## EXECUTIVE SUMMARY

There is an ever-increasing demand to improve the quality of potable wastewater in our surroundings. The nature of pollution and extreme threat to human and aquatic life caused by organic pollutants, especially aromatic compounds, has led to research being conducted on developing new methods fro the treatment and management of organic pollutants in water.

In this report, the sources and effect that aqueous phenol has on the environment are discussed. Different methods that are currently being used or commercialized, for the degradation of phenol in water are also discussed and the advantages as well as disadvantages of such processes are outlined.

The research discussed in this report is based on the development of a novel method for the degradation of organic compounds in water. The process is based on a flow-through system, which uses the combination of electrochemistry and membrane technology. Ceramic-based membranes were modified to exhibit properties for conducting electricity by deposition of various kinds of electroconductive layers on the membranes' surfaces. Electrocatalytic layers were also deposited on the electromembranes, which did not posses enough catalytic properties for the anodic decomposition of organic compounds in water.

Electromembrane reactors based on tubular ceramic membranes and flat sheet type ceramic membranes were designed and constructed. These purification units were used to study the electrochemical oxidation of aqueous phenol under different pH conditions, applied potential, flow rate and different types of materials that were coated on the membranes.

The electrochemical oxidation of phenol is also associated with the production of various types of intermediates. Among these are aromatic compounds, aliphatic acids and oligomers. It was, therefore, an important part of the research to develop fast and reliable analytical methods to monitor the disappearance of phenol in the feed solution as well as determine the type and concentration of all the by-products that would be formed. Three methods based on the measure of total phenol index, GC-MS and HPLC were developed. HPLC was found to be the quickest and reliable method for the qualitative and quantitative analysis of all the organic compounds. Measurements to determine the oxygen demand in the samples that had already passed through the electromembrane reactor were also carried out.

Aims of the contract

According to the contract, the objectives of the research project were as follows:

- Development of laboratory prototypes of novel high efficiency installations for the decomposition and total combustion of organic pollutants present in industrial effluent and potable water.
- Determination of optimum properties of ceramic-based membranes for the preparation of electrocatalytic composite membranes active in the direct electrochemical oxidation of organic pollutants.
- Development of synthetic procedures for the preparation of electrocatalytic membranes.
- Designing and development of optimal electromebrane reactors for the decomposition of organic pollutants.
- Manufacture of laboratory-scale as well as bench scale catalytic reactors for organic decomposition.
- Evaluation of reactor performance and determining decomposition efficiencies for selected effluents.

Findings

Tubular electromembrane units

The use of the tubular electromembrane, in general, for the electrochemical oxidation of organic pollutants in water was successful for the following reasons:

- A novel type of water purification unit was developed whereby, the organic pollutant (phenol) could be rapidly degraded by simply flowing through an electrically charged membrane.
- Methods for the preparation of electroconductive materials and electrocatalysts on the ceramic membranes' surface and matrix were developed.
- Apart form the material science and engineering involved with the development of these purification units, analytical methods and procedures based on spectrometry, GC-MS and HPLC for the determination of phenol concentration and its oxidation products were developed.
- The energy requirements for the complete oxidation of phenol in the electromembrane units, equipped with tubular ceramic membranes, were low (between 1.3 and 6.0 Wh/g).

Flat-sheet type electromembrane reactor

Flat-sheet type electromembrane reactor was designed and constructed.

- The bench-scale purification unit was used successfully for the electrochemical oxidation of phenol under different pH conditions and various types of electrolyte solutions.
- Complete degradation of phenol in phenolic effluent from the SAPREF (Durban, RSA) oil refinery was achieved over the entire pH range.
- In the bench-scale purification unit, COD could be reduced to less that 50 mg/L when treating the SAPREF (Durban, RSA) effluent.
- Apart from the immense technological advantage for oil refineries situated along the coast, the energy requirements for the degradation of phenol are very low.
- Under acidic conditions, when either acid mine drainage or $H_2SO_4$, is used as an electrolyte source, phenol is readily decomposed to p-benzoquinone and other hydrophilic, low molecular weight products, viz. the organic acids. These acids belong to non-hazardous solutes that have maximum permissible concentrations (MPC).
- In contrast, the maximum permissible concentrations of phenol and p-benzoquinone are at levels of 0.01 to 0.001 mg/L. The concentration of p-benzoquinone in most of the experiments that were conducted under acidic conditions was greater than 13 mg/L. From an electrosynthesis point of view p-benzoquinone is an interesting product since it has many important uses. It is used in the manufacture of unsaturated polyesters, as a polymerization inhibitor and raw material for hydroquinone. 1,4-Benzoquinone reacts with trialkylboranes to produce alkyl-substituted hydroquinones and so on.

Research Beneficiaries

The research is aimed at developing novel technology for the treatment of water polluted with organic compounds that will in turn be comparative with existing methods of treatment. The technology can be applied in the following industries:

ESKOM, Water Treatment Industry, Chemical Industry, Refineries, Food and Wine Industry, Textile Industry, Communities and Local Authorities.

Application areas

- Industrial feeds and waters with excessive total organic carbon (TOC)
- Natural draft wet cooling systems (for re-entry into the system)
- Industrial blowdown and raffinate waters - especially biorefractory organics

- Pretreatment for bio-degradation streams
- Treatment of groundwater

List of potential effluents

- Phenolic effluent from SAPREF oil refinery in Durban
- High COD organic effluent from wine makers such as KWV
- Phenolic effluent for the Cape Olives farm in Hugenot
- Organic effluent from fisheries, such as, I&J
- Phenolic and other simple effluents from the Pulp and Paper industry e.g. Sappi and Mondi
- Effluent resulting from the development of phenolic resins
- Chlorophenol-containg effluent in leather tanning and finishing industries