Risk assessment

Process	#	Risk Title
Reciept of goods	1	Damages to packages
	2	Ice/Snow
CATHODE (LFP)	3	NMP leakage
Feeding	4	Dusting
Mixing	5	Leakage - see #3 above
Coating	6	NMP recovery system breakdown
Slitting	7	Cutting fails
	8	Dusting
ANODE (HC)	9	
Feeding	10	Dusting / leakage
Mixing	11	Dusting / leakage
Calendering	12	Dusting
Slitting	13	-

Prelithiation	14	Breakdown of vapor recover unit (VRU)
	15	Leakage in system
	16	Spills (larger than 1 dm3)
	17	Water contamination
	18	Fire/explosion
	19	Filter becomes full
Die-cutting	20	-
Abandonnment	21	-
CATHODE (AC)	22	-
Feeding	23	Same risk as #10 for HC line
Mixing	24	Same risk as #11 for HC line
Coating	25	Particles/dust in drying stream. Dust from e.g. SBR is harmful for aquatic life with long lasting effects. Dust can settle in condensation of water in heat exchanger and exhausted with exiting water to sewage plant.
Calendering	26	Same risk as #12 for HC line
ALL	27	-
Stacking	28	-
Packaging/Degassing	29	Degassing release unexpected compounds

Packaging	30	-
Formation/Capacity/DCR	31	-
DSF	32	-
Visual inspection	33	-
Packing	34	-
Storage	35	Fire in cells
Transportation	36	Road accidents
Cleaning	37	Accidental release to drain
Language/communication	38	Faulty marking on containers
Radioactive sources	39	Damages to housing/container
Security systems	40	Sabotage/theft of hazardous materials

Electrolyte	41	Electrolyte HF evolution
Hazardous waste storage	42	Fire in storage
	43	Leakage in storage
	44	Explosion in storage
Planned development	45	Phasing out of NMP
	46	Increase reuse of electrolyte
	47	Supplier stops accepting returning chemicals
	48	Separator reuse not possible
	49	Separator from waste materials not possible

Filter dispsal	50	AC-filters
	51	HF-filters
	52	Dust filters

Date: 14.04.2021

Description /Cause	Impact	Probability
Collisions, tipping over, accidental opening of material	Moderate	Possible
Spills in snow/ice/sand	Minor	Possible
Leakage of NMP systems	Minor	Possible
Emissions of dust from room	Marginal	Almost certain
NMP recovery system not operational due to e.g. leaks or breaks of cooling units.	Minor	Unlikely
	Marginal	Unlikely
Larger particle dust	Marginal	Likely
Dusting or leakage	Marginal	Unlikely
Dusting or leakage	Marginal	Unlikely
Larger particle dust	Marginal	Likely

Cooling water shortage, leaks, faulty operation or similar causes that affect the efficiency of the VRU	Moderate	Unlikely
Leakage of solvents and gasses	Minor	Possible
Tipping over of or damages to barrels/connections/pipes	Minor	Unlikely
Water enters same volumes as electrolyte	Moderate	Rare
Ingintion sources present	Moderate	Possible
Break-through of emissions	Major	Almost certain
Particels are swept away with drying air	Marginal	Likely
Changes to formulation in chemistry may give rise to unexpected degassing compounds or scewed composition of analyzed gasses	Minor	Likely

Fire in storage of cells. Releases unknown fire gasses to the surrounding. (gasses from carbon-carbon cells, as in this case, is not well studied in the literature. Gasses from e.g. NMC or LFP-carbon cells are, and constitute a range of byproducts.). Risk for personal health due to smoke inhalation.	Moderate	Unlikely
Collisions or single accidents, contamination of e.g. water with leaking chemicals. Localized effect dependent on nature of transported chemical and amounts.	Major	Unlikely
Accidental release to drain instead of intended collection method	Minor	Possible
Materials stored in e.g. barrels not marked according to standards. Increase risk in handling, measures in case of accidents, and waste handling measures.	Minor	Possible
Damages to the housing/container of the radioactive source, leading to beta- or gamma-ray leakage	Marginal	Rare
Sabotage/theft of hazardous materials with ill intent	Moderate	Unlikely

