Electrolyzed Water as a Novel Sanitizer in the Food Industry: Current Trends and Future Perspectives

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RADICAL WATERS – CITREX CHILE

A NEW ECO-SANITISER

- Electrochemically Activated Water (ECA) – or Electrolyzed Water (EW)
  - Disinfectant - Anolyte (HOCl) and Detergent - Catholyte (NaOH)
- Produced on-site from regular water and salt
- Popular due to simplicity of production
- Actively used in a number of applications in:
  - Agriculture
  - Medical sterilization
  - Food sanitation
  - Livestock Management
  - Other fields
    - antimicrobial techniques

HISTORY

- Developed in Russia, used in Japan since the 1980's in medical institutions for disinfection.
- Use expanded into livestock management and agriculture.
- Electrolyzed Reduced Water (ERW or Catholyte) 1931 - agriculture + medical
- 1966 Ministry of health declared Catholyte effective in treating:
  - Diarrhoea, indigestion, hyperacidity and antacid and home use.
- Technological advances > popularity – better equipment available
- ECA Anolyte became a promising non-thermal disinfectant

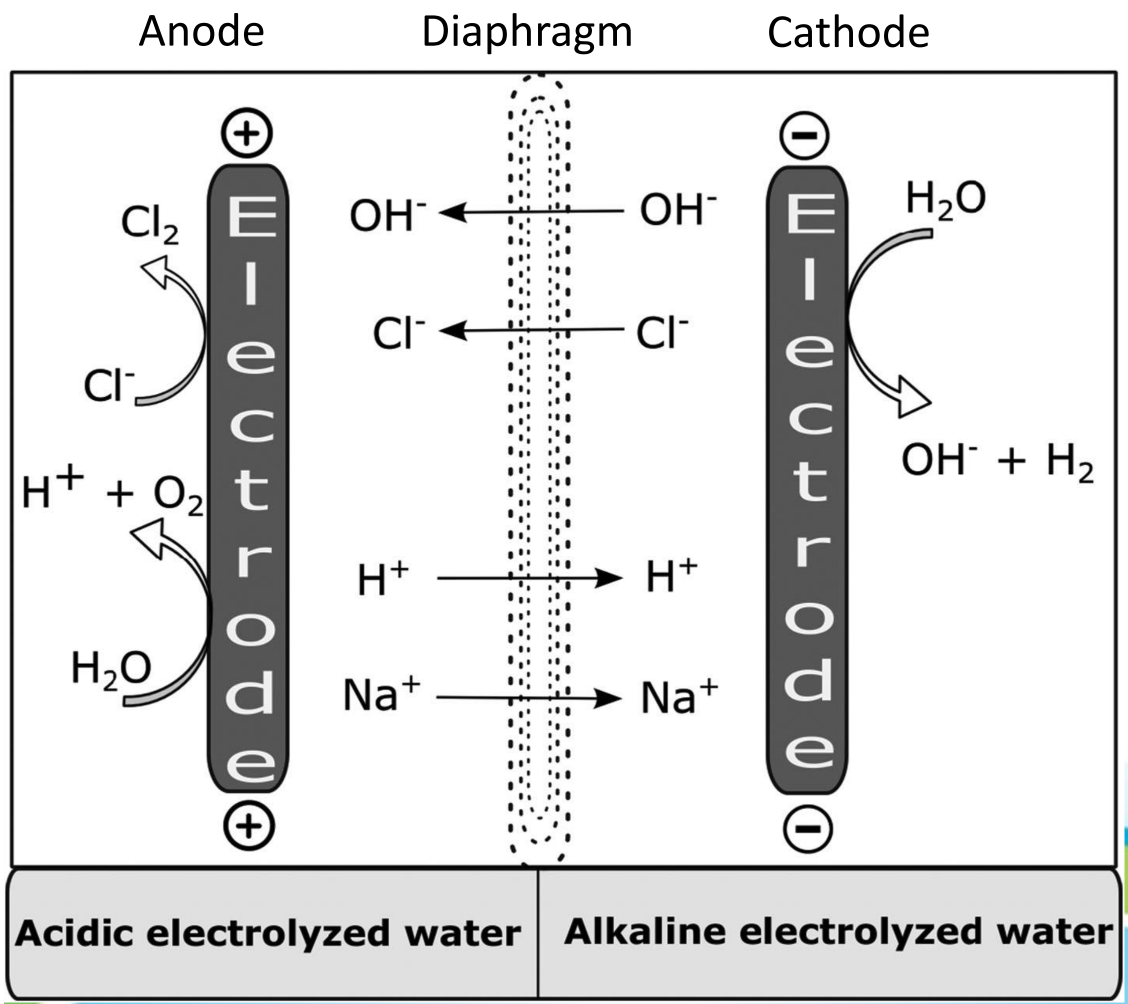
