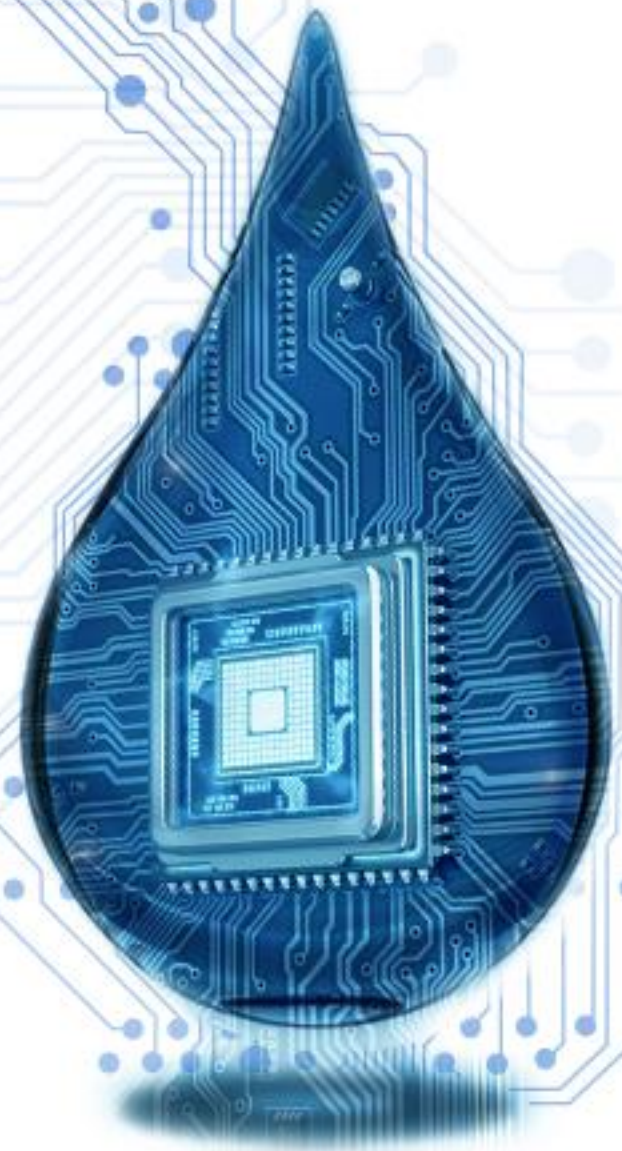
Stannous & Tin Dioxide for Waterborne and Airborne Contaminant Removal



Transforming the Way We See Water

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Agenda

- Introduction to Stannous and Tin Dioxide
- SafeGuard™ H2O In-situ Stannous Generator Applications
- SafeGuard™ H2O Applications of Tin Dioxide

Stannous & Tin Dioxide

A safe, non-toxic metal for drinking water treatment, industrial wastewater treatment and airborne contaminant removal.

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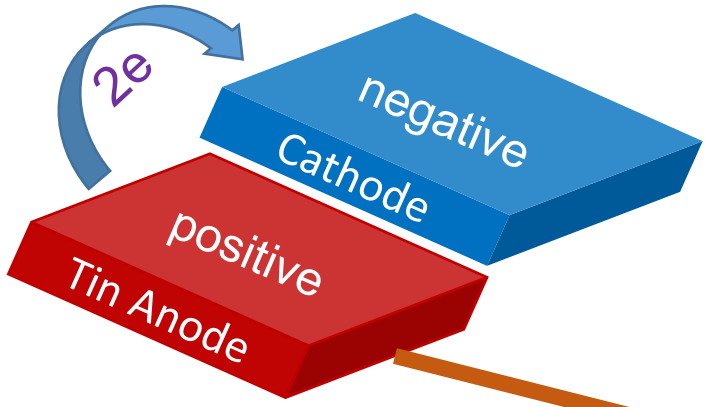
Novel Method Introduces Tin as Stannous Ions



In-situ, electrolytic Stannous generator with Tin metal precursor

The Fate of Electro-Generated Stannous Reagent

Sn^{2+} + O_2 → SnO_2

Soluble reactive reducer

Stable insoluble absorbent

In-situ Stannous Generator SafeGuard™ H2O

- Automated (remote control options)
- Controlled reagent dose
- Compact, modular and scalable
- NSF 61 Pending
- Economical (tin and electricity)
- On-demand reagent generation
- Stop and run mode

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The Power of Stannous & Tin Dioxide

		Industrial & Commercial Cooling Systems	Municipal/ Residential	Small Private Wells	Heavy Industry and Energy	Mineral Mining	Semi Conductor
Waterborne Contaminants	As		Groundwater		Process Effluent	Leaching & Byproducts	Process Effluent
	Cr(VI)						
	Pb/Cu		Anti Corrosion				
	Hg				Process Effluent		
	Se						
	Fe/Cu	Anti Corrosion					
Airborne Contaminants	$H_2S/SO_2/NOX/CO$				Flue & Process Gases		

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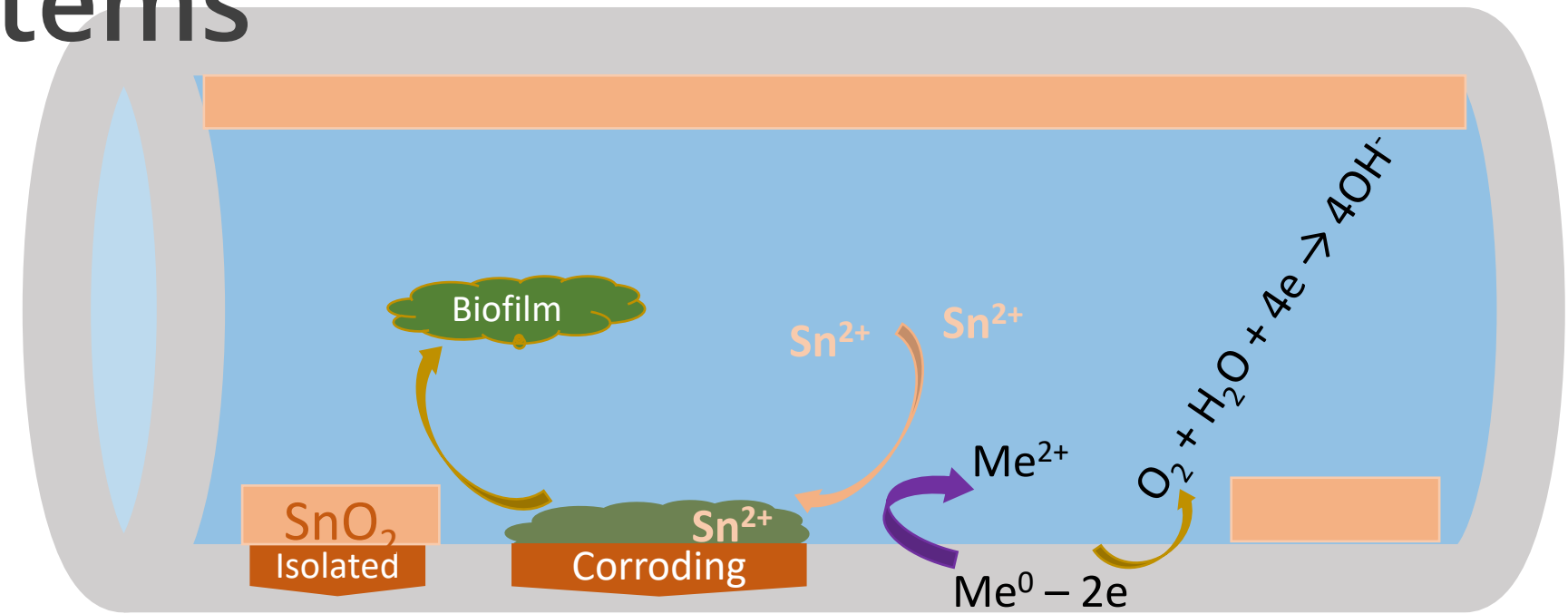
SafeGuard™ H2O

