Permascand Recognized for

2021

Technology Innovation Leadership

European Electrochlorination Technology for Water Treatment Industry

Excellence in Best Practices

FROST & SULLIVAN

Contents

Background and Company Performance

Industry Challenges

With rapid population increases, expanding urbanization, and industrialization, water pollution has become a serious global concern. To mitigate water pollution issues, especially in drinking water supplies, wastewater, process water, and ballast water, various water treatment methods (e.g., chemical, physical, and biological) have been explored by water treatment companies. However, conventional methods have disadvantages such as being time-consuming, requiring extensive land area, and posing waste disposal challenges. For example, chemical disinfection utilizes chemical agents such as halogen derivatives (e.g., chlorine, bromine, HOCl, HOBr), oxidizing compounds, and quaternary ammonium compounds for treatment, leading to undesired hazardous or residual compounds which are harmful to the aquatic environment. Physical disinfectants such as particle radiation, electromagnetic radiation, and UV rays are costly and unsuitable for treating large water quantities.

Moreover, conventional systems often lead to the formation of aqueous waste, which is difficult to dispose of and can contaminate the environment upon contact. While the technologies often align with stringent regulatory requirements, they do not always produce desired results when treating wastewater containing heavy metals, phenolic compounds, biological matter, and non-biodegradable pollutants.

To cater to the demand for cost-effective and efficient water treatment technology, electrochemical processes such as electrochlorination is gaining in popularity. However, such systems consume large amounts of energy, affecting the separation and overall efficiency of treating water from various sources. Considering these challenges, low energy-consuming electrochlorination technology is needed for water treatment applications.

Technology Leverage and Business Impact

Commitment to Innovation, Commitment to Creativity, and Application Diversity

Founded in 1971, Sweden-based Permascand AB has more than 50 years of experience in electrochemical process technology and water treatment system development. The company's flagship PermaChlor® electrochlorination water disinfection technology aids in low energy consumption and delivers high-efficiency water treatment for multiple applications. PermaChlor leverages Permascand's pioneering dimensionally stable electrode (Permascand DSA®) offering. Permascand DSA® comprises a titanium structure with a thin coating of catalytic metal oxide, allowing for safe and clean production of the hypochlorite solution.

Chlorination is one of the most widely used disinfection technologies for wastewater, municipal water, and process water treatment. It is often employed to prevent biofouling due to its high efficacy against a wide range of pathogenic organisms and organic and inorganic compounds.

Despite such advantages, chlorination systems often form disinfection byproducts that are toxic to aquatic environments even at low concentrations. Additionally, chlorine in any form (e.g., chlorine gas or hypochlorite liquid) is highly corrosive and considered a lethal chemical. Thus its storage, transportation, and handling impose risks that require safety regulations.

Permascand's PermaChlor technology is environmentally safe and works by applying direct electric current to seawater, subsequently generating a sodium or calcium hypochlorite solution on-site. Once seawater passes through PermaChlor's electrochemical cell comprising a dimensionally stable anode/cathode electrode, it generates non-hazardous diluted sodium hypochlorite and hydrogen gas. The technology hence eliminates the need to store potentially hazardous chlorine-based chemicals on site. It is simple to operate and can produce the solution as per requirement or on dosing demand. PermaChlor does not produce any toxic sludge or byproducts other than hydrogen, eliminating the need for highly concentrated chlorine or other toxic chemical agents.

Electrochlorination-based water treatment technology competitors require a regular supply of sodium chloride as an electrolyte to carry out hypochlorite production. Permascand's technology does not require sodium chloride and is dependent only on seawater and electricity for hypochlorite generation. Moreover, most commercially-available sodium hypochlorite is only available in 6%, 12%, and 15% concentrations, which are difficult to handle due to safety concerns. It can also cause discomfort (e.g., eye irritation) to workers. PermaChlor typically generates sodium hypochlorite solution in the range of 0.01-1%, significantly lower than the hazardous threshold value.