In contact with water, HF is formed. Highest risk in connection to fire fighting. Water spray binds HF but produces acidic conditions. Potential release of HF per barrel (200L) of electrolyte equals approximately 12 kg (0.5M salt concentration) if all salt is converted to HF. HF lifetime in air is very short lived (<0.25-1 day) depending on weather - but poses a direct risk for rescue personell/nearby persons.	Moderate	Unlikely
Fire in hazardous waste storage room can lead to substantial amounts of material burning, giving of e.g. HF, NMP and electrolyte vapors, and other toxic chemicals (NaOx, POx, NOx, BOx, peroxides, CO)	Major	Possible
Barrels are damaged and leaks its' content which spills into the surrounding - possibly entering the ground	Moderate	Unlikely
Explosion in storage, expelling contents of the containers/causing fire. NMP and electrolyte can form explosive mixture with air.	Moderate	Unlikely
NMP is unable to be phased out or replaced by other solvents	Minor	Unlikely
Higher reuse of electrolyte not possible due to degradation	Minor	Possible
Supplier does revert on accepting returning chemicals (NMP/electrolyte) - material recycling disabled leading to less atractive energy recovery by incineration	Minor	Possible
Not able to decrease separator (plastic) waste	Minor	Unlikely
Separator planned to be produced in cooperation with Ivar from waste plastics, including teflon that Ivar cannot burn	Marginal	Possible

Filters that are saturated need to be handled	Minor	Rare
NaF or KF is formed - solid but toxic, corrosive,	Moderate	Rare
General waste handling	Minor	Rare

Mitigation	Redisual risk (impact)
Depending on what material is released, how much and where. Routines for clean up of spills. Protective clothing for the chemicals to be handle. Ease of access to equipment to deal with spills/exposure. Rapid response reduces further risk substantially. Only transfer liquid goods on hard surfaces, as to minimize environmental leakage and to ease the cleaning by adsorbing materials or wet-vacuum cleaners. Adsorbing material to be safely stored at strategic points with easy access. Used adsorbing materials to be marked and disposed according to waste plan for the relevant chemical.	**Minor**
Do not transport goods over ice/snow - make sure that path is clear before transport	
Sensors to detect NMP - at elevated concentrations, stop or seal of process to assess where leakage is (equipment or faulty transferring), forced ventilation, protective clothing. Container to collect larger leakage in basin acording to regulations.	**Marginal**
Use dust filters in room and for exiting air.	**Marginal**
Stop coating process, ventilate room and await restoration of function. Monitor concentration where workers are to safeguard acceptable occupational exposure levels (OELs), use protective clothing. At too high concentration, have spare full body cover with overpressurized ox-mask to enable work in area that is too contaminated. Evacuate workers not equpied with proper protection for the current level of exposure. Warning lights/siren or other measure of alert should be in place. Small amounts of NMP to be ventilated to atmosphere from room - low overall concentrations based on amount in oven at any given time - possible to increase air flow to maintain acceptable transient emission levels. Reroute airflow from coater oven through active carbon filters to further reduce emissions.	**Marginal**
Increased waste - handle acording to protocol. Non hazardous.	**Marginal**
Larger particles collected by filters and regular maintainance	**Marginal**
Leakage of tanks/containers - spills (mainly SBR) should not enter drains. Do not place drains where leakage might occur.	**Marginal**
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Larger particles collected by filters and regular maintainance	**Marginal**

Seal all chambers (they are vacuum tight and can be sealed/flushed induvidially). With the chambers sealed, the flow is forced through the active carbon (AC) filters at an acceptable rate (within filter specifications). Increased usage of AC due to increased emissions - lower lifetime of filter. Secondary risk of hotspots in filters due to high concentration discharge to filters (exothermal reaction) - mitigated by mixing the flow with other inptus to filter (preferably pure nitrogen to reduce hot-spot devlopment and risk of ignition). In case of breaks inside - increase ventilation through unwinding machine output (goes to AC filter) to handle emissions inside pre-lithiation room.	**Marginal**
Use sensors to protect workers and detect emissions. Close valves to mitigate leakage and assess situation. Force ventilation through AC filters to mitigate environmental emissions.	**Marginal**
Basin to collect spills at containers. Adsorbing materials to collect materials. No drains to water. Spills in container is pumped to barrel and stored according to material/chemicals	**Marginal**
Results in evolution of e.g. POF3 and HF. Emission levels can be fairly high. Force ventilation through NaCO3/KCO3 coated active carbon filter to reduce acidic gas emissions. Use alternative fire fighting measures (gas)	**Marginal**
Use antistatic shoes and make sure all equipment is spark free etc. Use of extiguishing gas. Seal all valts if fire is detected. Sensors to avoid high concentrations that is hazardous for humans (which also means that they are below explosion limits for the compounds). Health issues onset at levels of 3-30 mg/m3 depending on solvent, lower explosive limits are on order of 1-2% (10 000 ppm). In case of major fire, release of HF is the main consern - small amount is expected from prelithiation or electrolyte rooms, does not pose a large risk for the surrounding area unless very unfavorable wind conditions.	**Minor**
Sensor between filters in series, when one is full, that one is changed, the second filter adsorbs remaining emissions	**Minor**
Particle filter on drain of heat exanger. Low volumes (ca 100 m3/year) expected. Low flowrates allows very efficient filtration units at low cost and infrequent replacement. Evaluate water stream post-filter - if additional species are present - store this water in buffer tank and use for cleaning.	**Marginal**
Changes in composition with maintained products most likely, with non or marginal impact. Production of more complex molecules in larger volumes with higher environmental impact unlikely as degassing products. Filtered to AC unit for mitigation - especially efficient for more complex molecules.	**Marginal**