Applications for Stannous (Sn^{2+})

- Biocide
- Cr(VI) reduction
- Corrosion inhibition: Pb, Cu, Fe
- Dissolved Hg removal and recovery
- Se(IV) reduction and recovery

Biocide: Drinking Water & Cooling Systems



- Stannous ion introduced into cooling water penetrates biofilm in affected areas causing degradation (removal) and supressing bio-corrosion
  - Inhibitor dose tightly controlled
- Stannous reagent residuals converted into Tin Dioxide precipitate on exposed metal zones and isolate them from exposure to oxidizers

SafeGuard™ H2O Biocide: Drinking Water & Cooling Systems

FEATURES	BENEFITS
Stannous generated in-situ, on demand	No bulk chemical deliveries, storage and handling
Small footprint, modular/scalable	Ideal for deployment at commercial and industrial sites Addresses both biological and electrochemical corrosion
Tin and electricity are the only consumables	Non-toxic reagent (Tin), displaces problematic orthophosphates (supply chain security, downstream impacts on waste treatment plants and the environment) Avoids corrosion caused by treatment chemicals and oxidants (chlorine, chlorides, etc...) Low operating costs and maintenance
Dosing controlled automatically	Operates unattended Remotely monitored

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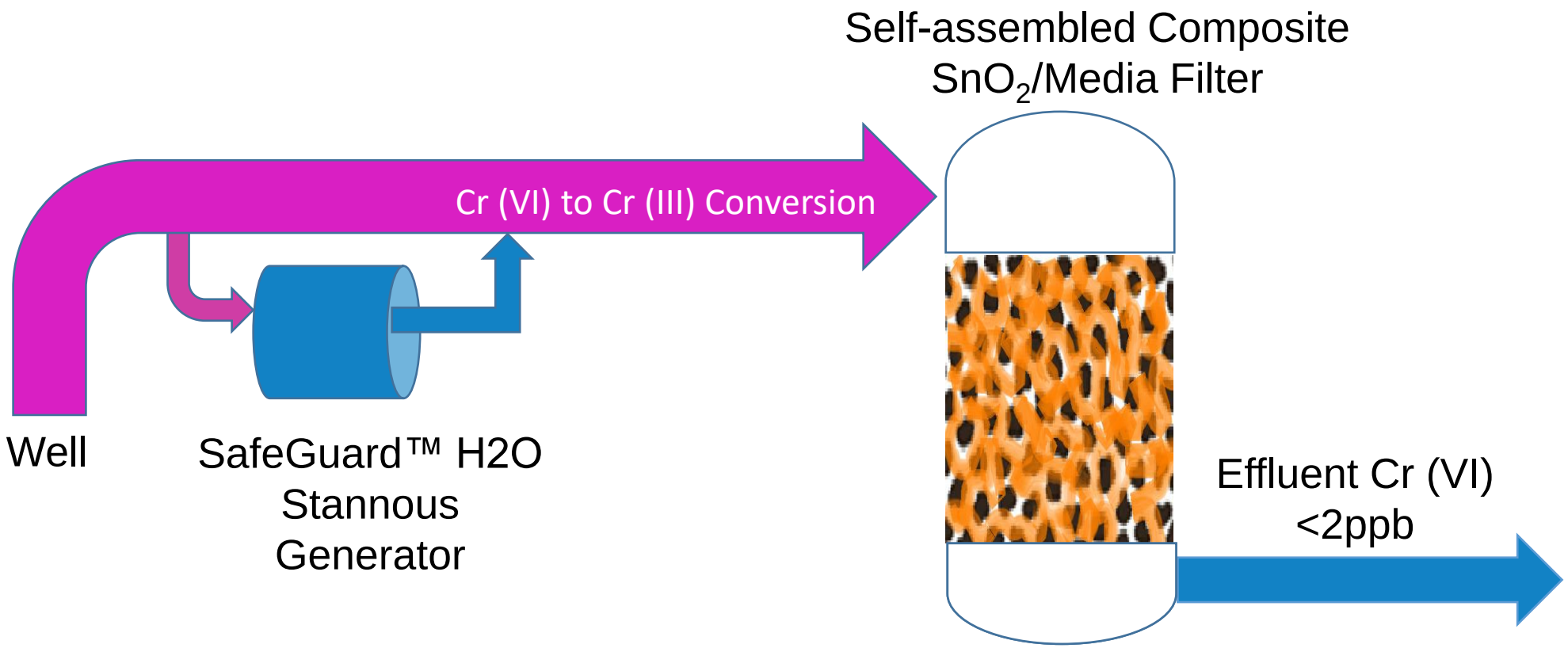
Cr(VI) Reduction Enhanced with SnO_2 Filter



$$3Sn^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 3Sn^{4+} + 2Cr^{3+} + 7H_2O$$

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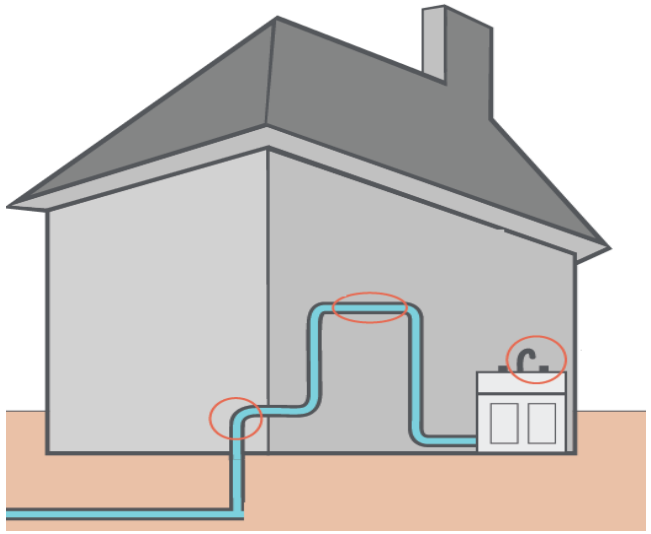
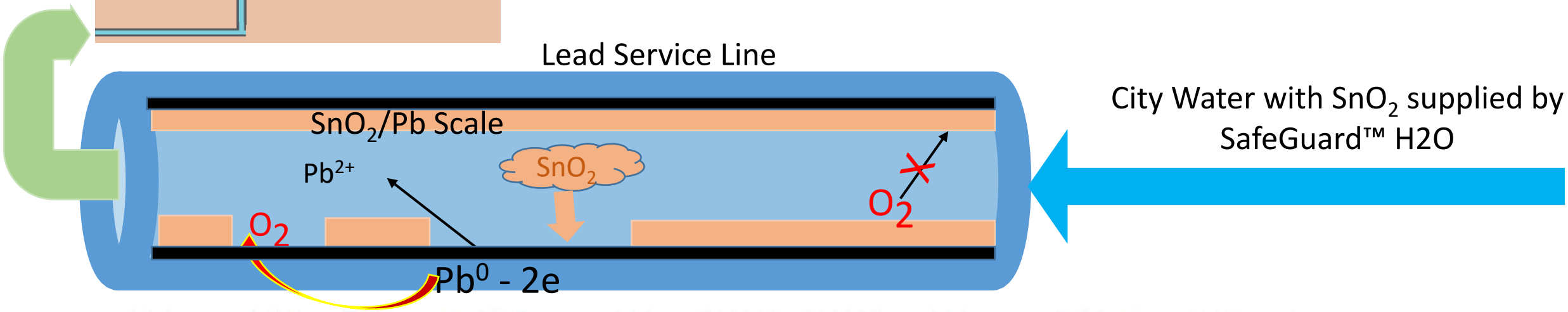
SafeGuard™ H2O
Cr(VI) Reduction Drinking Water