Traditional sodium hypochlorite-producing equipment is weakened due to the solution's corrosive nature. Additionally, high pH and chlorine concentrations can weaken hypochlorite piping systems and cause leakage issues. Conventional systems also require regular chemical cleaning to remove scaling, resulting in the increased consumption of seawater, salt, and energy to produce the hypochlorite needed. Additionally, such systems require a large footprint, contributing to their high cost.

PermaChlor is divided into two sub-categories: plate electrode concept (PEC) and tubular electrode concept (TEC), both of which have bipolar cell geometry. The bipolar cell geometry offers many benefits over traditional processes, including:

- Superior electrolytic efficiency due to quick hydrogen separation
- Low capital cost and low power consumption
- A design that ensures the electrolyzer operates for many years without hypochlorite leaks
- A rigid electrode assembly that is not susceptible to corrosion or flow-induced vibration
- The ability to inhibit the growth of scale buildup, thus eliminating the need for chemical cleaning
- Requiring a smaller footprint to operate

Moreover, conventional treatment technologies such as filtration find it challenging to treat brackish or seawater per International Maritime Organization (IMO) standards. Technologies involving hydrocyclone separation are also not efficient at separating smaller organisms, whereas the coagulation process requires extra ship tanks, pipes, and overall space onboard to carry out the treatment process. Water treatment companies explored mono-polar and multiple-stage horizontal bipolar-type electrochemical cells based on the electrochlorination solution to minimize conventional technologies' limitations. However, the electrochemical cells do not have a compact design and cannot be installed in narrow ship areas. Electrochemical effectiveness depends on the water's salt content and maintaining a high water temperature, affecting overall power consumption.

Permascand leverages its experience and knowledge of electrochemistry to design a compact and lightweight electrofiltration system for sodium hypochlorite applications, with an emphasis on the marine and aquaculture industries. PermaChlor incorporates a one-pass single unit, allowing installation in narrow areas. The system further combines both electrochemical disinfection and filtration, eliminating the need for external chemicals such as chlorine and thus making it a safer and more cost-effective alternative to conventional systems.

Frost & Sullivan notes that PermaChlor is more energy-efficient than alternative technologies and is basically unaffected by temperature or salinity. The technology can be utilized to treat drinking water supplies, wastewater, cooling water, water injection, swimming pools, and process water in industrial, marine, and oil and gas industries.

Customer Acquisition, Technology Incubation, and Financial Performance

The company operates through three business clusters: production, research and development, and the sale of electrodes, catalytic coatings, and electrochemical cells. Additionally, the company offers refurbishment services for electrodes and electrochemical cells. Permascand is a leading electrode supplier globally. The company has a dedicated research team and collaborates with international engineering companies and customers to develop modular electrochemical cell units.

For instance, Permascand is strengthening and widening its key technology and product portfolio through acquisition of Radical Filtration Ltd., a UK-based water treatment system provider. The company is also investing approximately $5 to 7 million USD in production equipment, new products, and business development to strengthen its foothold in the European water treatment industry.

Permascand provides ballast water treatment (BWT) through PermaChlor customized cells and industrial water treatment through its standard cells and systems. The company manufactures electrochemical cells and systems that can support small to large production capacities, both for full flow and slipstream treatment. For example, the PermaChlor BWT system leverages PEC electrolyzer configurations consisting of different modules and can produce between 4 to 250 kilograms (Kg)/hour (hr) of sodium hypochlorite. PermaChlor using a TEC electrolyzer can produce in a range of 1 to 100 Kgs/hr, while PermaChlor with standalone cells can produce up to 13.5 Kgs/hr per cell.

