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WEBINAR SERIES

CLOSING THE LOOP: ENVIRONMENTALLY SOUND MANAGEMENT OF END-OF-LIFE ODS AND HFC

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EPA United States Environmental Protection Agency

EOL ODS Destruction Technology and Action Strategies

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Introduction

- Presentation in two parts:
  - EOL/ODS destruction technologies
  - Action strategies/approaches for their application
- Main assumptions/principles
  - Main focus is on concentrated EOL ODS/HFC
  - Priority is to address the issue starting at source
  - Destruction is <u>not</u> technology limited in practical terms – either for concentrated chemicals or dilute contaminated solid waste.
  - The challenge is the organizational/logistical and economic linkage between source and destruction.

Part 1: Destruction Technology

- The ODS and HFCs of interest are halogenated chemicals which, as a general class of waste, are routinely subject to destruction or irreversible transformation globally.
- A range of technologies and commercial facilities using them exist globally, mainly in developed countries but increasingly in developing countries.
- Irrespective of technological process or its application in a specific facility, the key factors in qualifying/selecting what to use are:
  - Technical/environmental performance
  - Affordability of destruction (cost/kg)
  - Accessibility

The MP and EOL ODS/HFC Destruction

- MP destruction definition: "Permanent transformation or decomposition of all or a significant portion of the controlled substance".
- TEAP provides generic technology guidance on:
  - Approved technologies for production reporting
  - Recommended minimum technical/environmental performance criteria
  - Code of Good Housekeeping
- Generally track destruction requirements applicable to halogenated HW but generally less stringent and more flexible.

Destruction Technologies
Montreal Protocol/TEAP Guidance

- "Approved" destruction adopted only for purpose of production reporting as mandatory
- Can be used by countries and others as guidance in selecting methods/requirements for destruction but not mandatory, necessarily exclusive, or replace stricter national requirements.
- MP listed technologies do <u>NOT</u> mean any specific facility or operation would be suitable in terms of destruction efficient/environmental performance-should provide some direct demonstration

Decision XXX-6 Approved Destruction Processes -1

Technology	Concentrated				Dilute	
	Annex A	Annex C	Annex F			
	Group 1	Group 1	Group 1	Group 2		
	Primary CFCs	HCFCs	HFCs	HFC-23	ODS	HFCs
DRE*	99.99%	99.99%	99.99%	99.99%	95%	95%
Cement Kilns	Approved	Approved	Approved	Not determined		
Gaseous/Fume Oxidation	Approved	Approved	Approved	Approved		
Liquid Injection Incineration	Approved	Approved	Approved	Approved		
Municipal Solid Waste Incineration					Approved	Approved
Porous Thermal Reactor	Approved	Approved	Approved	Not determined		
Reactor Cracking	Approved	Approved	Approved	Approved		
Rotary Kiln Incineration	Approved	Approved	Approved	Approved	Approved	Approved
Argon Plasma Arc	Approved	Approved	Approved	Approved		

Decision XXX-6 Approved Destruction Processes - 2

Technology	Concentrated				Dilute	
	Annex A	Annex C	Annex F			
	Group 1	Group 1	Group 1	Group 2		
	Primary CFCs	HCFCs	HFCs	HFC-23	ODS	HFCs
DRE*	99.99%	99.99%	99.99%	99.99%	95%	95%
Inductively coupled radio frequency plasma	Approved	Approved	Not Determined	Not Determined		
Microwave Plasma	Approved	Approved	Not Determined	Not Determined		
Nitrogen Plasma Arc	Approved	Approved	Approved	Approved		
Portable Plasma Arc	Approved	Approved	Approved	Not Determined		
Chemical Reaction with H2 and CO2	Approved	Approved	Approved	Approved		
Gas Phase Catalytic De-halogenation	Approved	Approved	Approved	Not determined		
Superheated steam reactor	Approved	Approved	Approved	Approved		
Thermal Reaction with Methane	Approved	Approved	Not Determined	Not Determined		