HOW ECA IS MADE

Acidic Electrolyzed Water (AEW)
Electrolyzed Oxidizing Water (EOW)
Anolyte

Hypochlorous acid (HOCl)
Hypochlorite ion (OCl^-)
Hydrochloric acid (HCl)
Oxygen Gas (O_2)
Chlorine Gas (Cl_2)
pH 2-3
ORP>1100mV

NEW Neutral Electrolyzed Water
pH 7-8
ORP 750-900mV

SAEW Slightly Acidic EW
pH 5-6.5
ORP >850mV



Basic Electrolyzed Water (BEW)
Electrolyzed Reduced Water (ERW)
Alkaline Electrolyzed Water (AlEW)
Catholyte

Sodium Hydroxide (NaOH)
Hydrogen Gas (H_2)
pH 10-13
ORP -800 to -900mV

TYPES OF ECA-PRODUCING SYSTEMS

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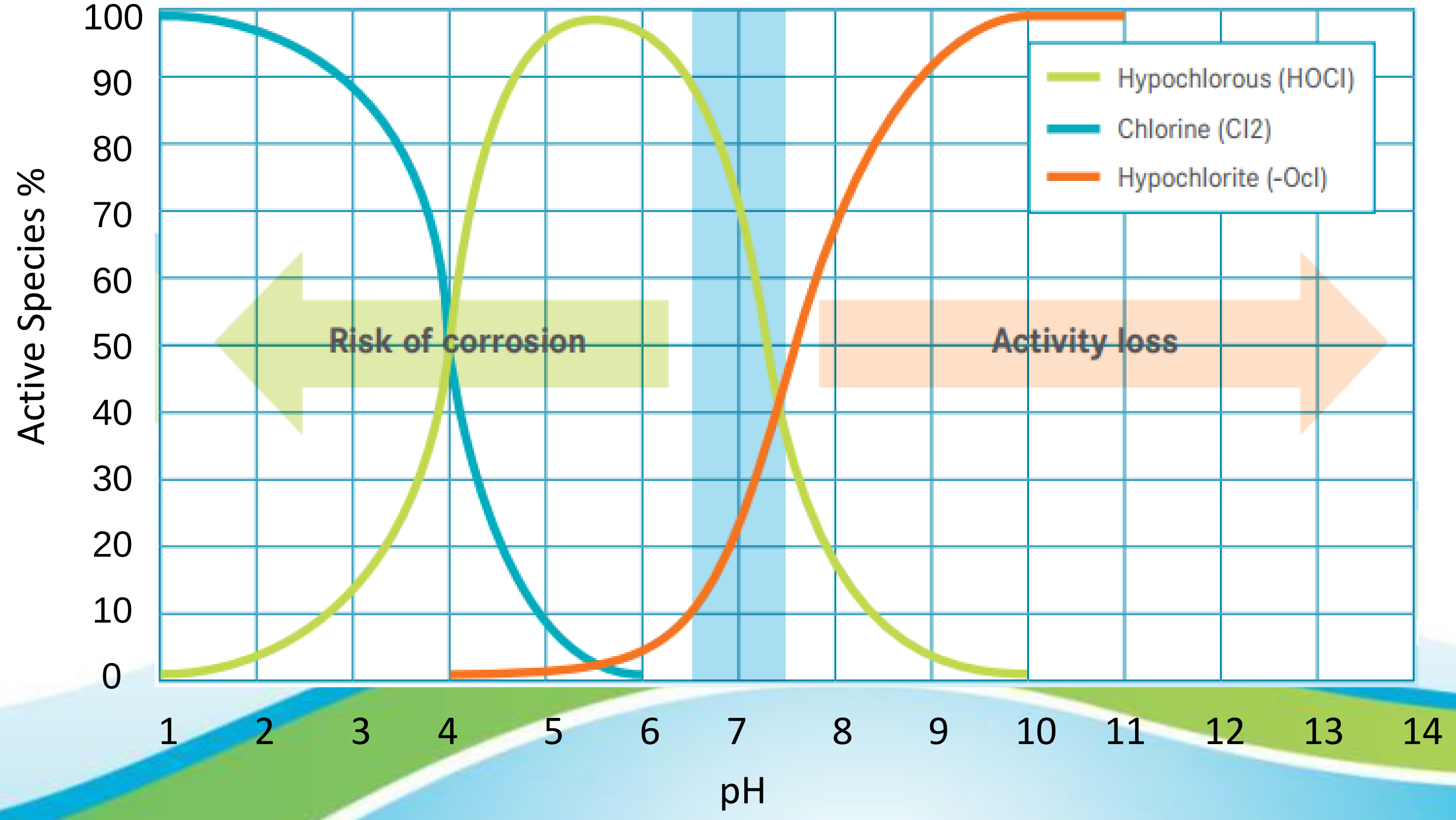
- Many systems for producing ECA available worldwide
  - Two main types – with and without diaphragms (pH differences),
  - single/dual stream
- AEW, NEW and SAEW (Anolyte) – powerful sanitizer
- BEW (Catholyte) – remove dirt and grease – strong reducing potential
- Brine, flow rate, voltage, amperage, available chlorine concentration
- Physiochemical properties of ECA varies depending on:
  - Concentration of sodium chloride (NaCl)
  - Current
  - Time of electrolysis
  - flow of water