Currently, Permascand is witnessing increasing interest from the maritime industry for BWT due to the adoption of the Ballast Water Management Convention. The aim is to help shipowners preserve ocean biodiversity by reducing the formation of harmful pathogens and organisms in ships' ballast water. Conventional BWT solutions often combine primary processes (e.g., filtration) and secondary processes (e.g., chemical reagents or UV filtration), contributing to high operational costs. Moreover, the solutions are not easy to install in hazardous areas and are not suitable to treat ballast water due to high flow rates. PermaChlor, on the other hand, is inexpensive, easy-to-install, and well-suited for hazardous areas and vessels with large flows.

To cater to maritime industry demands, the company opened a new assembly line with a state-of-the-art workshop and production capacity of 2,000 PermaChlor cells per year in 2018. The production facility maintains a high level of technical competence due to its multifunctional production capabilities. Moreover, it ensures waste heat recovery and closed system product testing with recycled water. Permascand's customers are receiving system approvals (e.g., IMO certification and USCG regulatory approval) for BWT, off-shore, and industrial applications. Additionally, customers value Permascand's efforts to efficiently utilize waste heat and water resources in its production facility.

The company has a production unit in Sweden, sales offices in Sweden and Canada as well as established manufacturing partners in the United States, China, and Brazil. It also has a massive client base across Europe and the Americas, and is focused on expanding its footprint in Asia-Pacific. 90-95% of Permascand's sales come from exports outside of Europe, and it achieved strong sales growth at an annual rate of more than 30% in 2019 alone (i.e., revenue of $52.3 million USD in 2019 from $23.5 million USD in 2016). In 2019, 63.7% of sales came from Europe and the United Kingdom. The rest of the world, including the United States, constitutes 24.8% of global sales. Sweden and Norway constituted 3.2% and 8.4% of the sales, respectively.

Conclusion

Conventional water treatment technologies such as chlorination produce sodium hypochlorite on-site, leading to challenges with safe handling, storage, and transportation. Permascand AB (Permascand)'s innovative PermaChlor® electrochlorination technology comprises the company's proprietary dimensionally stable electrodes (Permascand DSA®), allowing for low power consumption and high-efficiency water treatment. PermaChlor is environmentally-friendly and produces sodium hypochlorite in a significantly lower concentration range than the hazardous threshold value. Permascand further leverages its electrochemistry expertise for applications including ballast and drinking water treatment. The company's strong financial performance, technical excellence, and ability to broaden its network and product portfolio through partnerships are factors contributing to Permascand's global recognition and brand equity.

For its strong overall performance, Permascand earns Frost & Sullivan's 2021 Technology Innovation Leadership Award in the European electrochlorination technology for the water treatment industry.

Significance of Technology Innovation Leadership

Technology-rich companies with strong commercialization strategies benefit from the demand for high-quality, technologically innovative products that help shape the brand, resulting in a strong, differentiated market position.

Understanding Technology Innovation Leadership

Technology innovation leadership recognizes companies that lead the development and successful introduction of high-tech solutions to customers' most pressing needs, altering the industry or business landscape in the process. These companies shape the future of technology and its uses. Ultimately, success is measured by the degree to which a technology is leveraged and the impact it has on growing the business.

Key Benchmarking Criteria

For the Technology Innovation Leadership Award, Frost & Sullivan analysts independently evaluated 2 key factors, Technology Leverage and Business Impact, according to the criteria identified below.

Technology Leverage

Criterion 1: Commitment to Innovation
Criterion 2: Commitment to Creativity
Criterion 3: Technology Incubation
Criterion 4: Commercialization Success
Criterion 5: Application Diversity