Technical/Environmental Performance Standards for Destruction

Performance Parameter	MP/TEAP	Basel Convention G/L (POPs)	EC 2010/75/EU
Particulates (mg/Nm^3)	50	NR	10
HCl (mg/Nm^3)	100	NR	10
HF (mg/Nm^3)	5	NR	1
HBr/Br_2 (mg/Nm^3)	5	NR	
CO (mg/Nm^3)	100	NR	
Dioxin/Furan ($ng\text{-}ITEQ/Nm^3$)	0.2 (Conc.) 0.5 (Dilute)	0.1	0.1
DE (%)	n/a	99.999	n/a
DRE (%)	99.99 (Conc.) 95.0 (Dilute)	99.9999	n/a

Commercial High Temperature Incineration (HTI)

- High DE/DRE >99.99 DE/99.9999 DRE
- Readily available prequalified service providers in developed countries – Caution: Performance variation across facilities.
- Generally well monitored/regulated in developed countries - tracking and validation
- Variable capacity – Cl/F tolerance – 1-4 t/hr.
- Unit Cost Range US$1.5 – 15.0/kg depending on volumes
- Predominant technology of choice to date
- Public acceptance/ENGO opposition issues

Commercial High Temperature Incineration (HTI)

Commercial Scale Plasma Arc

- Designed for specialty HW destruction including EOL ODS/HFC - Several suppliers, main one is PLASCON
- Modular/transportable (single shipping container)
- Commercial facilities in Australia, Mexico, Japan and US
- High DE/DRE >>99.99/99.9999 and low emissions
- Capacities range -20-40 kg/hr. (125-250 t/year) for ODS/HFC
- Capital Costs - US$2.5-3.0 million w/o infrastructure
- Unit costs quoted in the range of US$5-20/kg. depending on overall plant throughput/market – US$9/kg quoted in Mexico
- Relatively high operating cost/power consumption
- Typically needs another stable waste market to be viable

Commercial Scale Plasma Arc

Cement Kilns

- High DE/DRE in theory but difficult to verify
- Limited direct systematic qualification data available
- Operator interest limited due to small volumes/revenue and product quality issues
- Option may be limited to relatively new/current process facilities achieving BAT/BAP air quality standards
- Unit costs for an established/qualified facility should be similar to HTI but often higher – US$7/kg quoted in Mexico for CFC-12
- Potentially a good option in absence of HTI access and possible for foam (low cost effectiveness terms of GEB)

Cement Kilns

Small Scale Portable Plasma Arc

- Small footprint transportable unit
- Reported installations in Japan and China as well as Argentina and Ecuador (neither operational)
- DE/DRE >99.99 and emission compliance reported
- Capacities range from 1-2 kg/hr. (3.6-7.2 t/year)
- Capital Costs - approximately US$150,000 w/o infrastructure cost which are high (electrical, pad etc.)
- High operating costs (US$30-50,000/year) for labor, utilities, service/maintenance and imported consumables
- Unit costs estimated to be > US$25/kg. dependent on refrigerant and throughput
- Potential viability in small but stable markets with a sustaining financiall mechanism.

Small Scale Portable Plasma Arc

Global Destruction Capacity -1

- United States (Based on 2021 USEPA Survey Report)
  - 29 commercial facilities, 13 of which list ODS refrigerants/blowing agents as a market
  - Approximately 40 non-commercial facilities supporting internally generated chemical waste/by-product destruction.
  - Technologies used primarily various forms of incineration as part of a general HW market.
  - One facility dedicated to ODS destruction (Plasma Arc), one integrated refrigeration de-manufacturing plant including destruction (catalytic destruction process)
  - Current commercial generation represents <0.1% of commercial US HW market

