SIX FEASIBILITY STUDIES

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on the performance of EVALED® Evaporators

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Automotive, Aviation, Furniture, Appliances

Mechanical and surface processes that involve the automotive, aviation, furniture, and appliances industries require large quantities of water and produce highly pollutant wastewater that cannot be discharged directly into the sewer without proper treatment. This requirement can easily increase a company's operating costs.

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- Chemical Analyses

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EVALED® MECHANICAL AND SURFACE PROCESSES

Feasibility Study No. 145/14

Waste Typology: Oil emulsion containing coolant from machine tools and rinsing water of metal components from washing machines.

Results (PC F-AA)

In the laboratory evaporation test, a distillation yield of 90% was reached, meaning the waste was concentrated about 10 times. Normally, productivity will decrease according to the rise in boiling point. This value was strictly correlated to solution characteristics. The presence of volatile organic substances may involve the development of incondensable vapors that may cause problems to the vacuum system. During distillation, the liquid produced a considerable foam. It was necessary to check the foam to avoid dragging in distillate. At this yield, some fouling could appear inside the heat exchanger, so more frequent maintenance may be needed in order to maintain unit performance.

Materials

The waste was slightly alkaline and contained a small amount of chlorides. To guarantee good corrosion resistance, the austenitic steels of the AISI 316 series must be used for the parts of the unit that are exposed to the waste.

Evaporator Type

According to:

- the analytical results of the supplied sample,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a forced circulation vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by a heat pump.

It is also possible to use other installation types (immersed coil heat exchanger or plate heat exchanger with a SCRAPING SYSTEM, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:

- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change in distillate characteristics

Chemical Analysis No. 145/14

Parameters	M.U.	Feed	Distillate	Concentrate
pH		9.0	10.2	10.4
Density	g/ml	1.006		1.008
Color		Pale grey	Colorless	
Odor		Unpleasant	Unpleasant	
Suspended solids	mg/l	316		
Settleable solids 2 h	ml/l	<0.1		
Dry matter at 105°C (221°F)	%	1.88		
Dry matter at 600°C (1112°F)	%	0.19		
Conductivity	µS/cm	2620	79	
COD	mg/l	79300	1730	
Chlorides	mg/l	106	<5	
Fluorides	mg/l	<0.5		
Nitric nitrogen	mg/l	<30		
Ammonium	mg/l	212	9.3	
Boron	mg/l	54.6	<1	
Iron	mg/l	<5	<1	
Copper	mg/l	<5		
Tot. extractable organic sub.	mg/l	18700	<10	
Anionic surfactants	mg/l	6.5	0.2	
Non ionic surfactants	mg/l	20	0.3	
Total surfactants	mg/l	26.5	0.5	
Sulphates	mg/l	69	<5	
Calcium	mg/l	41.6	1.5	
Aluminum	mg/l	65.4		
TKN	mg/l	168	<10	

Waste Typology: Oil emulsion containing coolant from machine tools and rinsing water of metal components from washing machines.

NOTE: The distillate and the concentrate were obtained by vacuum evaporating the waste. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER (Type PC F) is: 89-91%.

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EVALED® MECHANICAL AND SURFACE PROCESSES

Feasibility Study No. 256/13

Waste Typology: Oil emulsion from diesel engine manufacturing. Sample named Multan B 204 (Henkel).

Results (PC F-AA, PC F-AA with Yield< 88%)

In the laboratory evaporation test, a distillation yield of 93% was reached, meaning the waste was concentrated 14 times. Normally, productivity will decrease according to the rise in boiling point. This value was strictly correlated to solution characteristics. The presence of volatile organic substances may have involved the development of incondensable vapors and may have caused problems to the vacuum system. During the distillation process, the liquid produced a moderate foam. It was necessary to check the foam to avoid dragging in the distillate.

Materials

The waste was slightly alkaline and contained a small amount of chlorides. To guarantee good corrosion resistance, the austenitic steels of the AISI 316 series must be used for the parts exposed to the waste.

Evaporator Type

According to:

- the analytical results of the supplied sample,
- the production of scaling phenomena,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a vacuum evaporator with a SCRAPING SYSTEM, powered by a heat pump.

It is also possible to use other installation types (forced circulation with a SHELL-AND-TUBE HEAT EXCHANGER, immersed coil heat exchanger, or plate heat exchanger, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:

- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change of distillate characteristics

By working with lower concentration factors (distillation yield lower than 88%), it is possible to use a vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by a heat pump.

