Wet Air Oxidation in Quebec: Industrial Opportunities and Challenges An Update on CTTEI's Research Program

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1. Introduction

In 2014, the CTTEI started an extensive applied research program on Wet Air Oxidation (WAO), as a clean technology using subcritical water for the treatment of organic wastes and effluents, while generating energy from the oxidation reactions or organic compounds. Even if economic conditions seem favorable to WAO processes in the province of Quebec, Canada, where clean and affordable hydroelectricity is available and national regulations are dissuasive to incineration, WAO was still unknown to local industries back then. While catalyzed and non-catalyzed WAO processes have been industrialized in other countries for many years now, mainly for the treatment of refinery spent caustic wastes and municipal sludges [1,2], local residues have specific characteristics that required technological adaptation. For instance, lagoon sludges that are generated from more than 600 wastewater treatment plants (WWTP) in Quebec contain up to 30% silica minerals and differ from the activated sludges that are usually treated by WAO. Pulp and paper industry and hazardous waste management industry also face specific challenges that will be further discussed.

Since 2014, hundreds of laboratory tests have been carried out at CTTEI's, enabling proofs of concept on a dozen of industrial applications, including several new and innovative ones. In 2021, a new milestone has been reached with the inauguration of a new laboratory on Supercritical Fluids at CTTEI's, which features a continuous WAO pilot equipment. This equipment allows for further studies towards scale-up and support for industrial implementation. An overview of the progress made so far on the different research projects will be presented and the challenges to overcome to aim for technology transfer will be discussed.

2. Methodology

Batch experiments were conducted using two laboratory batch equipment's that were previously described [4]. During the reaction, the oxidation efficiency was measured by the reduction of COD and TOC overtime, while observing a rise of biodegradability (BOD to COD ratio). Acetic acid was detected as a reaction by-product in most of the case, and analysed by ionic chromatography. The continuous pilot-scale equipment was manufactured by A3i-Inovertis and co-designed with CTTEI. It is equipped with an Inconel reactor, with a maximum flow-rate of 8 L/h and maximum operating temperature and pressure of 325 °C and 25 MPa. (fig.1).

Figure 1 WAO continuous pilot-scale equipment from A3i-Inovertis

CTTEI's team developed a step-by-step methodology aiming to quickly assess the techno-economic feasibility of each WAO project with the industrial partners. The main steps involved are :

1. Proof of concept : 2 to 5 batch experiments;

2. Optimization of operating variables (T, duration, O_2 stoichiometry) : 8 to 15 batch experiments;
3. Preliminary techno-economic study: process simulation, mass and energy balance, CAPEX-OPEX ± 50%: => GO/NO-GO for pilot-scale testing;
4. Pilot scale testing and optimization;
5. Second techno-economic study (CAPEX-OPEX ± 40 %) => GO/NO-GO for industrial phase;
6. Industrial phase – on-site pilot or industrial implantation (handover to industrial partners).

3. Results and discussion

Many innovative environmental applications of WAO have been studied by the CTTEI team since the beginning of this research program. Each of them as reached a different stage and faces specific challenges. An overview of these projects will be presented, and the environmental and economic benefits of each will be discussed, as well as the challenges to overcome.

Applications	**Current step**	**Outputs / Main advantages of WAO**
Municipal WWTP - lagoon sludges	Pilot-scale	Inert solid, Biodegradable liquid, Reduced landfilling, handling and transport of sludges.
Concentrated aqueous waste from chemical industry	Pilot-scale	Energy, Biodegradable liquid, Lower toxicity, Reduced GHGs, transport and incineration outside of province.
Municipal WWTP - activated sludges - Coupling with anaerobic digestion	Preliminary techno-economic analysis	Inert solid, Destruction of microplastics and pharmaceuticals, Energy, Reduce transport and handling of sludges
Hospital wastewater	Preliminary techno-economic analysis	Biodegradable liquid free of pharmaceuticals, Energy – heat (if sufficiently concentrated before treatment)
Pulper waste containing mixed plastics	Preliminary techno-economic analysis	Inert solid, Energy – heat for steam production, Biodegradable liquid, Reduce landfilling, Reduce natural gas consumption
Conversion of dairy wastes to organic acids	Batch - optimization	Production of acetic acid for the cleaning products industry
Conversion of wastes to high-value bioproducts – coupling with bioprocesses	Batch - optimization	Production of high value industrial bioproducts Reduce landfilling
Waste paint recycling	Batch - optimization	Recovery of TiO_2-rich minerals Reduced landfilling of hazardous waste
Electronic wastes recycling	Proof of concept (to come)	Solubilization of plastics Recuperation of high-value metals for recycling

4. Conclusion

This applied research program enables not only to explore innovative applications of WAO, but also to make it more accessible to businesses and municipalities in Quebec and Canada, as a cleaner alternative to landfilling and incineration.

References

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