Business Impact

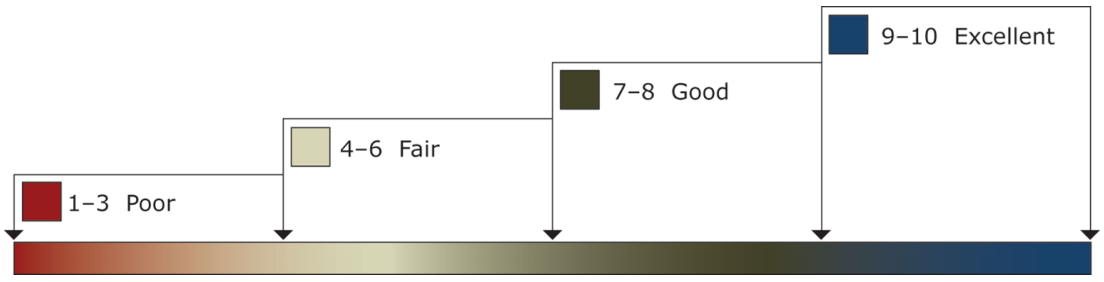
Criterion 1: Financial Performance
Criterion 2: Customer Acquisition
Criterion 3: Operational Efficiency
Criterion 4: Growth Potential
Criterion 5: Human Capital

Best Practices Award Analysis for Permascand AB

Decision Support Scorecard

To support its evaluation of best practices across multiple business performance categories, Frost & Sullivan employs a customized Decision Support Scorecard. This tool allows research and consulting teams to objectively analyze performance according to the key benchmarking criteria listed in the previous section, and to assign ratings on that basis. The tool follows a 10-point scale that allows for nuances in performance evaluation. Ratings guidelines are illustrated below.

RATINGS GUIDELINES



The Decision Support Scorecard considers Technology Leverage and Business Impact (i.e., the overarching categories for all 10 benchmarking criteria; the definitions for each criterion are provided beneath the scorecard). The research team confirms the veracity of this weighted scorecard through sensitivity analysis, which confirms that small changes to the ratings for a specific criterion do not lead to a significant change in the overall relative rankings of the companies.

The results of this analysis are shown below. To remain unbiased and to protect the interests of all organizations reviewed, Frost & Sullivan has chosen to refer to the other key participants as Competitor 1 and Competitor 2.

Measurement of 1–10 (1 = poor; 10 = excellent)			
Technology Innovation Leadership	Technology Leverage	Business Impact	**Average Rating**
Permascand AB	**9.0**	**9.2**	**9.1**
Competitor 1	8.5	8.3	8.4
Competitor 2	8.3	8.0	8.2

Technology Leverage

Criterion 1: Commitment to Innovation

Requirement: Conscious, ongoing development of an organization's culture that supports the pursuit of groundbreaking ideas through the leverage of technology.

Criterion 2: Commitment to Creativity

Requirement: Employees rewarded for pushing the limits of form and function by integrating the latest technologies to enhance products.

Criterion 3: Technology Incubation

Requirement: A structured process with adequate investment to incubate new technologies developed internally or through strategic partnerships.

Criterion 4: Commercialization Success

Requirement: A proven track record of commercializing new technologies by enabling new products and/or through licensing strategies.

Criterion 5: Application Diversity

Requirement: The development of technologies that serve multiple products, multiple applications, and multiple user environments.

Business Impact

Criterion 1: Financial Performance

Requirement: Overall financial performance is strong in terms of revenue, revenue growth, operating margin, and other key financial metrics.

Criterion 2: Customer Acquisition

Requirement: Overall technology strength enables acquisition of new customers, even as it enhances retention of current customers.

Criterion 3: Operational Efficiency

Requirement: Staff is able to perform assigned tasks productively, quickly, and to a high quality standard.