Chemical Analysis No. 256/13

Parameters	M.U.	Feed	Distillate	Concentrate
pH		9.2	>11	9.2
Density	g/ml	1.001		1.003
Color		Pale grey	Colorless	
Odor		Unpleasant	Unpleasant	
Suspended solids	mg/l	159		
Settleable solids 2 h	ml/l	<0.1		
Dry matter at 105°C (221°F)	%	3.11		
Dry matter at 600°C (1112°F)	%	0.12		
Conductivity	µS/cm	2850	180	
COD	mg/l	>100000	954	
Chlorides	mg/l	<50	<5	
Fluorides	mg/l	<0.5		
Nitric nitrogen	mg/l	<30	<5	
Ammonium	mg/l	225	44.8	
Boron	mg/l	244	0.1	
Iron	mg/l	18.4	<0.1	
Copper	mg/l	<5		
Tot. extractable organic sub.	mg/l	8340*	<50	
Anionic surfactants	mg/l	<5	<0.2	
Non ionic surfactants	mg/l	8	N.D.	
Total surfactants	mg/l	<=1.3	N.E.	
Sulphates	mg/l	<50		
Calcium	mg/l	13.3		
TKN	mg/l	178	35	

Waste Typology: Water from surface treatment with potassium ferrocyanide.

NOTE: The distillate and the concentrate were obtained by vacuum evaporating the waste.

*Indicative value for the nature of the sample. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER (Type PC F) is 85-88%. The recommended yield for a scraped heat exchanger evaporator (Type PC R) is: 92-94%

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Food and beverage processes use water for container and plant rinsing, raw materials and plant washing, and boiler feeding.

All the effluents used in the production process can be reused a second time for water saving and matter recovery (when needed).

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EVALED® FOOD AND BEVERAGE INDUSTRY

Feasibility Study No. 011/14

Waste Typology: Reactor washwater from coffee sweets production.

Results (RV F-AA)

In the laboratory evaporation test, a distillation yield of 95% was reached, meaning the waste was concentrated about 20 times. Normally, productivity decreases according to the rise in boiling point. This value was strictly correlated to solution characteristics. The wastewater had a quantity of settleable solids: A sedimentation before evaporation could be advised.

The wastewater had a large quantity of suspended solids: A pre-treatment before evaporation could be advised. We recommend the metering of an anti-scaling compound to limit the scaling phenomena, as well as frequent maintenance operations.

Materials

Before the distillation test, the pH of the waste was corrected at a value of 8.1 with sodium hydroxide 32%. After pH adjustment, the waste contained a considerable amount of chlorides. To guarantee good corrosion resistance, the austenitic steels of the AISI 316 must be used for the parts exposed to the waste. In order to avoid corrosion problems on the upper parts of the evaporator, it is necessary to use the INOX series for the BLOWER.

Evaporator Type

According to:

- the analytical results of the supplied sample,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a forced circulation vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by Mechanical Vapor Recompression.

It is also possible to use other installation types (immersed coil heat exchanger, plate heat exchanger with a SCRAPING SYSTEM, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:

- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change in distillate characteristics

Chemical Analysis No. 011/14

Parameters	M.U.	Feed	Distillate	Concentrate
pH		4.8	4.3	9.1
Density	g/ml	1.005		1.080
Color		Beige	Colorless	
Odor		Unpleasant	Unpleasant	
Suspended solids	mg/l	12600		
Settleable solids 2 h	ml/l	1.2		
Dry matter at 105°C (221°F)	%	1.01		
Dry matter at 600°C (1112°F)	%	0.05		
Conductivity	µS/cm	1570	24	
COD	mg/l	11000	557	
Chlorides	mg/l	213	<5	
Fluorides	mg/l	<0.05		
Sulphites	mg/l	16	<10	
Nitric nitrogen	mg/l	<30		
Ammonium	mg/l	25	<5	
Iron	mg/l	<5	<0.1	
Copper	mg/l	<5		
Tot. extractable organic sub.	mg/l	265	<10	
Anionic surfactants	mg/l	<5	<0.2	
Non ionic surfactants	mg/l	8	0.8	
Total surfactants	mg/l	<=1.3	<=1	
Volatile organic acids	mg/l	356	59	
Sulphates	mg/l	114		
Calcium	mg/l	152	1.1	

Waste Typology: Reactor washwater from coffee sweets production.

NOTE: The distillate and the concentrate was obtained by vacuum evaporating the waste after having raised its pH to 8.1 by adding about 2 ml of sodium hydroxide 37% w/w to one liter of waste. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER evaporator (Type RV F) is: 94-96%.

