) If measured one > designed one > real one, --> insufficient disinfection.	x		x			16	48	96
			T10_23	UV sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Automatic mechanical cleaning system	T10_24	Cleaning system malfunctioning	Dirty collars unable to remove deposits on the lamp surface	3	4	Periodic maintenance.	Lower UV irradiation, lower disinfection efficiency.	x		x			16	48	192
			T10_25		Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the electrical power distribution board can work properly.						1	2	2
			T10_26	Cleaning system breakage	Ageing, collar breakage	2	4	Periodic maintenance.	Lamps are not cleaned, insufficient disinfection.	x		x			16	32	128
		Electrical power distribution board	T10_27	Breakage	Internal problem	3	2	Periodic maintenance.	UV step does not work.	x		x			16	48	96
			T10_28		Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the electrical power distribution board can work properly.						1	2	2

Subsystem	Compartment or Equipment	Component	Identifier	Failure mode	Causes	Likelihood of occurrence, S _o	Ease of detection, S _d	Existing corrective actions	Consequences	HAZARD for the environment		HAZARD for the human health		Magnitude of consequences, S _M	Risk R	RPN	
CHLORINATION (for emergency situations) (T11)	Chemical tank	Chemical tank (disinfectant, NaClO)	T11_1_1	Different chemical	Different supplier, human error	1	5	Accurate control with the supplier, updating of the technical datasheet.	If the added amount is not sufficient for the desired level of disinfection, the final effluent will not meet the legal limits.	x	x	x	x		16	16	80
			T11_1_2			1	5	Accurate control with the supplier, updating of the technical datasheet.	Excess (waste) of chemical added. Higher costs for the excess of chemicals. Potential formation of disinfection byproducts.		x		x		16	16	80
			T11_1_3	Different concentration of chemical in the supplied solution	Different supplier, human error	3	5	Accurate control with the supplier and at the delivery.	Failure to provide the requested dosage/dose of disinfectant. Insufficient disinfection, final effluent not meeting the legal limits.	x		x			16	48	240
			T11_1_4			3	5	Accurate control with the supplier and at the point of delivery.	Failure to provide the requested dosage/dose of disinfectant. Excess (waste) of chemical added. Higher costs. Potential formation of disinfection byproducts.		x		x		16	48	240
			T11_1_5	No disinfectant available	Human error, delay in the delivery	2	2	Level sensor, remote control.	No disinfection occurs.	x		x			16	32	64
			T11_1_6	Tank leakage/breakage	Ageing/defective tank	2	1	Containment tank for potential losses of material.	Loss of disinfectant, environmental and human health risks, economic losses.		x		x		16	32	32
		Dosage system/valve	T11_1_7	Valve leakage	Ageing/defective valve	1	2	Periodic maintenance.	Chemical outflow, environmental and human health risk.		x		x		16	16	32
			T11_1_8	Valve breakage	End of life	3	1	Periodic maintenance.	Loss of disinfectant, extraordinary maintenance.		x		x		8	24	24
			T11_1_9	Valve blockage	Ageing/defective valve	2	3	Remote control, periodic maintenance.	If the valve is blocked open, an excess of disinfectant might be added. There may be the potential formation of disinfectant byproduct. Higher costs.		x		x		16	32	96
			T11_1_10			2	3	Remote control, periodic maintenance.	If the valve is blocked closed, no disinfectant is added. No disinfection.	x		x		16	32	96	
			T11_1_11	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Chlorine detection system (tank storage room)	T11_1_12	Chlorine sensor breakage/malfunctioning	End-of-life, uncalibrated device	3	2	Periodic maintenance.	Higher concentration measured than the real one, alarm might go on when not necessary.						2	6	12
			T11_1_13			3	2	Periodic maintenance.	Lower concentration measured than the real one. Alarm does not go on when necessary.	x		x			16	48	96
			T11_1_14	Chlorine sensor does not work	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2
		Pipe	T11_1_15	Pipe leakage	Ageing/defective pipe/corrosion	2	3	Periodic maintenance, remote control.	Failure to transport the disinfectant to the disinfection unit. Environmental and human health risks.	x	x	x	x		16	32	96
			T11_1_16	Pipe obstruction	Obstacles in the pipe	2	2	Periodic maintenance.	Too low or no disinfectant is fed to the tank. The disinfection is not complete/does not occur.	x		x			16	32	64
	Chlorine contact basin	Inlet line valve	T11_2_1	Valve leakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow into the environment.	x	x	x	x		4	4	8
			T11_2_2	Valve breakage	Ageing/defective valve/overheating	1	2	Periodic maintenance.	Water outflow, the basin is not correctly fed.	x	x	x	x		8	8	16
			T11_2_3	Valve blockage	Ageing/defective valve	2	4	Periodic maintenance.	If the valve is blocked open, the flow rate might be higher than the designed one. Disinfection might not be completed.	x		x			16	32	128