FEATURES	BENEFITS
Stannous generated in-situ, on demand	No bulk chemical deliveries, storage and handling
Skid-mounted, small footprint	Ideal for urban locations (point-of-supply/point-of-entry) Requires minimal civil works, reduces engineering overhead
Tin and electricity are the only consumables	Non-toxic precursor (Tin) and useful by-product (Tin Dioxide) Low operating costs and maintenance
Dosing controlled automatically	Operates unattended, reduces site supervision requirements
Low system inertia	Ideal for unattended non-continuous well operation
By-product (Tin Dioxide) can be reused	Reduces net operating costs, enables waste reuse

Corrosion Inhibition: Lead



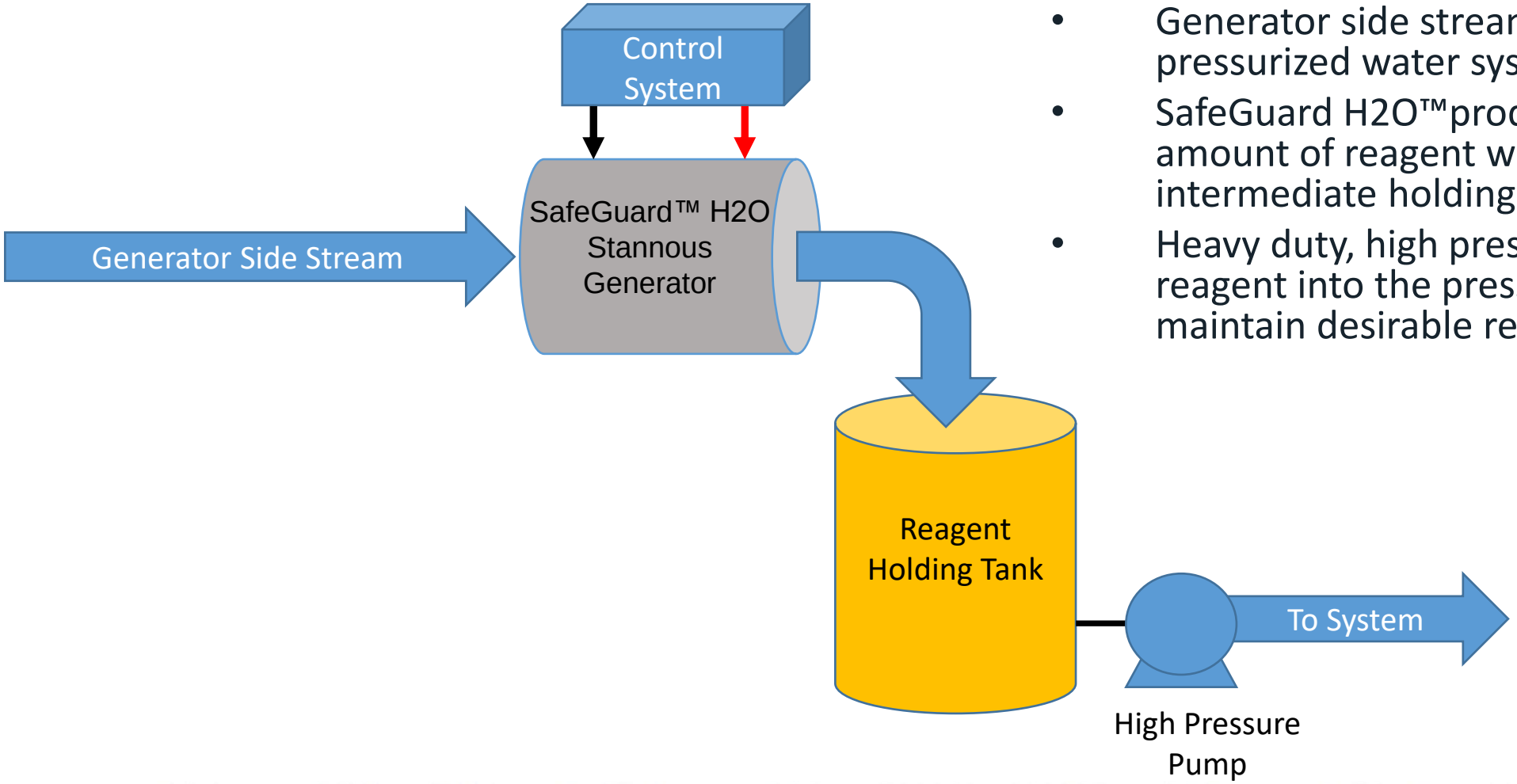
- Stannous is injected into lead service lines serving residential zones and buildings, schools, day cares, etc...
- Stannous turns into suspended insoluble tin dioxide
  - Precipitates on internal surface of the corroding pipe to form a protective layer
  - Inhibits massive electrochemical corrosion of lead metal by corrosive agents (oxygen, chlorine, etc…)



SafeGuard™ H2O
Corrosion Inhibition: **Lead in Drinking Water**

FEATURES	BENEFITS
Stannous generated in-situ, on demand	No bulk chemical deliveries, storage and handling
Small footprint	Ideal for localized deployment in urban risk zones (schools, day-care, residential areas and buildings)
Tin and electricity are the only consumables	Non-toxic reagent (Tin), displaces problematic orthophosphates (supply chain security, downstream impacts on waste treatment plants and the environment) Avoids corrosion caused by treatment chemicals and oxidants (chlorine, chlorides, etc...) Low operating costs and maintenance
Dosing controlled automatically	Operates unattended Remotely monitored Can respond immediately to increased risk of lead/copper corrosion caused by transient changes in water quality (see MetalGuard Lead Alert™)