Criterion 4: Growth Potential

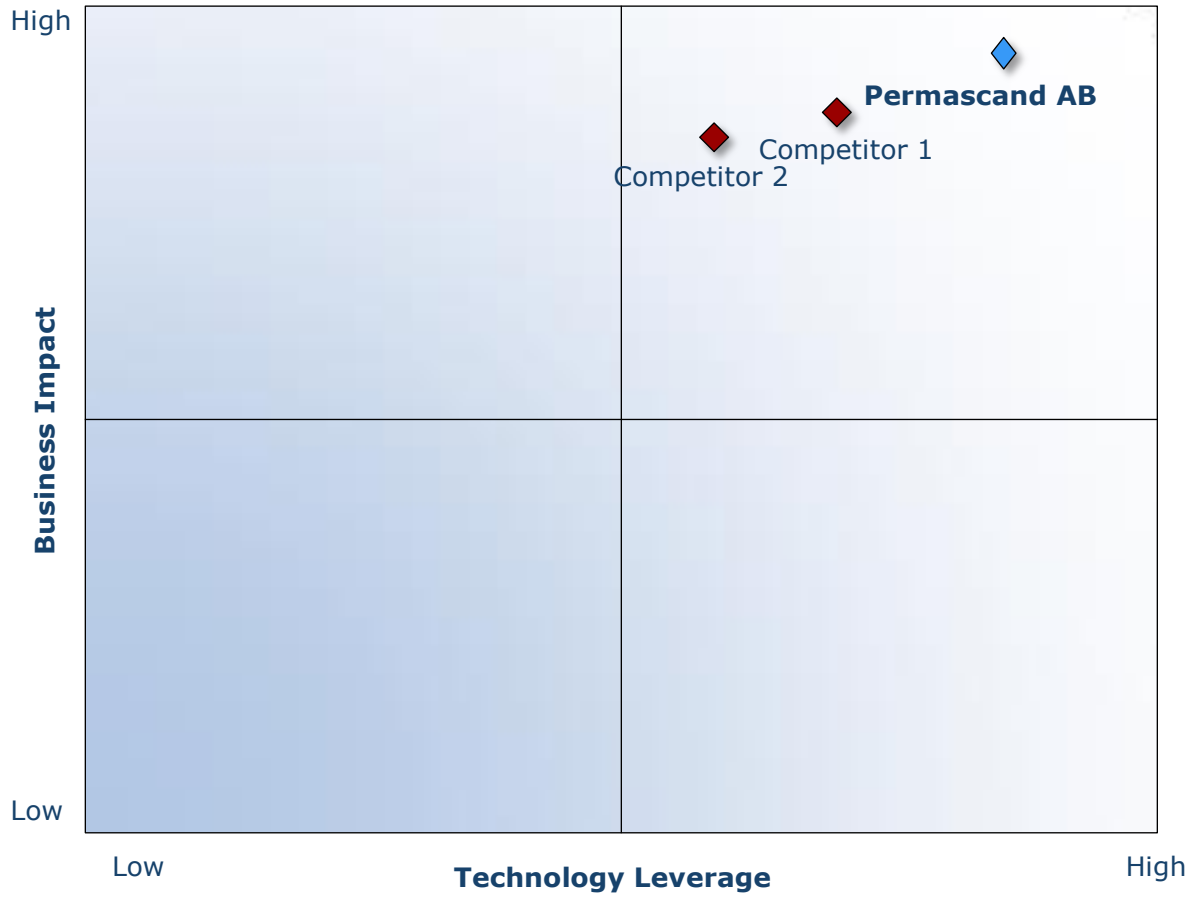
Requirements: Technology focus strengthens brand, reinforces customer loyalty, and enhances growth potential.

Criterion 5: Human Capital

Requirement: Company culture is characterized by a strong commitment to customer impact through technology leverage, which enhances employee morale and retention.

Decision Support Matrix

Once all companies have been evaluated according to the Decision Support Scorecard, analysts then position the candidates on the matrix shown below, enabling them to visualize which companies are truly breakthrough and which ones are not yet operating at best-in-class levels.



Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

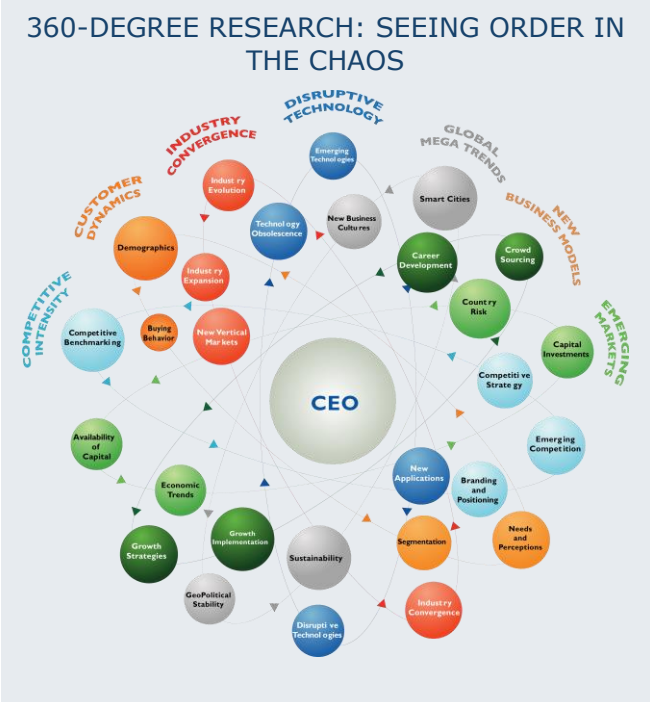
Frost & Sullivan analysts follow a 10-step process to evaluate award candidates and assess their fit with select best practices criteria. The reputation and integrity of the awards are based on close adherence to this process.

STEP		OBJECTIVE	KEY ACTIVITIES	OUTPUT
1	**Monitor, target, and screen**	Identify award recipient candidates from around the world	• Conduct in-depth industry research • Identify emerging industries • Scan multiple regions	Pipeline of candidates that potentially meet all best practices criteria
2	**Perform 360-degree research**	Perform comprehensive, 360-degree research on all candidates in the pipeline	• Interview thought leaders and industry practitioners • Assess candidates' fit with best practices criteria • Rank all candidates	Matrix positioning of all candidates' performance relative to one another
3	**Invite thought leadership in best practices**	Perform in-depth examination of all candidates	• Confirm best practices criteria • Examine eligibility of all candidates • Identify any information gaps	Detailed profiles of all ranked candidates
4	**Initiate research director review**	Conduct an unbiased evaluation of all candidate profiles	• Brainstorm ranking options • Invite multiple perspectives on candidates' performance • Update candidate profiles	Final prioritization of all eligible candidates and companion best practices positioning paper
5	**Assemble panel of industry experts**	Present findings to an expert panel of industry thought leaders	• Share findings • Strengthen cases for candidate eligibility • Prioritize candidates	Refined list of prioritized award candidates
6	**Conduct global industry review**	Build consensus on award candidates' eligibility	• Hold global team meeting to review all candidates • Pressure-test fit with criteria • Confirm inclusion of all eligible candidates	Final list of eligible award candidates, representing success stories worldwide
7	**Perform quality check**	Develop official award consideration materials	• Perform final performance benchmarking activities • Write nominations • Perform quality review	High-quality, accurate, and creative presentation of nominees' successes
8	**Reconnect with panel of industry experts**	Finalize the selection of the best practices award recipient	• Review analysis with panel • Build consensus • Select recipient	Decision on which company performs best against all best practices criteria
9	**Communicate recognition**	Inform award recipient of recognition	• Announce award to the CEO • Inspire the organization for continued success • Celebrate the recipient's performance	Announcement of award and plan for how recipient can use the award to enhance the brand
10	**Take strategic action**	Upon licensing, company is able to share award news with stakeholders and customers	• Coordinate media outreach • Design a marketing plan • Assess award's role in strategic planning	Widespread awareness of recipient's award status among investors, media personnel, and employees

The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of the research process. It offers a 360-degree view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often companies make important growth decisions based on a narrow understanding of their environment, resulting in errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry players and for identifying those performing at best-in-class levels.



About Frost & Sullivan

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