Sprinkling of cells to reduce risk of further fire or fire spread while awaiting fire fighters. Notification/warning to surrounding area to close ventilation, doors and windows.	**Minor**
Partly outside of Beyonder control - in control of logistic firm. Goods in: Ensure transport suppliers have the neccessary training and awareness of tranportation of dangerous good. Goods out: Same as goods in and provide suppliers with infromation on goods tranported and waste handling in case of accidents. Consider an extended emergency response to provide assistance n the case of a 3rd party spill. Possible to reduce amounts per shipment to avoid larger contaminations in case of accidents. Proper packaging and sealing to avoid leakage even in case of accident - especially that the sealing of containers shall prevent leakage even if upside down. The most potent chemicals are the liquid hazardous chemicals - which are biodegradable and non-bioaccumulative - no long term/permanent effects expected.	**Moderate**
Routines, cleaning procedures, and training. Modes of cleaning. All cleaning water collected and transported to treatment facility.	**Minor**
Have pre-printed information tags and hazard pictographics for stations where waste is collected. Attach before filling/collecting waste. Have second tag for more individual/specific information - e.g. date, volume/mass, lot number/batch, notes from production etc.	**Minor**
Do not transport goods over the housing. Beta-rays have exceedingly short reach (some cm in air). No environmental or external impact unless the radioactive material itself is released.	**Marginal**
Monitoring of pilot plant and storage by video monitors in control room. Unlikely as the potential use of the chemicals for ill-intended actions are limited and/or very complicated compared to other sources (less burning energy compared to e.g. diesel, no/low health effect if diluted etc.)	**Moderate**

If started, continue with water spraying to dilute HF content to low acidity/concentration and to avoid HF (boiling point 19.8 degC) going into gaseus phase. Use overpressurized oxygen mask for fire fighting larger amounts of electrolyte. Inform rescue services about the conditions beforehand on type of chemicals as to allow quick and safe fire fighting measures. In case of leakage in cooling system (water coming into the process) - close all vessels to avoid contact between water and salt.	**Marginal**
Sprinkling if fire nearby is posing a spread risk. No smoking within X meters. No vegetation next to storage room to decrease risk of wild fire spreads. Fire fighting measures in storage for quick response. Store combustible material in separated fire cabinets. Ground barrels to avoid sparks. Empty waste room as often as possilbe to decrease amount of materials. Warning systems and routines for sourrounding area to decrease risk of adverse health effects.	**Moderate**
Store liquid chemicals (NMP and electrolyte) in special cabinets that has collection trays/system to take care of spills. Sensors to detect elevated levels in air - also prompting detection of leakage. Depending on collection chamber volume, risk of leakage to surrounding if several leaks occurs simultaneous.	**Marginal**
Design of building to have explosion ventilation upward to decrease risk to surrounding area. Store chemicals separately in cabinets (sectioned within large group of same chemicals), sealed, and ventilated as well as grounded in case that a leak would arise. Mainly a risk at elevated temperatures (at ambient temperatures the vapor pressure of the explosive components are too low to reach explosive mixtures in air by evaporation alone - some type of forced mixing/spraying/etc is required).	**Minor**
Consider work-up scheme for NMP on-site to reduce transports and amounts in storage. Following a pilot study in Germany for small scale NMP-refinery.	**Marginal**
Follow present waste management plan. Continue trial for less use of electrolyte and considerations regarding electrolyte properties on product, health and waste/environment.	**Minor**
Cooperation with Ivar to accomodate routines for energy recovery, and barrel returns.	**Marginal**
If reuse is not possible, recycling of materials or energy recovery is possible. Numbers of reuse unknown - as separators are used in cells for several years/thousands of cycles, no reason to believe reuse should not be possible - possibly a washing/soaking step could be needed.	**Marginal**
Separator that is used in process (and not in final product) does not have as high of a quality concern as the final product. Impact of this task failing is that a further decrease of material use and CO2 impact is not met. Risk that Ivar will not "get rid of" excess waste on thier part.	**Marginal**

