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LANDFILL LEACHATE AND INDUSTRIAL EFFLUENT TREATMENT USING ADVANCED EVAPORATION TECHNOLOGY

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ABSTRACT

Evaporation is one of the most efficient methods for separation of dissolved solids and water. Using evaporation, high quality, recyclable or dischargeable water can be produced. An advanced evaporation technology for industrial effluent and landfill leachate treatment has been developed. Construction material of the evaporative heat transfer surface is the key difference to conventional systems: thin, corrosion resistant and elastic polymeric film is used instead of rigid metals. The cost of the polymeric surface is low, decreasing the high costs that are associated with conventional evaporators. Thus, evaporation is now a feasible alternative in a number of effluent treatment applications. The technology applies Mechanical Vapor Recompression (MVR) concept using electrical energy or Multi-Effect (ME) concept utilizing waste heat as energy source. In both concepts the evaporative surface areas are larger than in conventional systems. As a result of the large surface electrical energy consumption is low in the MVR-type evaporators, typically 8-12 kWh/m^3 of recovered water; in ME-type evaporators the large area enables the utilization of low value waste heat in an efficient way.

KEYWORDS

closed water cycle, effluent treatment, evaporation, leachate, recycle

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INTRODUCTION

Concentration of aqueous solutions by evaporation is an old and widely used method in a number of industries and applications, including treatment of industrial effluents and landfill leachates.

Evaporation has long been associated with high energy use; however, improvements in evaporation systems have been made to increase their energy efficiencies. The most significant progress in energy savings has been achieved through increasing the number of effects in Multi Effect evaporators and reusing the vapor in different ways. In Thermal Vapor Recompression (TVR) evaporators, the inertia of steam is used for recycling part of the vapors through ejectors. In Mechanical Vapor Recompression (MVR) evaporators, all vapor is recycled back as heating steam using vapor compression with high pressure fans or compressors. In many applications, MVR evaporators are superior because they do not need steam or cooling water. In case waste heat or low cost thermal energy is available Multi-Effect (ME) evaporators can be the feasible option.

Evaporation in treatment of effluent

The global need to minimize environmental impacts caused by effluent discharges and to save fresh water resources is resulting to stricter discharge limits and higher water costs. In many applications, simple, conventional treatment methods will not be sufficient. Evaporation is one of the most efficient methods for separation of dissolved solids and water. Using evaporation, high quality, recyclable water can be produced. From a technological point of view, evaporation is an ideal method for the following reasons:

- Water recovered from the effluent stream is of high quality and can, in most cases, as such be reused in the process or discharged into the nature
- All non-volatile substances can be completely separated from the "distillate" stream
- Harmful solids can be recovered for appropriate disposal or valuable solids can be recovered and reused

Evaporation covers the whole particle size spectrum as own in Fig. 1 and removes most efficiently dissolved substances such as salts and organic material (COD) as shown in Fig. 2.

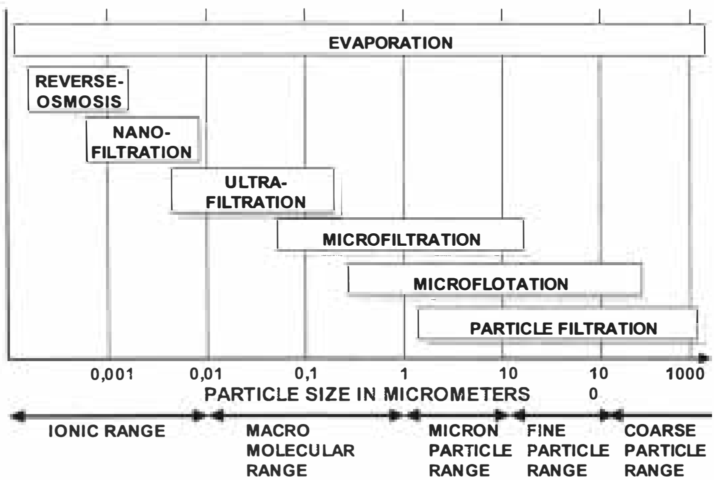


Fig. 1. Filtration spectrum of separation methods

Treatment of effluent with conventional evaporation processes does have some drawbacks. Among them are:

- High operating costs
- High capital costs especially in corrosive environment, where noble construction materials are required
- Problems with scaling and fouling, especially with varying influent quality and composition
- Steam and cooling water availability for thermal evaporative systems

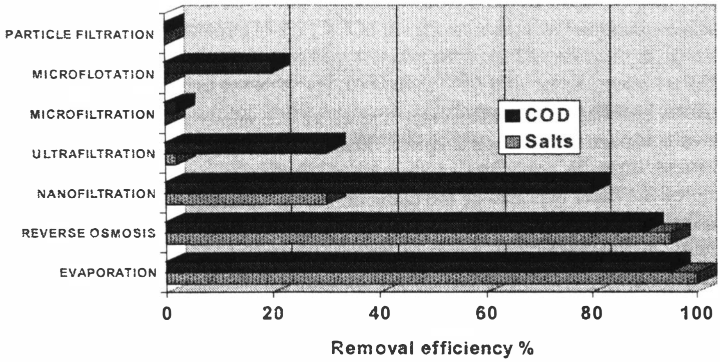


Fig. 2. Salt and COD removal efficiency in a pulp & paper industry effluent stream

THE ADVANCED EVAPORATION TECHNOLOGY

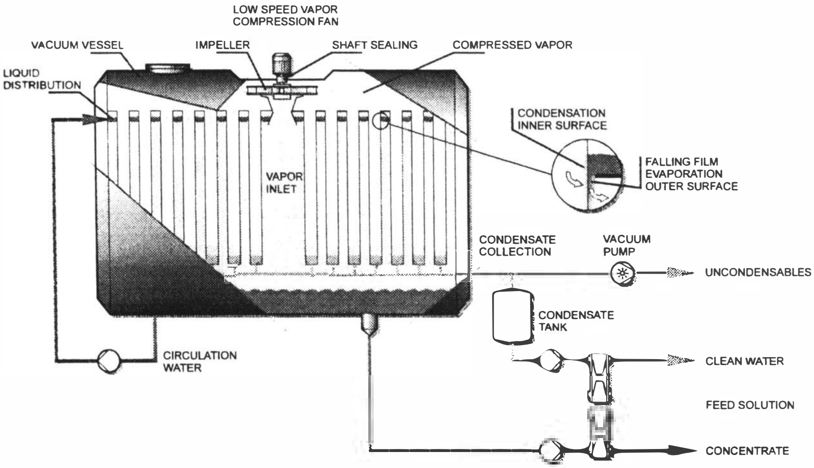
The target in the development work of the new evaporation technology has been to solve or minimize the above drawbacks of conventional systems and make the evaporative process competitive for industrial effluent and landfill leachate applications. The new evaporation technology applies the Mechanical Vapor Recompression (MVR) OR Multi-Effect (ME) principle and combined with Falling Film (FF) evaporation method.

Operating principle

The operating principle of the evaporator applying the MVR principle is shown in figure 3 and the ME principle in Figure 4.

Figure 3. MVR operating principle

The main components of the MVR system are: vacuum vessel, evaporative heat transfer



surface installed inside the vessel and vapor recompression fan. The polymeric heat transfer surface element has a square, double-sided structure.

The solution to be concentrated is circulated to the top of the element and distributed on both of the outer surfaces of the element. As the solution reaches its saturation state, it begins to evaporate when heated. The vapor generated flows into a fan, which adds energy by increasing the pressure and temperature of the vapor. After the fan, the compressed vapor is introduced inside the heat transfer element.

Here the vapor condenses; latent heat is released and transferred through the polymeric surface causing the solution on the exterior surface to release more water vapor. The condensed vapor, the product of the process, is then discharged from inside the element as clean condensate. The concentrated liquid is discharged from the bottom of the vessel for disposal.

In the Multi Effect evaporators (Figure 4.) effluent pumped to the first effect is heated with thermal energy. The energy source is a hot liquid solution (temperature >70°), hot gas, vapor or low pressure steam. The vapor evaporated from the effluent in the first effect is used as heating steam in the second effect and vapor from second effect again in the third effect and so on. After the final effect the vapor is condensed in condenser. The total number of effects will chosen based on the required capacity as well as based on temperature levels of the energy source and the cooling system.