Corrosion Inhibition: Cooling Systems

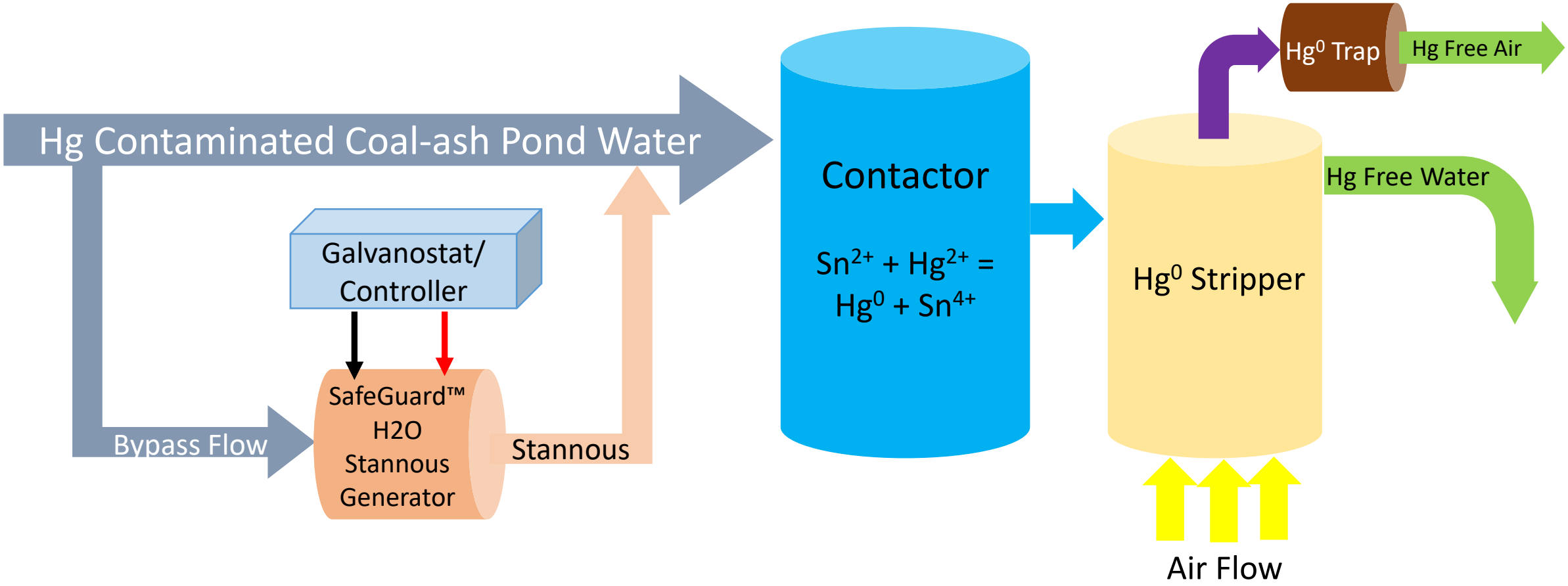


- Generator side stream comes from the pressurized water system
- SafeGuard H2O™produces a predetermined amount of reagent which is discharged into intermediate holding tank
- Heavy duty, high pressure pump injects fresh reagent into the pressurized water system to maintain desirable reagent concentration

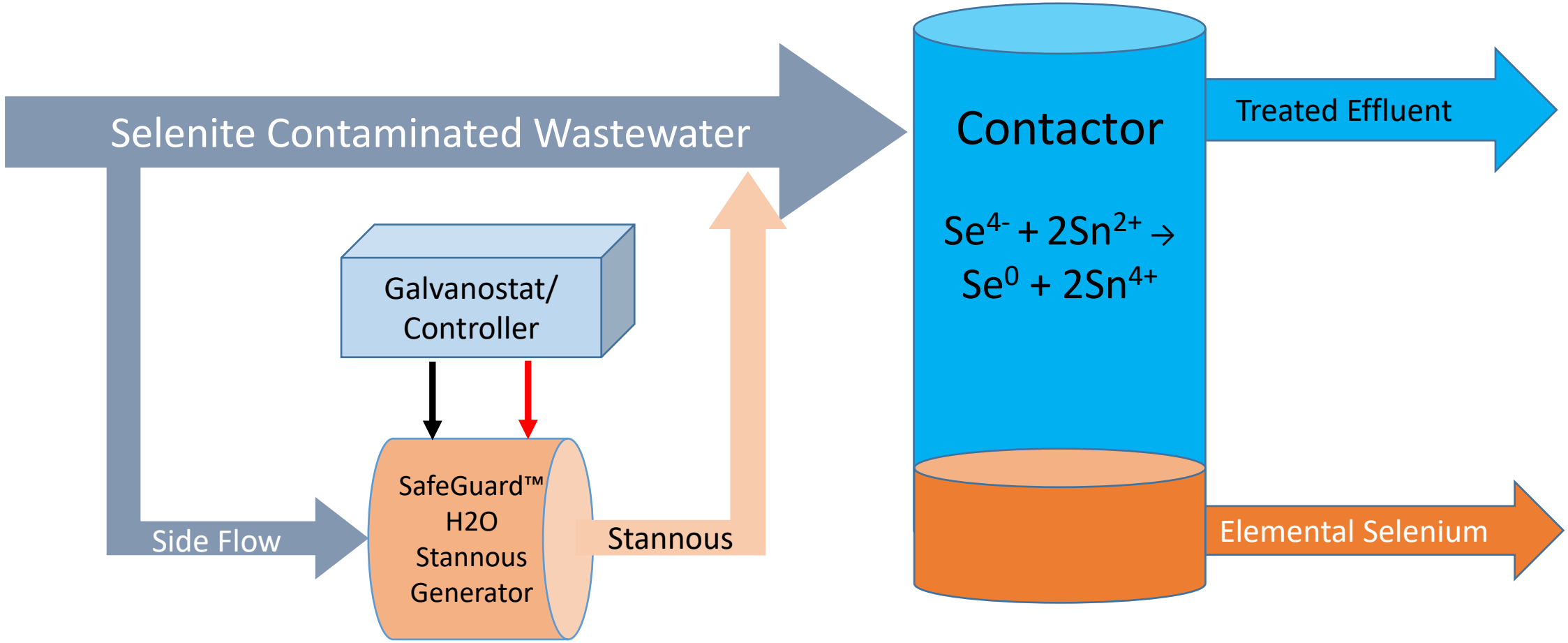
SafeGuard™ H2O
Corrosion Inhibition: **Cooling Systems**

FEATURES	BENEFITS
Stannous generated in-situ, on demand	No bulk chemical deliveries, storage and handling
Small footprint, modular/scalable/mobile	Ideal for localized deployment at commercial and industrial sites
Tin and electricity are the only consumables	Non-toxic reagent (Tin), displaces problematic orthophosphates (supply chain security, downstream impacts on waste treatment plants and the environment) Low operating costs and maintenance
Dosing controlled automatically	Operates unattended Remotely monitored

Dissolved Mercury Recovery



Selenium Recovery



SafeGuard™ H2O
Selenium & Mercury Recovery: Industrial Wastewater

FEATURES	BENEFITS
Stannous generated in-situ, on demand	No bulk chemical deliveries, storage and handling compared to physicochemical alternatives
Ease of operation and reliability	Operates under wide range of ambient conditions compared to biotreatment systems
Small footprint	Rapid to deploy and mobile
Tin and electricity are the only consumables	Low operating costs and maintenance compared to organosulfides and biotreatment
Recovery of elemental mercury and selenium	Eliminates toxic waste disposal costs associated with biotreatment and physicochemical processes Valuable non-renewable resources (Selenium)

SafeGuard™ H2O

Applications for Tin Dioxide (SnO_2)

- Airborne metal removal: Hg, Cr, etc...
- Corrosion inhibition: Pb, Cu, Fe, etc…
- Dissolved metal removal: As, Cr, Pb, Hg, etc…
- Dissolved non-metal removal: hydrocarbons, phenol, organic dyes
- Gas desulfurization: SO_2, H_2S