Desotec delivers and collects filters, regenerate active carbon for reuse.	**Minor**
May be classified as hazardous waste depending on concentration, declear and handle accordingly.	**Minor**
	Minor

Residual risk (probability)	Risk status				
Possible					
Possible					
Unlikely					
Unlikely					
Unlikely					
Unlikely					
Unlikely					
Unlikely					
Likely					

Unlikely					
Possible					
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Rare					
Unlikely					
Unlikely					
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Rare					
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Possible					
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Rare					
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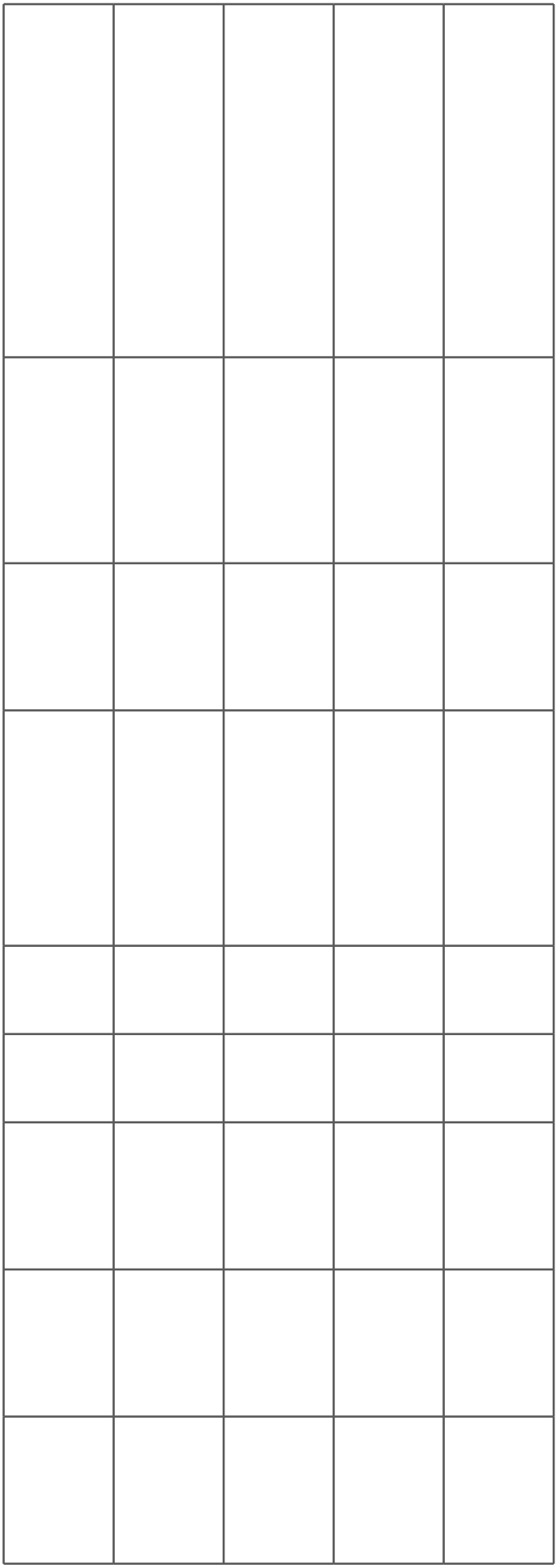
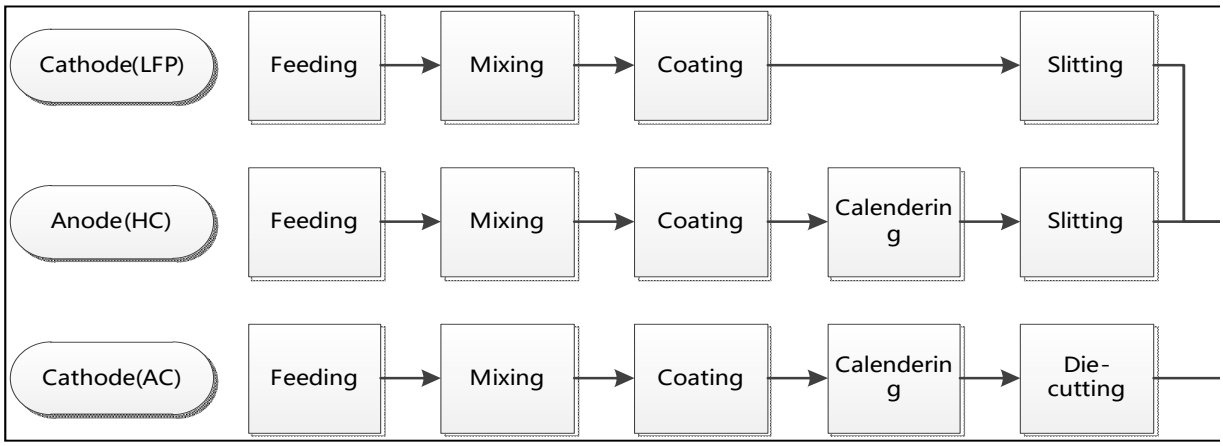
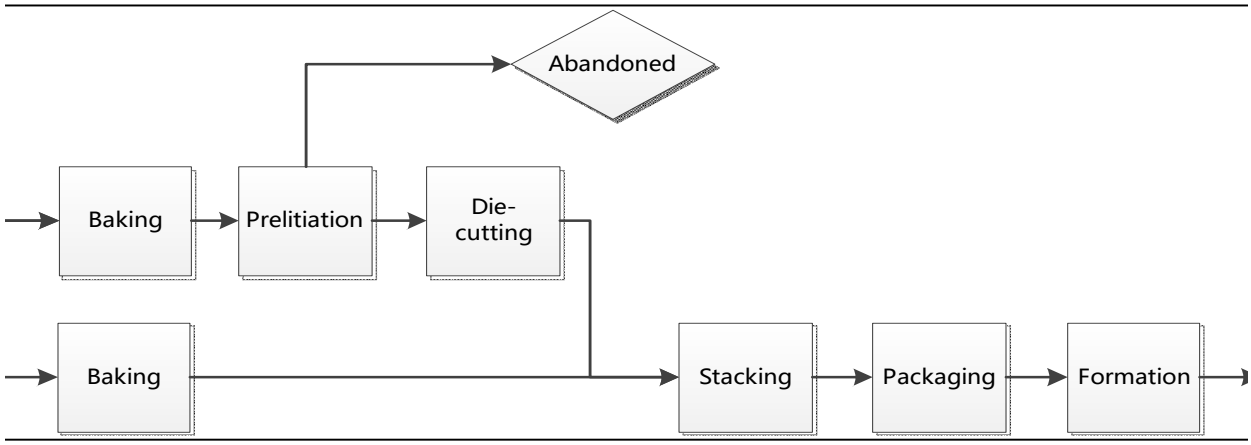
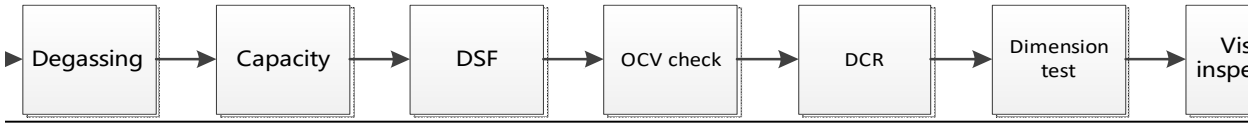
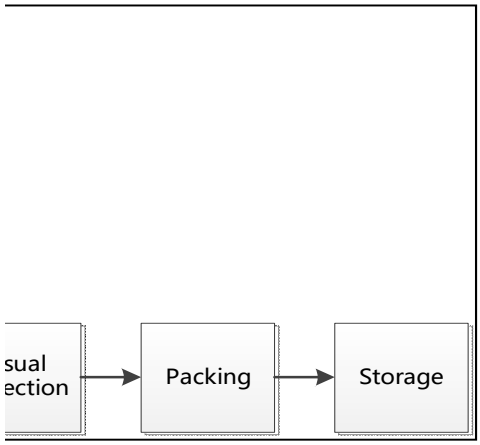
Rare					