BASIC PROPERTIES OF ECA

- Antimicrobial efficacy Influenced by pH, ORP and FAC

HOCl 80 times more effective than CLO^-



BASIC PROPERTIES OF ECA

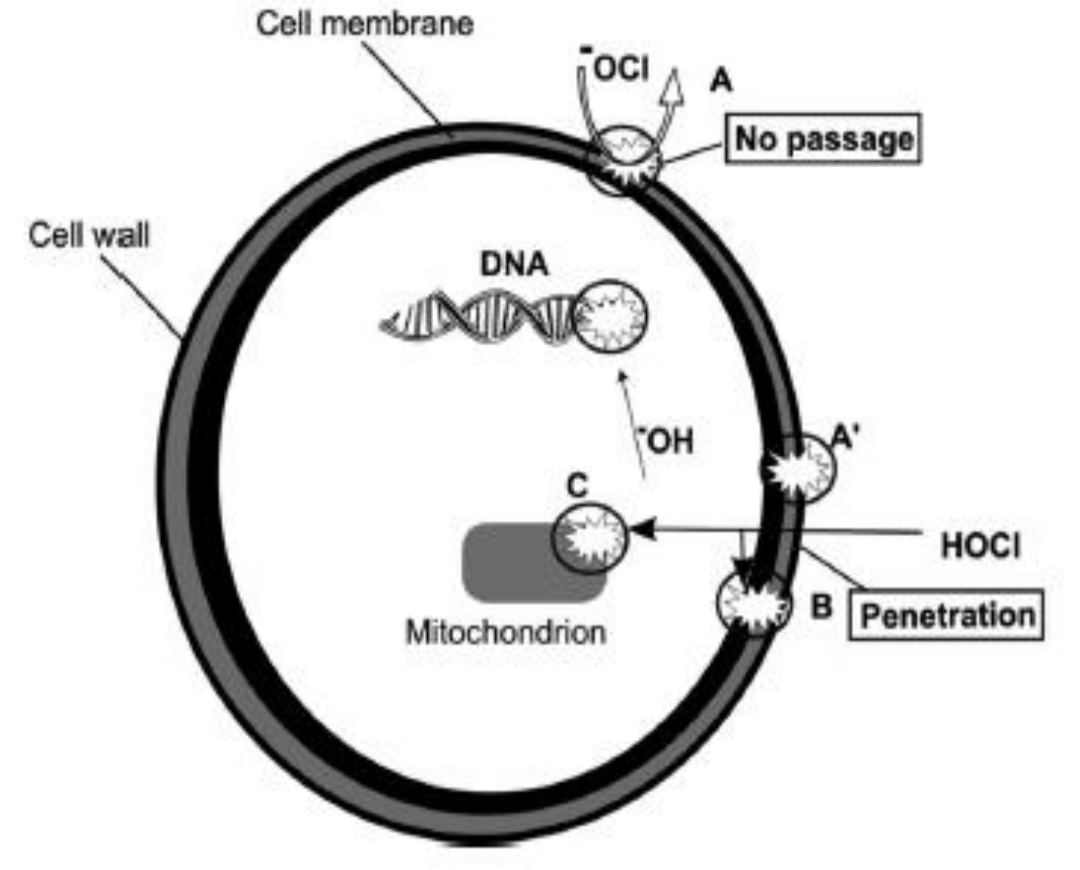
- Other factors having an influence on properties of ECA
  - current
  - water flow rate
  - salt concentration
  - storage conditions
  - electrolyte
  - electrode material
  - water temperature
  - water hardness

ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
Environmentally friendly – Salt, water, electricity	High Initial cost of equipment
Returns to original state after use.	Tendency to lose its antimicrobial potential quickly
Safety – Humans and the environment	Reduction in concentration of chlorine over time
On-site production	Pungent chlorine gas formation at pH <5
Broad-spectrum antimicrobial	Phytotoxicity, irritation and corrosion - Acidic Anolyte
No microbial resistance	Reduction in efficacy – storage and organic matter
Sensory quality of food products not affected	
Cost effective – cost 0.04 $/L	

ANTIMICROBIAL MECHANISM FOR ZERO TOLERANCE

- Active chlorine species (Cl_2, HOCl and OCl^-) inactivation of micro.
- Oxidants – reactive oxygen species (O_3 and H_2O_2) also contribute.
- HOCl – neutral charge – diffuse through cell
- HOCl attack on out outer membrane (A) and
- Also inside the cell (B) and (C)
- OCl^- unable to penetrate cell membrane
- Antimicrobial activity due to:
  - Inhibition of enzyme activity
  - Damage to membrane and DNA
  - Membrane transport capacity



APPLICATION OF ECA – IN-VITRO

- Anolyte strong antimicrobial activity in vitro avg. of >6 log CFU/ml
  - Variety of bacteria. Also effective against yeast, mould, spores.
- Foodborne pathogens – different sensitivities towards Anolyte
- Rahman et al (2010): increase in CT – reduction in log CFU/ml
  - 1 min – significant, 3, 5, 10 min – not significant reduction
- Factors influence antimicrobial activity
  - ORP, pH, FAC, and Temperature

Microorganisms	EW type	Exposure time (min)	Reduction (log CFU/mL)	[a]Chlorine conc. (ppm)	pH	ORP (mV)	Temp.
Escherichia coli	StAEW	1	6.0	50.3	2.6	1140	20
	SAEW	1	5.0	23.7	5.6	940	20
	SAEW	2	6.2	23.7	5.6	940	20
	NEW	1	>5.4	89	8.55	733	20
E. coli O157:H7	StAEW	1	6.0	50	2.6	1100	35
	LcEW	1	6.0	5	6.3	500	35
	LcEW	1.5	6.4	10	6.8	700	23
	SAEW	3	5.2	1.5	6.5	805	25
	NEW	1	ND	21	6.3	265	20
	AEW	1	ND	25	3.0	1079	20
	AEW	1	6.3	63	2.4	1183	22
E. coli O104:H4	StAEW	2	5.1	20	3.1	1150	20
	SAEW	2	4.2	10	3.5	950	20
	StAIEW	2	1.5	NA	11.1	-840	20
	SAIEW	2	1.5	NA	10.4	-715	20
Salmonella spp.	NEW	1	>5.5	89	8.5	733	20
	StAEW	1	6.1	50.6	2.6	1140	20
	SAEW	2	6.1	23.7	5.6	940	20
	StAEW	1	6.1	50	2.6	1100	35
	LcEW	1	6.3	5	6.3	500	35