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EVALED® FOOD AND BEVERAGE INDUSTRY

Feasibility Study No. 064/13

Waste Typology: Reactor washwater containing sugar from sweets production.

Results (RV F-AA)

In the laboratory evaporation test, a distillation yield of 85% was reached, meaning the waste was concentrated about 6 times. Normally, productivity decreases according to the rise in boiling point. This value was strictly correlated to solution characteristics.

Materials

Before the distillation test, the pH of the waste was corrected at a value of 6.5 with sodium hydroxide 32%. After pH adjustment, the waste contained a small amount of chlorides. To guarantee good corrosion resistance, the austenitic steels of the AISI 316 must be used for the parts exposed to the waste. In order to avoid corrosion problems on the upper parts of evaporator, it is necessary to use the INOX series for the BLOWER.

Evaporator Type

According to:

- the analytical results of the supplied sample,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a forced circulation vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by Mechanical Vapor Recompression.

It is also possible to use other installation types (immersed coil heat exchanger, plate heat exchanger with a SCRAPING SYSTEM, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:

- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change in distillate characteristics

Chemical Analysis No. 064/13

Parameters	M.U.	Feed	Distillate	Concentrate
pH		2.9	5.9	8.5
Density	g/ml	1.026		1.192
Color		Opalescent	Colorless	
Odor		Pleasant	Pleasant	
Suspended solids	mg/l	741		
Settleable solids 2 h	ml/l	0.5		
Dry matter at 105°C (221°F)	%	4.36		
Dry matter at 600°C (1112°F)	%	0.02		
Conductivity	µS/cm	560	20	
COD	mg/l	52200	1400	
Chlorides	mg/l	70.9	<5	
Fluorides	mg/l	<0.5		
Nitric nitrogen	mg/l	<30		
Ammonium	mg/l	<5	<5	
Iron	mg/l	<5	<0.1	
Copper	mg/l	<5		
Tot. extractable organic sub.	mg/l	36.8	<10	
Sulphates	mg/l	73		
Calcium	mg/l	23.2		
Volatile organic acids	mg/l	59	30	
Alcalinity	meq/l	<1		
Total hardness	°F	7.5		
BOD5	mg/l	17600	480	

Waste Typology: Reactor washwater containing sugar from sweets production.

NOTE: The distillate and concentrate was obtained by vacuum evaporating the waste after having raised its pH to 6.5 by adding about 2 ml of sodium hydroxide 32% w/w to one liter of waste. The distillate and the concentrate was obtained by vacuum evaporating the waste. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER evaporator (Type RV F) is: 83-85%.

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EVALED® OIL AND GAS INDUSTRY

Feasibility Study No. 121/11

Waste Typology: Fracking wastewater from drilling.

Results (AC F-FF)

In the laboratory evaporation test, a distillation yield of 70% was reached, meaning waste was concentrated about 3 times. Normally, productivity decreases according to the rise in boiling point. This value was strictly correlated to solution characteristics. The presence of volatile organic substances may involve the development of incondensable vapors that may cause problems to the vacuum system. PRAB suggests the metering of an anti-scaling compound to limit the scaling phenomena, as well as frequent maintenance operations. The concentrate has the tendency to solidify; therefore, it was necessary to discharge it before the stand-by period. During the distillation process, the liquid produced a considerable foam. It was necessary to check the foam to avoid dragging in the distillate. The wastewater had some quantity of settleable solids: A suitable sedimentation before evaporation can be advised.

Materials

The waste was practically neutral and contained a very high amount of chlorides. To guarantee good corrosion resistance, a duplex steel (UNS S32750/S32760) must be used for the parts exposed to the waste.

Evaporator Type

According to:

- the analytical results of the supplied sample,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a forced circulation vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by hot/cold water.

It is also possible to use other installation types (immersed coil heat exchanger, plate heat exchanger with a SCRAPING SYSTEM, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:

- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change in distillate characteristics