Cathode(LFP)
Feeding
Mixing
Coating
Slitting
Anode(HC)
Feeding
Mixing
Coating
Calenderin g
Slitting
Cathode(AC)
Feeding
Mixing
Coating
Calenderin g
Die- cutting


Abandoned
Baking
Prelitiation
Die-
cutting
Baking
Stacking
Packaging
Formation


Degassing
Capacity
DSF
OCV check
DCR
Dimension test
Vis
inspe

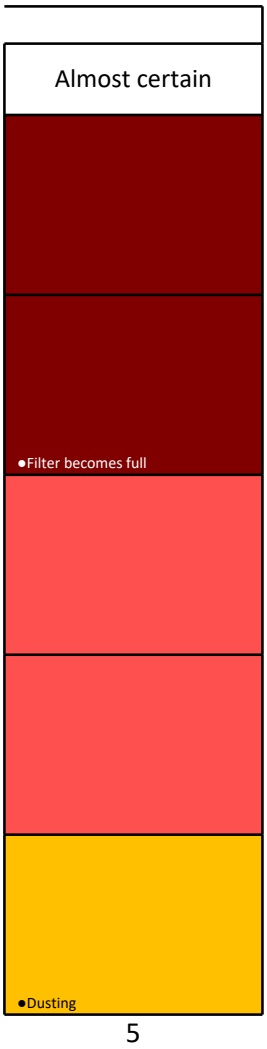

sual
ection
Packing
Storage

Risk assessment

PREMITIGATION

Impact	Probability: Rare	Unlikely	Possible	Likely
Severe				
Major		●Road accidents	●Fire in storage	
Moderate	●Water contamination ●HF-filters	●Breakdown of vapor recover unit (VRU) ●Fire in cells ●Sabotage/theft of hazardous materials ●Electrolyte HF evolution ●Leakage in storage ●Explosion in storage	●Damages to packages ●Fire/explosion	
Minor	●AC-filters ●Dust filters	●NMP recovery system breakdown ●Spills (larger than 1 dm3) ●Phasing out of NMP ●Separator reuse not possible	●Ice/Snow ●NMP leakage ●Leakage in system ●Accidental release to drain ●Faulty marking on containers ●Increase reuse of electrolyte ●Supplier stops accepting returning chemicals	●Degassing release unexpected compounds
Marginal	●Damages to housing/container	●Cutting fails ●Dusting / leakage ●Dusting / leakage	●Separator from waste materials not possible	●Dusting ●Dusting ●Particles/dust in drying stream. Dust from e.g. SBR is harmful for aquatic life with long lasting effects. Dust can settle in condensation of water in heat exchanger and exhausted with exiting water to sewage plant.
	1	2	3	4

Action	Scale
Stop / Emergency	Above 90% chance of happening
Urgent action	Between 60% - 90% of chance of happening
Action	Between 20% - 60% of chance of happening
Monitor	Between 5% - 20% of chance of happening
No action	Less than 5% of chance of happening



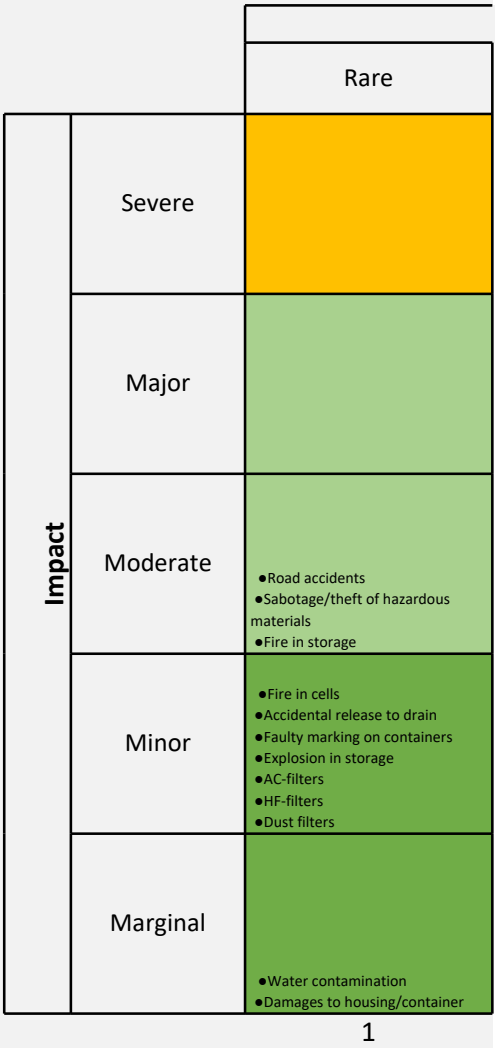
			IMPACT CONSEQUENC
Health and safety	**Environment**	**Production quality**	**Commercial**
Fatality	Catastrophic effect - long term/irreversible damages	Production requirements not acheived	Loss of contract /global reputation
Serious personal injuries resulting in permanent disability	Major effect	Sustantial effect on performance objectives	Loss of job/ major warranty issues/ national reputation
Injuries to personnel not leading to permanent disability	localised effect	All design and operating margins eliminated	Serious customer complaint /National media attention
Medical treatment of personnel. Lost time incident.	Minor effect	Minor decrease/setback in production performance	Customer complaint/local media attention or internal impact
Minor inuriy. First aid only. No lost time.	Slight effect	Slight effect on production performance	Negligable impact

[redacted]

CES

Financial	Schedule	Assets/Security
1 M +	> 6 months	Loss of asset(s)
500 K > 1 M	3-6 months	Major assets compromised
250 K > 500 K	1-3 months	Critical assets affected
100 K > 250K	2 weeks - 1 month	Assets affected. Non-compliance with internal security requirements.
0 > 100K	0 - 2 weeks	Negible threat to assets/security