Drinking Water Treatment

As, Hg, Cr(VI), Pb, removal for homes and wells (point-of-entry, point-of-supply)

Pb removal for homes (point-of-entry, point-of-use)

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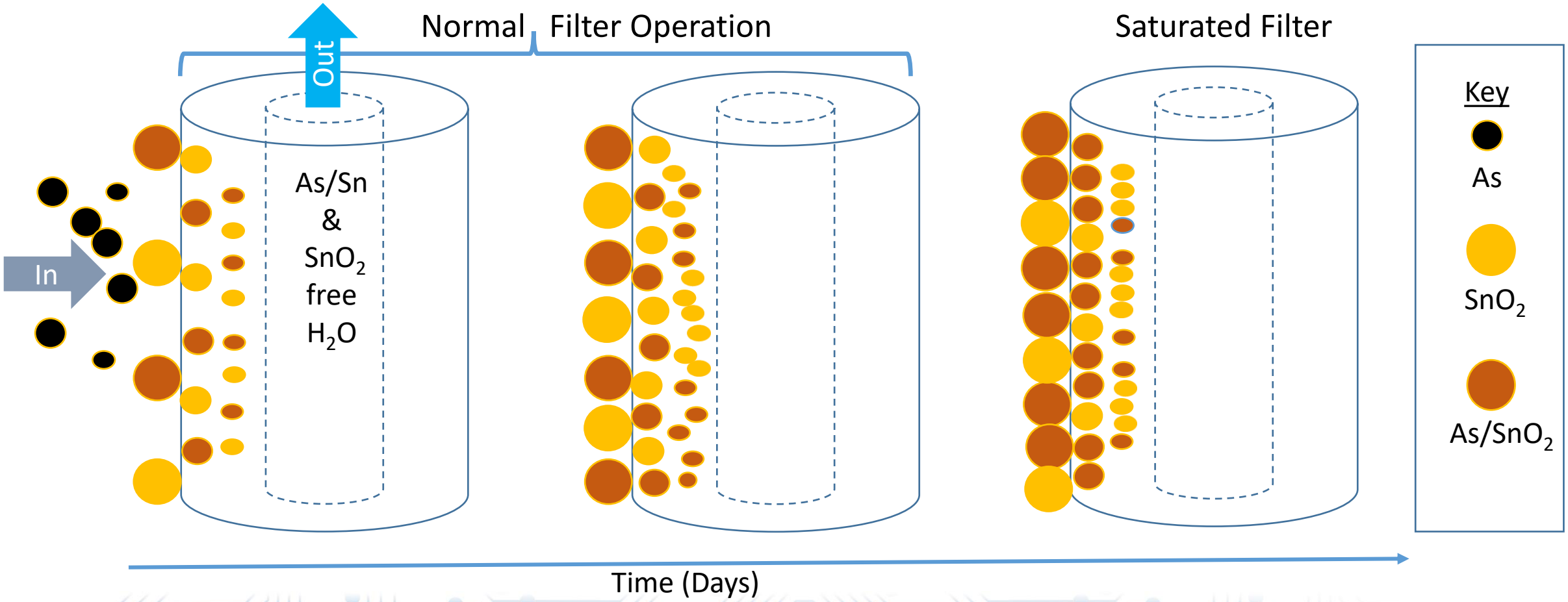
Arsenic (As^{3+} / As^{5+}) Removal

The "active mass" of the dynamic composite filter accumulates continuously as tin dioxide is deposited and this increases its capacity.



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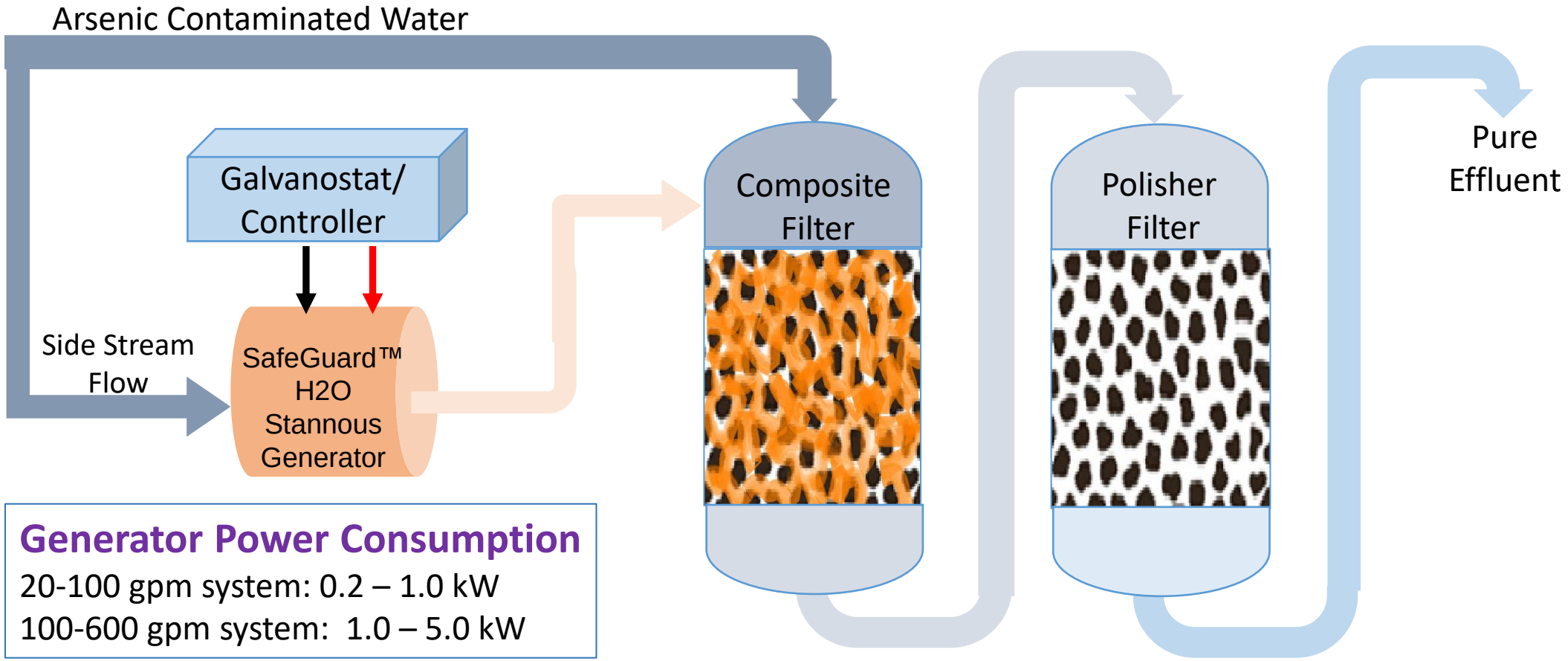
Arsenic Removal: Point-of-Supply (Wells)



Generator Power Consumption

20-100 gpm system: 0.2 – 1.0 kW

100-600 gpm system: 1.0 – 5.0 kW

- Non-toxic Tin Dioxide active material applied uniformly onto substrate without additional process steps
- Sorbent can be removed from substrate in controlled, automated manner which allows media regeneration and reuse
- SafeGuard™ H2O suitable for 1-600 gpm