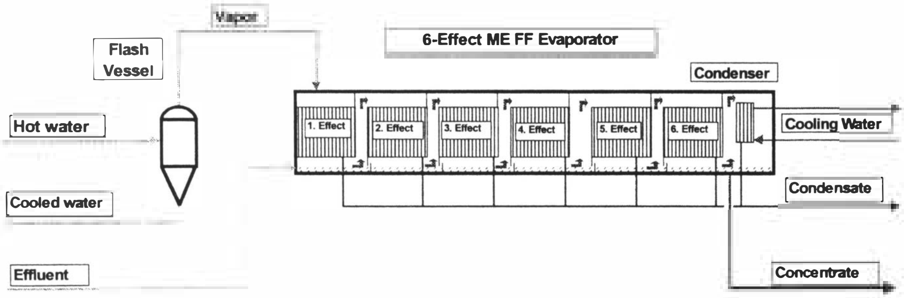


Figure 4. ME operating principle utilizing hot water as energy source

The innovation

The key innovation of the technology is the new heat exchanger concept, where the surface is manufactured of high-tech polymeric film. The innovation is related to the construction, special welding and assembly methods of the film itself and involves specially designed liquid distributors and condensate collectors that are also fabricated of polymeric materials.

Low cost polymeric materials can be used as basic component in the film because of the low operating temperature (55-65°C). On the other hand, low temperature also leads to a low pressure differential over the heat transfer surface. The pressure difference over the heat transfer surface is equal to approximately 200 mm water gauge (at 60°C), which enables the use of thin films in the evaporator surfaces. The use of thin walls is essential because thermal conductivities of polymeric materials are low, typically in order of 0.15-0.5 W/(m×K). These are very low figures compared to metallic materials; for example thermal conductivity of stainless steel is typically 16 W/(m×K). Wall thickness of metallic surfaces is usually between 0,5 to 1,5 mm. The polymeric heat transfer surfaces have wall thickness between 0,02 - 0,04 mm. Using such thickness, the relatively low heat conductivity of the surface material is overcome and heat transfer coefficients rival that of metallic surfaces.

Suitable polymeric materials can be found for practically every aggressive process environment and application. In addition, the cost of the heat exchanger is reduced to a fraction of the metallic counterpart. Because of the low cost, it is economically feasible to have a much larger surface than before.

Advanced technology evaporators

Fifty individual heat transfer surface elements are combined to form a single, modular heat transfer surface cartridge. The number of identical cartridges of each system will depend on the required capacity.

The cartridges are installed in a horizontal, cylindrical vessel. In the MVR evaporators a simple, low speed fan integrated with the vessel is used for vapor recompression. During a cold start-up, the system is heated to the operating temperature using an energy outer source (steam, hot water, electricity); however, once the process starts, only the electrical energy needed by the recompression fan and the pumps is required.

The feed effluent entering the evaporator is preheated by heat recovered from both the condensate and concentrate streams being discharged from the system, as well as the vapor stream to the fan. Typically, the discharge temperatures of these streams are 2°C higher than the inlet temperature of the effluent stream.

Modular concept. Both the heat transfer cartridges and the evaporator system are modular in concept. Two basic designs of the heat transfer cartridges are used, depending on the vessel diameter, and they are identical within each individual system. This feature allows the user to maximize their coverage while keeping spare parts inventory to a minimum. Additionally, the heat transfer cartridges, unlike their metallic counterparts in conventional evaporators, are easy to handle and replace. This modular concept also allows stepwise enlargement of the installation, which can grow as the needs of the user grow. The units are delivered fully assembled with only external connections to the user's outer systems being completed on site. The units are built for outdoor operation thus requiring no additional building.

APPLICATIONS

Treatment concepts and operational data of some applications are described in this chapter.

Paper mill process water/effluent treatment

Saudi Arabia. The technology has been used in the paper mill of Arab Paper Manufacturing Co. in Saudi Arabia. The mill produces 200 t/d liner and fluting from recycled paper. The plant set-up is shown Figure 5.