POST MITIGATION



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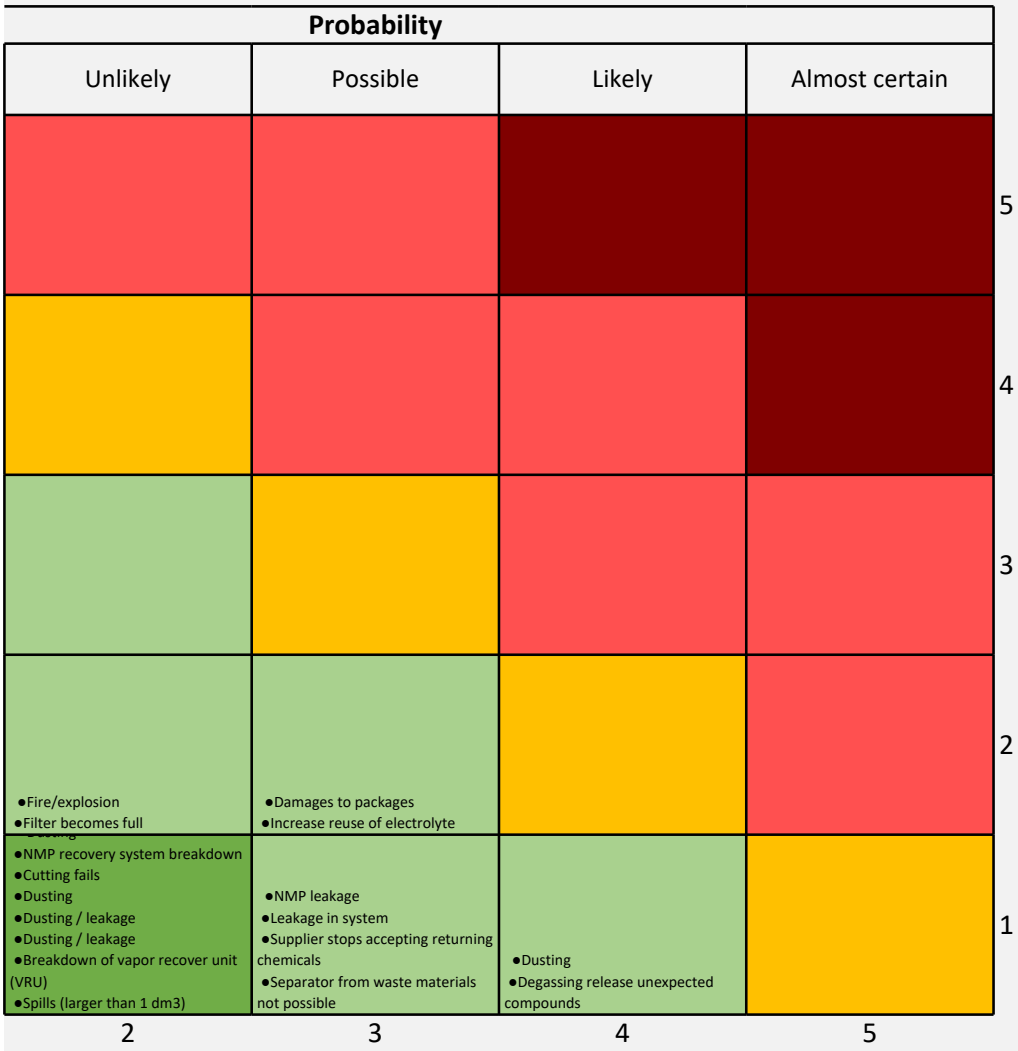
Probability
Unlikely
Possible
Likely
Almost certain
5
4
3
2
1
●Fire/explosion
●Filter becomes full
●Damages to packages
●Increase reuse of electrolyte
●NMP recovery system breakdown
●Cutting fails
●Dusting
●Dusting / leakage
●Dusting / leakage
●Breakdown of vapor recover unit (VRU)
●Spills (larger than 1 dm3)
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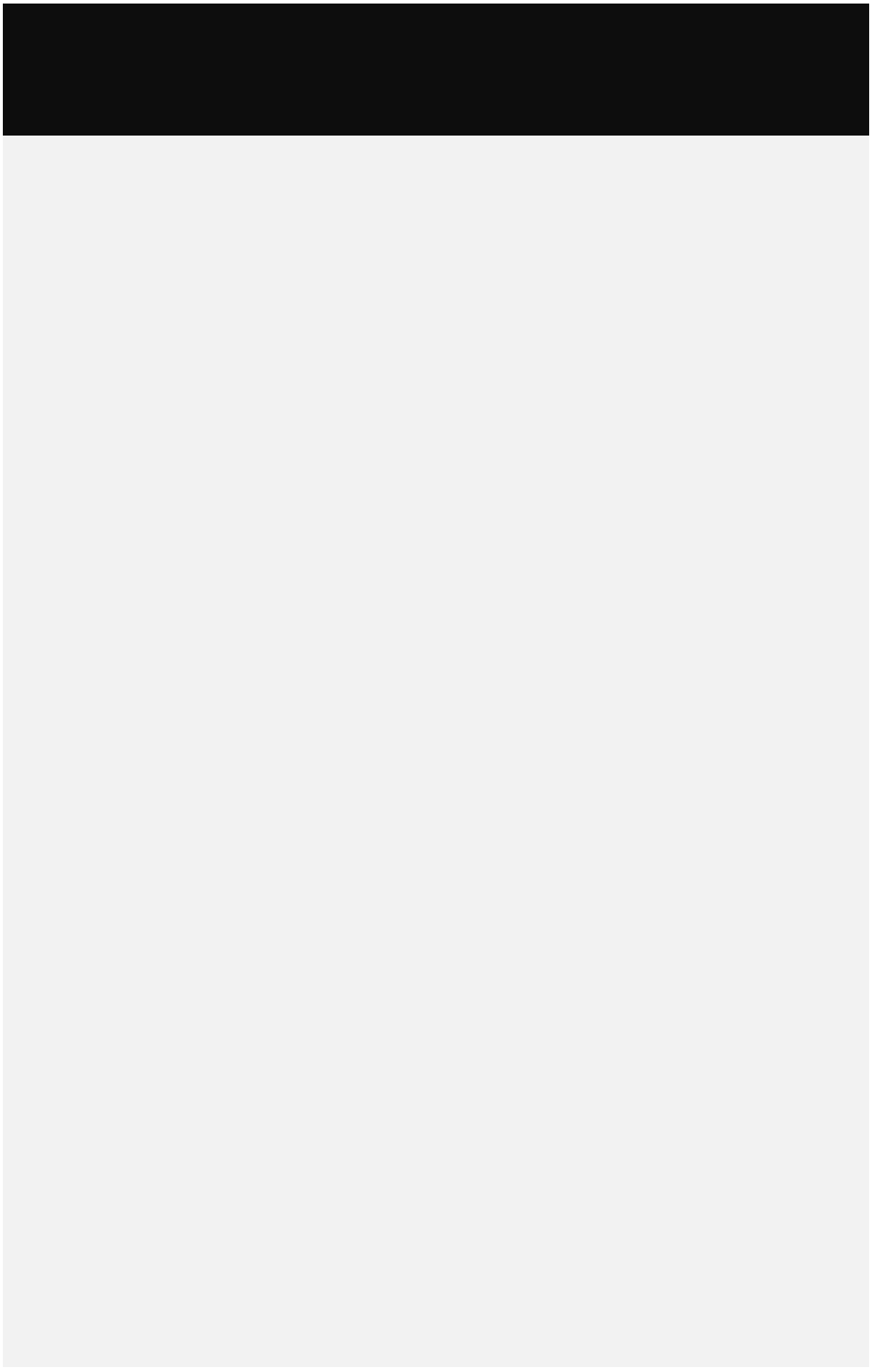