Global Destruction Capacity - 2

- NA5 Countries (Based on 2021 USEPA Survey Report)
  - 139 commercial facilities potentially available.
  - 54 are located in the EU and 80 in Japan
  - Technologies used primarily various forms of incineration but extend to wider range listed by TEAP.
- A5 Countries
  - 27 potential facilities concentrated in industrialized countries (i.e. China, Brazil, Colombia, Mexico, Turkey).
  - Range of incineration technologies (rotary kilns/cement kilns) but also including plasma arc
  - Limited data on facility specific performance qualification
- Adequate global destruction capacity exists

Destruction Cost Factors

- Destruction costs (including transportation from source) may range from USD2/kg to USD15/kg of chemical.
- Factors determining destruction costs:
  - Quantity lots shipped for destruction
  - Containment used
  - Distance between source and destruction facility
  - Transportation related transaction costs
  - Technology used and feed infrastructure required
  - Size/efficiency of destruction facility
  - Destruction certification requirements
  - Market maturity/predictability of business
- Could develop such that USD 2-3/kg would generally apply.

Future Destruction Technology Development

- Parallels with trends in polymer waste management
- TEAP (2018) identifies these as Conversion Technologies that generally break down the halocarbon into directly useful feedstock elements – approved for ODS/High potential for HFCs
  - Chemical Reaction with H2 and CO2
  - Gas Phase Catalytic De-halogenation
  - Superheated steam reactor
  - Thermal Reaction with Methane
- Potential to move from destruction to circular economy oriented technologies in the future.
- Active R&D globally on other conversion processes - HFCs
- Similar commercial developments applied to PU and PS foam

National and Global Destruction Strategies

- At this point, no significant market for destruction generally in developed or developing countries - Exceptions Japan, parts of EU
- Market perquisites
  - supportive policy policy/regulatory commitment
  - implementation of available financing mechanisms
  - Public/stakeholder awareness of the issue.
- Starting place for action is in developed counties generally –Account for majority of historical and current/near term ODS/HFC Banks

Action Strategy - Developed Countries

- Driven by emerging national climate change oriented policy policy/regulatory commitments
- Expanded implementation of available financing mechanisms
- Existing refrigeration servicing/commercial chemical waste mgt. service providers have capacity to respond as the market develops.
- Destruction costs will stabilize as economies of scale are reached and competition increases.
- Replicable experience already exist in Japan and increasingly in the EU.

Action Strategy - Industrialized Developing Countries

- Climate policy policy/regulatory commitments
- Apply approaches taken in developed countries, replicating and adapting good practice as applicable.
- A5 EOL ODS/HFC banks/growth concentrated in a few well advanced countries.
- Same list of perquisite conditions apply/can be implemented limited international support.
- Core technical/and commercial capacity is now in place to be incrementally expanded based on market.
- Expectation of future technology and operational innovation in these countries.

Action Strategy – Smaller/Less Developing Countries

- Progress climate oriented policy policy/regulatory commitments
- Focus on expanding/formalizing refrigeration servicing sector/basic HW capacity.
- Accumulation of quantities to provide economies of scale – by country and multi-country partnerships
- Facilitating access to global qualified destruction capacity
- Equitable sharing of carbon revenues in long term

- *Where material International support required!*

Action Strategy – International Institutions/Players

- Coordinated international action required as a priority if the EOL ODS/HFC issue is to be addressed
- Main players:
  - Climate/Ozone Conventions, (inc. subsidiary organs, funding facilities and implementing agencies etc.)
  - IFIs/National-Regional development agencies
  - International private sector stakeholder business associations and alliances.
- Promote and agree on need for action.
- Facilitate cooperation between developed/industrial developing countries.
- Direct international assistance to smaller/less developed countries

Concluding Summary

- Destruction of EOL ODS/HFC not technologically limited
- ESM global destruction capacity exists in both developed and industrialized developing countries
- Principal barriers are:
  - Availability of EOL ODS/HFC (market) at required scale
  - Capacity/willingness to pay for destruction
- Future technology innovation consistent with circular economy concepts and scaling down for application closer to source
- Substantive ESM of most EOL ODS/HFC within the capacity of developed and industrialized developing countries now if they want to.
- International support required for other developing counties.

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Thanks for your attention

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