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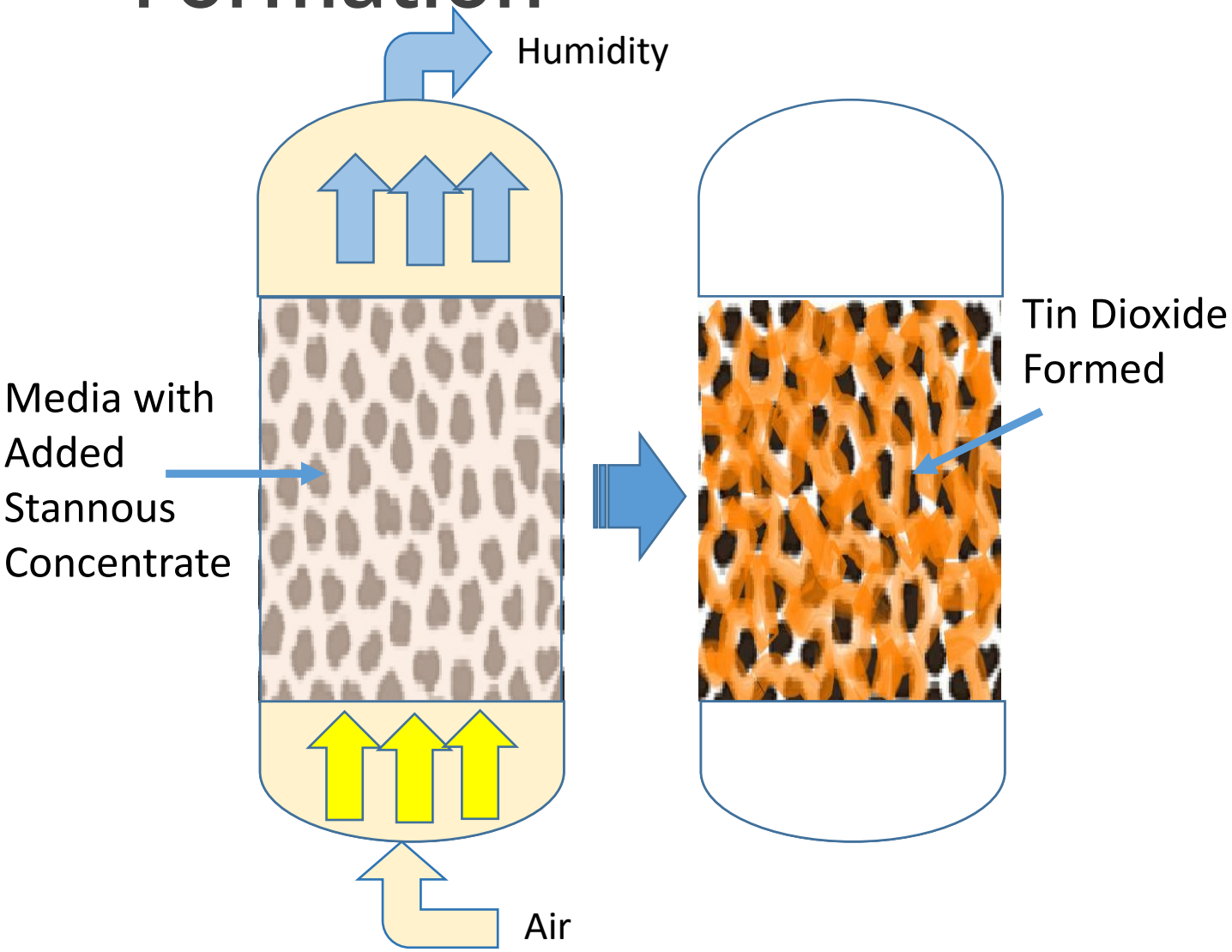
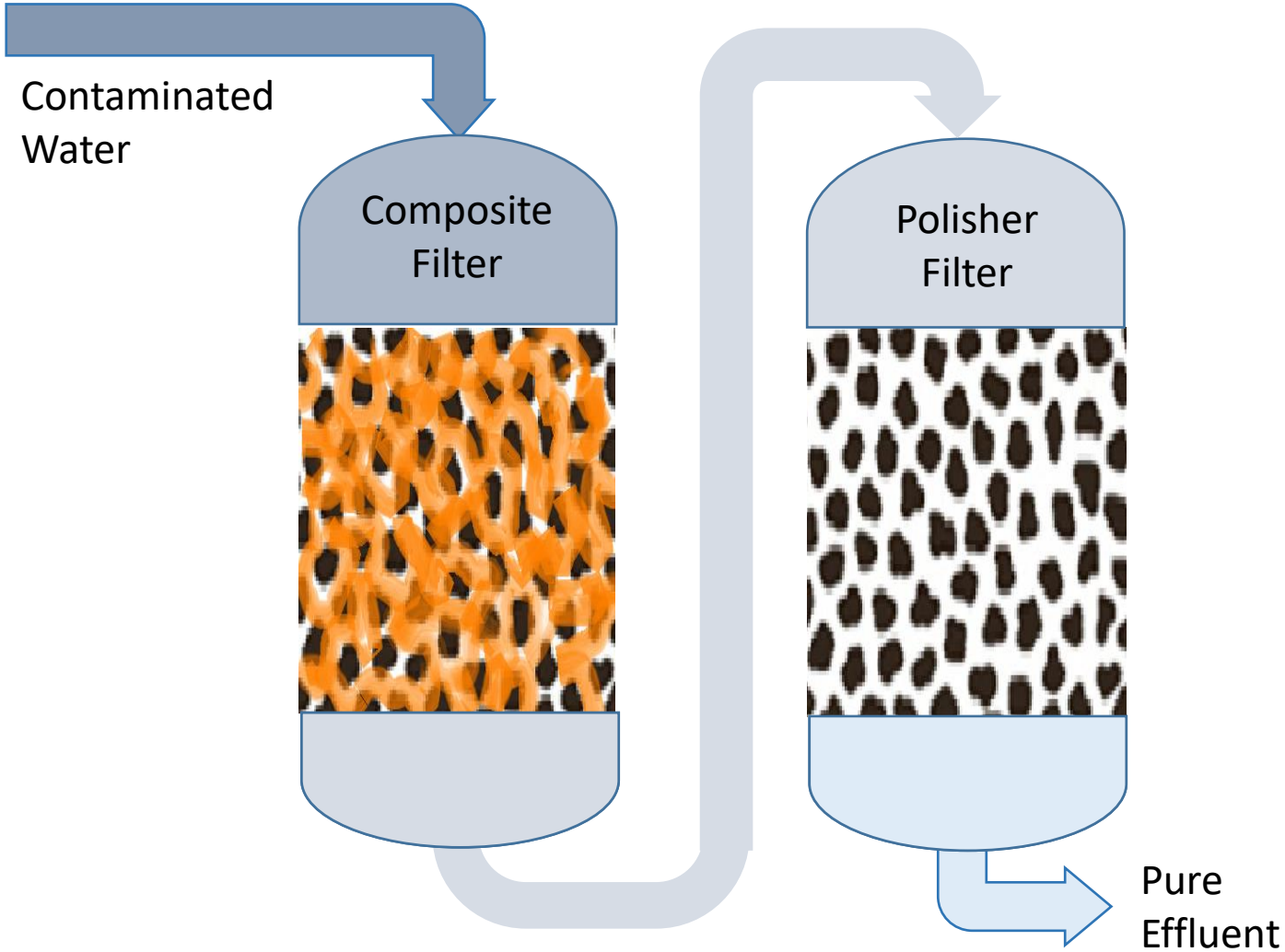
Step 1: Composite Filter Formation