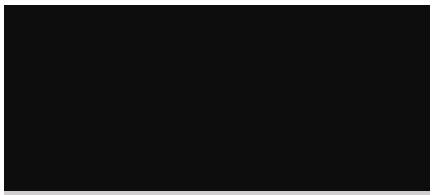
●Leakage in system
●Supplier stops accepting returning chemicals
●Separator from waste materials not possible
●Dusting
●Degassing release unexpected compounds
2
3
4
5

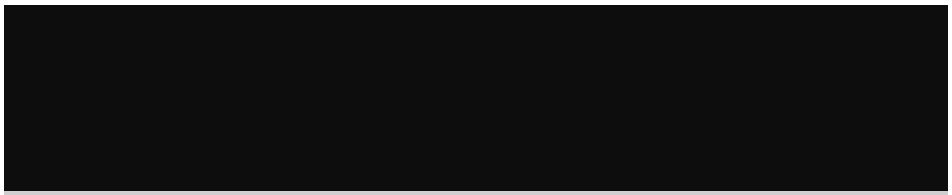


Risk assessment

Date of assessment	Attendees
21.03.2021	Sara Sahara (Scribe)
	Chao Lv
	Jean Lescoeur
	Joachim Wallenstein



Organisation
Beyonder
Beyonder
Beyonder
Advansia



Role

HSEQ Manager