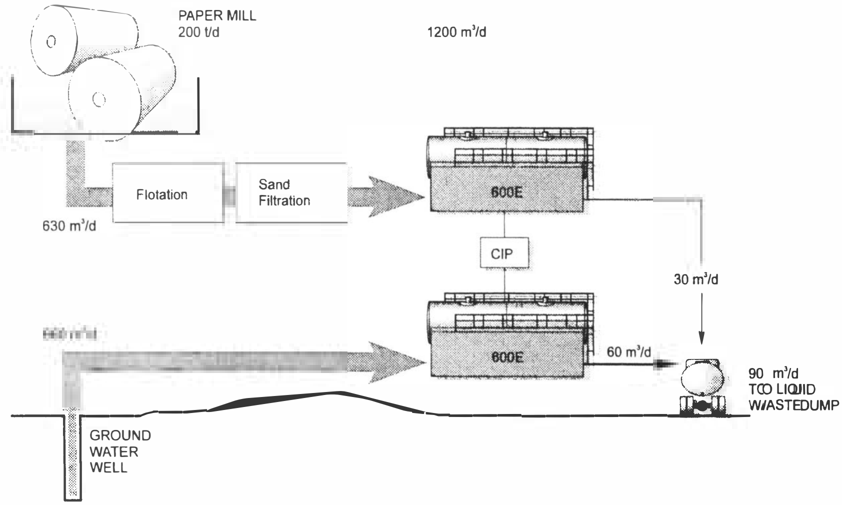


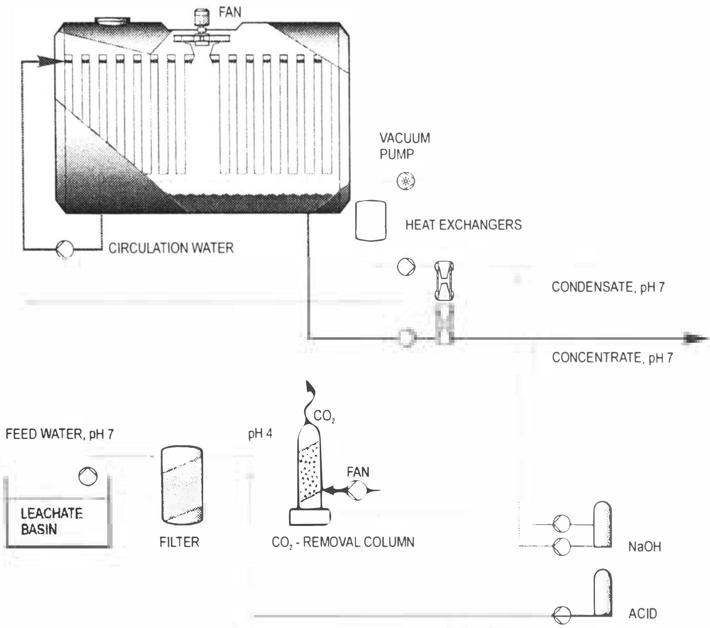
Figure 5. Set-up of Saudi Arabian paper mill water treatment plant

The facility contains two evaporator units, both of which consist of two modules. The plant has been designed so that any of the four units can be taken off line for cleaning or maintenance while the other three units remain in operation.

Landfill leachate treatment

Kujala Landfill, Lahti, Finland. The general set-up of the Kujala landfill leachate treatment facility is shown in Figure 6 . The critical parameters in the purification process are ammonium nitrogen (NH_4-N) content, chemical oxygen demand (COD_{Cr}) and conductivity. Ammonium nitrogen is kept non-volatile during evaporation by adjusting the leachate pH to 4 prior to evaporation. Sulfuric acid (H_2SO_4) is used for the pH adjustment. After the pre-treatment, leachate is introduced in the evaporator.

Leachate is discharged from the final section, where the pH is adjusted back to neutral using caustic (NaOH), to the landfill body. Clean condensate flows from the heat transfer cartridges to a condensate tank where, again after pH adjustment with caustic, it is released



to a small ditch, through which condensate flows to a river and, finally, to the Baltic Sea. The purification results are shown in Table 1.

Figure 6. Lahti landfill leachate treatment concept

Parameter	Unit	Leachate	Purified Leachate	Purification Efficiency
Conductivity	mS/m	360	4,2	99 %
pH	-	7,7	7,7	
COD_{Cr}	mgO_2/l	228	< 30	> 87 %
BOD_7(ATU)	mgO_2/l	27	< 3	> 89 %
Ammonium	mgN/l	101	0,63	99 %
AOX	mg/l	0,077	< 0,005	> 94 %
TDS	mg/l	2063	10	99,5 %
TSS	mg/l	46	0	100 %

Table 1. Purification results of the Lahti landfill leachate treatment plant