Chemical Analysis No. 121/11

Parameters	M.U.	Feed	Distillate	Concentrate
pH		6.8	4.8	7.6
Density	g/ml	1.062		1.186
Color		Brown	Colorless	
Odor		Unpleasant	Unpleasant	
Suspended solids	mg/l	3944		
Settleable solids 2 h	ml/l	0.5		
Dry matter at 105°C (221°F)	%	9.12		
Dry matter at 600°C (1112°F)	%	8.52		
Conductivity	µS/cm	63500	39.4	
COD	mg/l	5144	168	
Chlorides	mg/l	45022	<5	
Fluorides	mg/l	<0.5		
Nitric nitrogen	mg/l	<30		
Ammonium	mg/l	5.6	<5	
Boron	mg/l	<1.0	<0.1	
Iron	mg/l	17.9	<0.1	
Copper	mg/l	<1.0		
Tot. extractable organic sub.	mg/l	<10	<5	
Anionic surfactants	mg/l	<5.0	0.2	
Non ionic surfactants	mg/l	53.3	0.7	
Total surfactants	mg/l	<=58.3	0.9	
Sulphates	mg/l	5747		
Calcium	mg/l	1735		
Bromide	mg/l	<50		
Total solvents as n-hexane	mg/l	146	41.1	
Magnesium	mg/l	53.9		

Waste Typology: Fracking wastewater from drilling.

NOTE: The distillate and concentrate was obtained by vacuum evaporating the waste. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER evaporator type AC F is: 65-70%.

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EVALED® OIL AND GAS INDUSTRY

Feasibility Study No. 094/12

Waste Typology: Fracking wastewater from drilling.

Results (PC R-FF or PC F-FF with Yield< 88%)

In the laboratory evaporation test, a distillation yield of 93% was reached, meaning the waste was concentrated about 14 times. Normally, productivity will decrease according to the rise in boiling point. This value was strictly correlated to solution characteristics. At this yield, some fouling may appear inside the heat exchanger, so maintenance operations will have to be more frequent in order to maintain unit performance. We recommend the metering of an anti-scaling compound to limit the scaling phenomena, as well as frequent maintenance operations. The wastewater has a large quantity of settleable solids: A pre-treatment before evaporation can be advised.

Materials

The waste was practically neutral and contained a very high amount of chlorides. To guarantee good corrosion resistance, a duplex steel SAF 2507 (UNS S32750) must be used for the parts exposed to the waste.

Evaporator Type

According to:
- the analytical results of the supplied sample,
- the production of scaling phenomena,
- the segregation of precipitates,
- the viscosity of the solution under evaporation,
- the production of foam,
- the boiling point rise, and;
- the characteristics of the distillate correlated to the evaporation temperature,

PRAB recommends using a vacuum evaporator with a SCRAPING SYSTEM, powered by a heat pump.

It is also possible to use other installation types (forced circulation with a SHELL-AND-TUBE HEAT EXCHANGER, immersed coil heat exchanger, plate heat exchanger, etc.) powered by steam/hot water or by thermocompression.

These options require redefining the following parameters:
- variation of concentration factor
- variation of man hours used for maintenance and plant stop
- variation of operating costs
- possible additional pre- or post-treatment of solution
- change in distillate characteristics

By working with lower concentration factors (distillation yield lower than 88%) it is possible to use a vacuum evaporator with a SHELL-AND-TUBE HEAT EXCHANGER, powered by a heat pump.

Chemical Analysis No. 094/12

Parameters	M.U.	Feed	Distillate	Concentrate
pH		6.3	4.2	8.2
Density	g/ml	1.020		1.118
Color		Brown	Colorless	
Odor		Unpleasant	Unpleasant	
Suspended solids	mg/l	1866		
Settleable solids 2 h	ml/l	0.4		
Dry matter at 105°C (221°F)	%	2.99		
Dry matter at 600°C (1112°F)	%	2.65		
Conductivity	µS/cm	41000	188.9	
COD	mg/l	1660	152	
Chlorides	mg/l	14535	<50	
Fluorides	mg/l	<0.5	<0.5	
Nitric nitrogen	mg/l	<30	<5	
Ammonium	mg/l	<5	<5	
Iron	mg/l	10.2	<0.1	
Copper	mg/l	<1.0	<0.1	
Tot. extractable organic sub.	mg/l	<10	<5	
Total solvents as n-hexane	mg/l	<0.5	<0.5	
Anionic surfactants	mg/l	<5	<0.2	
Non ionic surfactants	mg/l	<5	<0.3	
Total surfactants	mg/l	<10	<0.5	
Bicarbonate	mg/l	549	<5	
Carbonates	mg/l	<1	<1	
Barium	mg/l	3.4	<0.1	
Sulphates	mg/l	688	<5	
Calcium	mg/l	221	0.5	

Waste Typology: Fracking wastewater from drilling.

NOTE: The distillate and the concentrate was obtained by vacuum evaporating the waste. The recommended yield for a SHELL-AND-TUBE HEAT EXCHANGER evaporator (Type PC F) is: 88-90%. The recommended yield for a scraped heat exchanger evaporator (Type PC R) is: 91-93%.

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