REPLACING CHEMICALS IN FOOD INDUSTRY

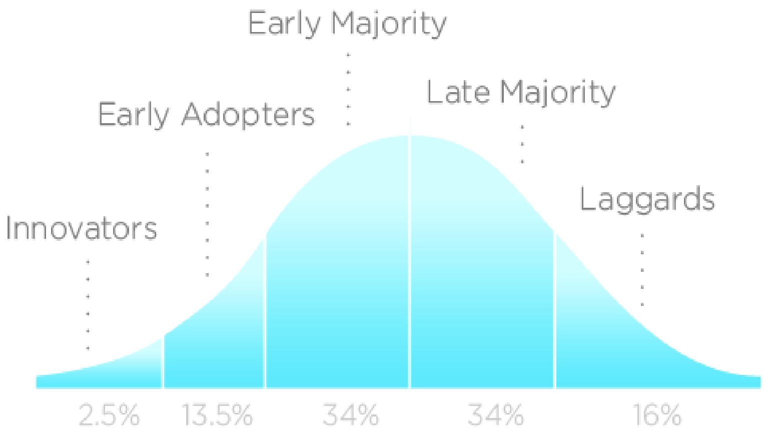
- Beverages – CIP
  - Water, CSD, Beer
- Fruit and Vegetables
  - Applied via dipping, spraying, soaking, washing during processing
- Poultry and Meat
  - Direct, fogging, CIP/COP, Equipment, water
- Seafood and Fish
  - Pre-processing, direct, CIP/COP, equipment, water, ice

APPLICATION OF ECA – OTHER

- Agriculture
  - Growth promotion, antifungal, disinfecting greenhouses, packing houses
  - Hydroponics – control of biofilm
- Livestock
  - Replacing antibiotics, increase FCR, fogging and sanitation of barns and houses
- Hospitality
  - Metal/plastic, cutlery, plates, glasses, cutting boards in the kitchen
  - Other areas and water supply - legionella
- Hospitals
  - Hard surfaces, equipment
  - Scopes, infectious waste

FUTURE PERSPECTIVES

- ECA approved by US regulators
  - Green and sustainable solution for home/industry use
  - Recently (USDA) approved ECA in organic products
- EU Biocides Regulation 528/2012 (EU BPR)
- Growing trend for commercialization
- In future – most industry likely to start using ECA
  - Simplicity, environmentally friendly, human safety aspect, efficacy, etc.
- Not sufficient knowledge – more advertisement required
- Over the next 10 years most food plants will start using ECA



INNOVATION ADOPTION LIFECYCLE

CONCLUSIONS

- ECA Anolyte exhibits strong bactericidal, virucidal and fungicidal effects
- Already operational in various sectors
- Acidic Anolyte – corrosive and affects organoleptic properties some foods
  - Solved with introduction and development of slightly acidic and neutral Anolyte.
- Combination of multiple techniques (hurdle enhancement) – advantages:
  - Micro reduction, enhanced shelf-life, food quality maintenance.
- Various factors govern the efficacy of ECA
  - Monitored and managed during production and application
- Advanced and dynamic ECA systems – overcome challenges
  - Available through RW-CITREX CHILE

THANK YOU

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Reference: Rahman, S.M.E., Khan, I., Oh, D.H.,2016. Electrolyzed water as a novel sanitizer in the food industry: current trends and future perspectives. Compr. Rev. Food. Sci. F 15, 471–490.