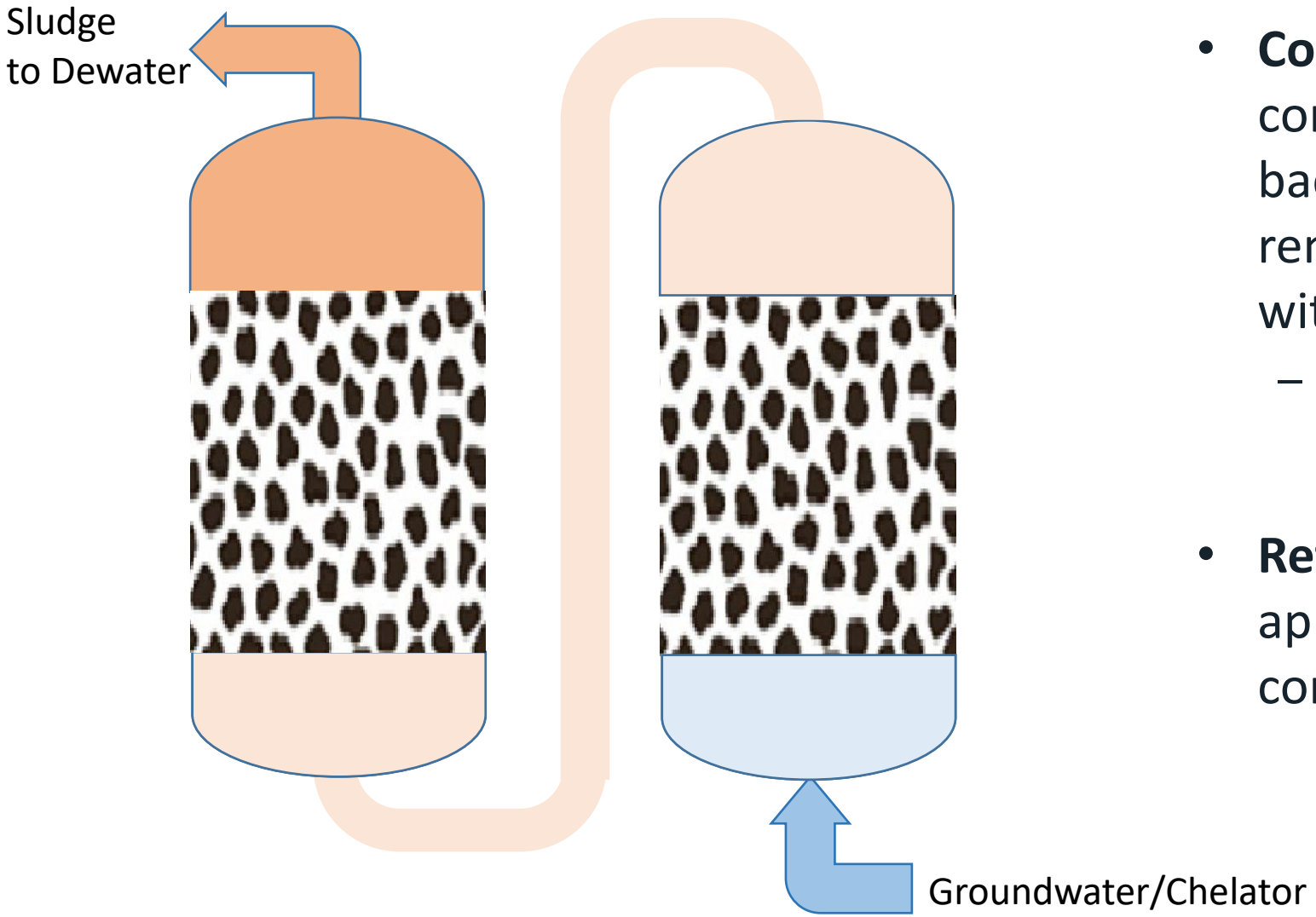
- **Fresh** in-situ, electro-generated stannous reagent concentrate added into clean sand filter media
- **Insoluble** Tin Dioxide absorbent formed by oxidizing Stannous by oxygen during air purge step
- **Stabilized** onto the sand granules Tin Dioxide serves as an active mass for contaminant removal

Step 2: Arsenic Remediation



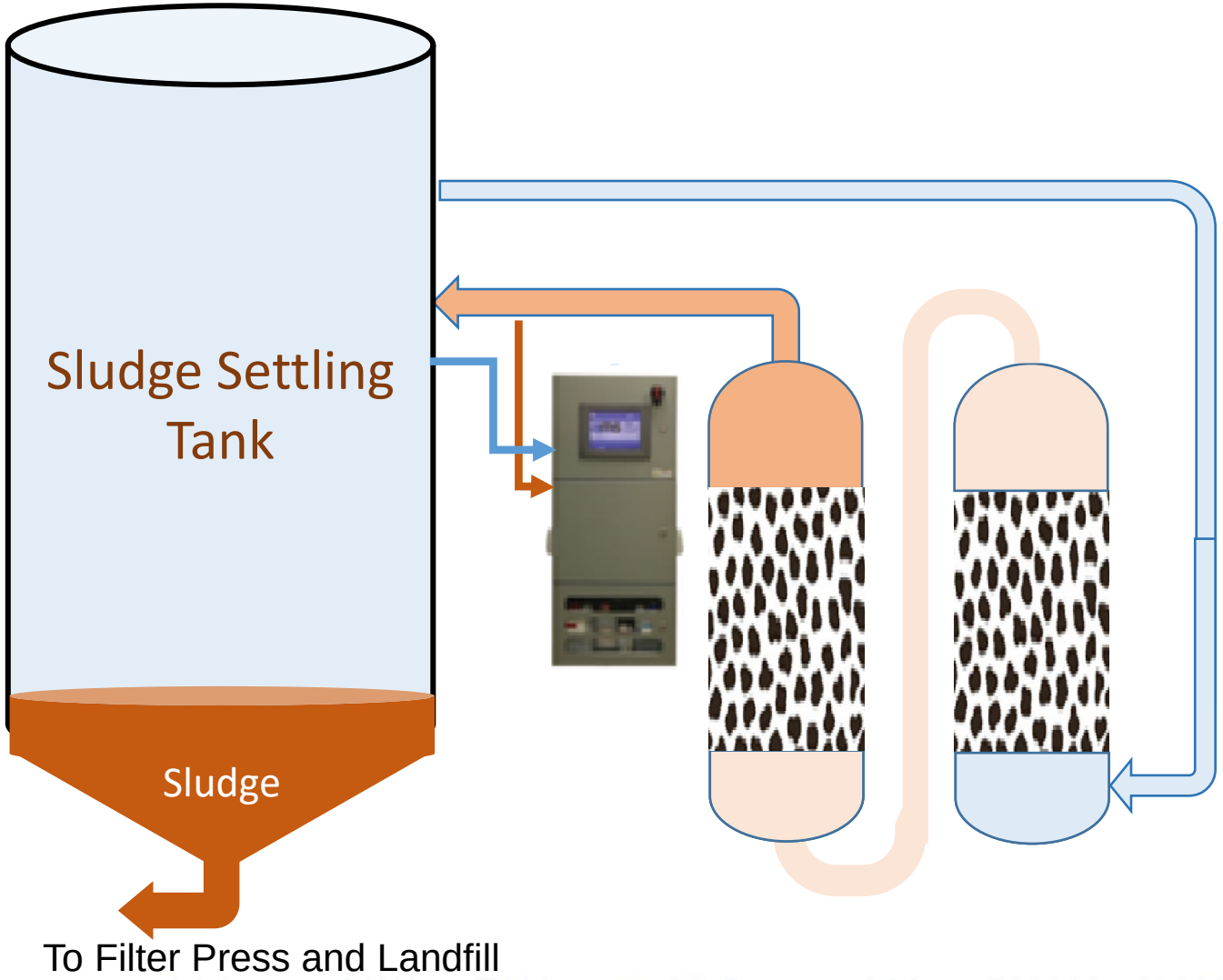
- **Contaminated** water passed through series of freshly prepared composite filters to reduce Arsenite (As^{3+}) and Arsenate (As^{5+}) to <5ppb
- **Polisher** media filter traps any Tin Dioxide particles and Arsenic traces that break through from the composite filter