			T11_2_4			2	4	Periodic maintenance.	If the valve is blocked closed, the flow is not fed to the basin and chemical disinfection does not occur.	x		x			16	32	128
			T11_2_5	Valve fails to open	Electricity interruption	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the valve can work properly.						1	2	2
		Influent flow characteristics	T11_2_6	Higher flow rate	Strong rain event	2	2	Periodic maintenance.	Insufficient dose of disinfectant, insufficient disinfection efficiency.	x		x			16	32	64
			T11_2_7	Presence of competitor compounds	Lower removal efficiency in the previous step	4	1	Periodic maintenance.	Lower disinfection efficiency, formation of transformation products.	x	x	x	x		16	64	64
		Flow rate sensor	T11_2_8	Flow rate sensor malfunctioning	Air may be entered during maintenance operations	3	3	Alarms on PLC. The control system can exclude the values provided by the instrument guaranteeing the continuity of the feeding to the treatment train.	The values measured by the flow rate sensors are not correct. It is not possible to know the real flow rate fed to the chlorination, but there is a flow rate sensor at the biological treatment and the working staff know the flow rate.						8	24	72
			T11_2_9	Flow rate sensor breakage/malfunctioning	End-of-life, uncalibrated device	3	2	Periodic maintenance.	Higher flow rate than the designed one, lower residence time in the disinfection unit, lower disinfection efficiency. Microbiological parameters might not meet the legal limits.	x		x			16	48	96
			T11_2_10			3	2	Periodic maintenance.	Lower flow rate than the real one, no effect on the disinfection performance.						1	3	6
			T11_2_11	Flow rate sensor does not work	Electricity interruption	2	3	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	6
EFFLUENT (T12)		Multiparametric sensor	T12_1	Multiparametric sensor fouling	Substances present in the influent	2	4	Periodic maintenance.	Unreliable measurements.						16	32	128
			T12_2	Multiparametric sensor breakage	Debris and bulky materials in the influent	1	1	Periodic maintenance/replacement.	Measurements are not available and the control of the effluent is not possible.	x	x	x	x		4	4	4
			T12_3	Multiparametric sensor does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the sensor can work properly.						1	2	2

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THE WHOLE SYSTEM (miscellaneous issues) (T13)		Pipe conveying wastewater from one step to another	T12_1	Pipe leakage	Ageing/defective pipe	1	3	Periodic maintenance.	Failure to transport the water to the next step. (Under treatment) water outflow into the environment.	x	x	x	x		4	4	12
			T12_2	Pipe obstruction	Obstacles in the pipe	2	2	Periodic maintenance.	Too low or no water flow in the pipe, failure to transport the water to the next step.						16	32	64
		Any electrical component in the system	T12_3	Out of service	Lightning	2	2	A generator is available to guarantee operation.	Need to replace some components if the damage is serious.						8	16	32
		Equipment room	T12_4	Flooding	Strong rain event	2	2	Slit channels for water drainage into the sewer system.	Damage to the equipment installed in the room, economic issues, risk for the workers.	x	x	x	x		16	32	64
		Mechanical equipment (pump, blower, compressor)	T12_5	Overheating	Extremely high ambient temperature	3	2	Located in dedicated and refrigerated rooms, submerged pumps.	Damage to the equipment, economic issues, risk for the workers.					x	16	48	96
		PLC	T12_6	Control system breakage/malfunctioning	End-of-life	3	2	Periodic maintenance.	Inaccurate monitoring.	x	x	x	x		16	48	96
			T12_7	Control system does not work	No electricity	2	1	A generator is available to guarantee operation.	No effect as there is a generator which can immediately cope with this situation and the PLC can work properly.						1	2	2
			T12_8	Corrosion of metallic components	Acid gases in the room due to the presence of chemicals stored nearby (e.g., NaClO stored for emergency disinfection or other needs)	3	1	A generator is available to guarantee operation.	The PLC is out of order and requires immediate assistance.						1	3	3
		PLC/sensors	T12_9	"Err" appearing on sensor display	Electrical disconnections and problems	1	5	The software logic can by-pass the instrument guaranteeing the continuity on the operation (feeding, aeration, recirculation, etc.).	Alarms on PLC, request for electrical maintenance, manual management of the biological feeding without this control.	x	x	x	x		16	16	80
		Any subsystem of the WWTP	T12_10	Temporary shutdown	Requested extraordinary maintenance due to relevant failures to subsystems, natural disasters (floods, earthquakes, etc.), relevant accidents (fire, explosion, release)	1	1	More treatment lines can cope with this situation and treat the whole flow rate. In the case of natural disasters, it is difficult to guarantee the continuity in operation.	Depending on the damaged section, the final effluent might not meet the legal limit.	x	x	x	x		16	16	16