Step 3: Composite Filter Regeneration



- **Contaminated** polisher and composite filters periodically back washed by treated water to remove loose Tin Dioxide layer with adsorbed Arsenic
  - If required, chelator solution can be used to remove adhesive fraction of the Tin Dioxide
- **Refreshed** filters reused by applying fresh Tin Dioxide to the composite filter (Step 1)

Backwash Water Reuse Through Residual Arsenic Monitoring



- **Backwash water** collected into sludge settling tank held to decant Tin Dioxide/Arsenic particulates to the bottom of the tank
- **Online** MetalGuard™ Analyzer continuously monitors clear water in upper part of the tank to ensure its high purity for reuse in media filter backwash
- **Backwash** frequency automatically adjusted to optimize sludge quality for landfill disposal

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Bench Scale Arsenic Removal Data Preliminary Results

Arsenic Specie	Before Treatment (ppb)	After Treatment (ppb)	Efficiency (%)
Arsenite	50	6.1	88
Arsenate	20	1.1	95
Arsenate	2000	217	89

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SafeGuard™ H2O Arsenic Removal

Feature	Benefit
In-situ, on-demand, active reagent generation	No toxic chemical, storage, handling No pH adjustment required Non-toxic Tin Dioxide sorbent produced on demand Non-toxic Tin Dioxide material applied uniformly onto substrate without additional process steps Sorbent can be removed from substrate in controlled, automated manner
Low system inertia	Ideal for 'stop-go' and unattended wells
Small footprint, modular, skid mounted	Minimal civil works, fast to deploy, scalable to wells of any size, ideal for small sites in urban areas
Tin and electricity are the only consumables	Low capital, operating and maintenance cost
Dosing controlled automatically, remote monitoring optional	Operates unattended – ideal for remote, infrequently attended sites
Removes As^{3+} and As^{5+}	Eliminates pre-oxidation step

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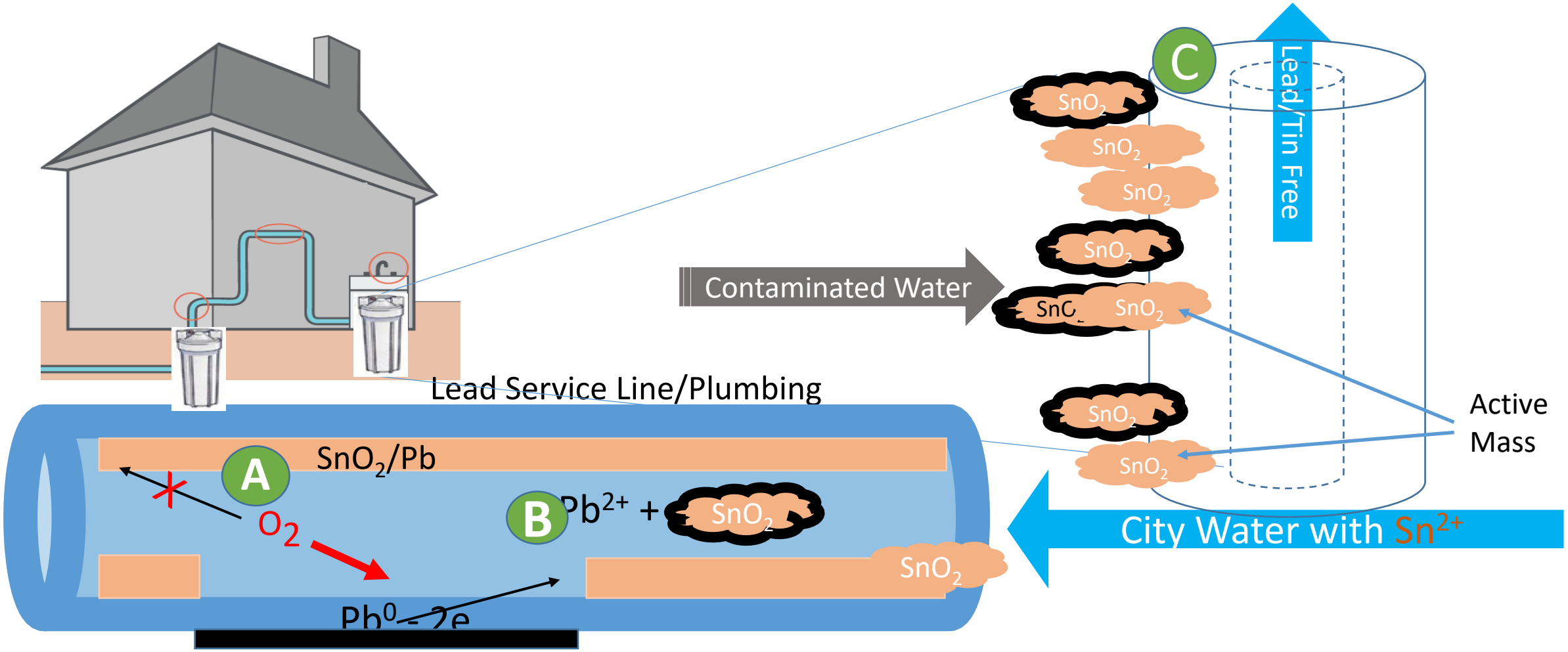
Lead Corrosion Inhibition & Lead Removal

3 Mechanisms



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Mechanism 1: Lead Corrosion Inhibition

Stannous turns into suspended insoluble Tin Dioxide which precipitates on internal surface of the corroding pipe to form a protective layer that inhibits massive electrochemical corrosion of lead metal by corrosive agents (oxygen, chlorine etc).

Mechanism 2: Lead Corrosion Retention

Lead corrosion occurs in areas where the lead surface is exposed.

Corrosive agents have access to the surface causing oxidation of the lead metal.

Due to the high affinity of dissolved lead species to suspended Stannic Dioxide particles, a significant amount of dissolved Lead is retained by suspended Tin colloids converting highly toxic dissolved Lead species into easy to particulates that can be easily filtered.

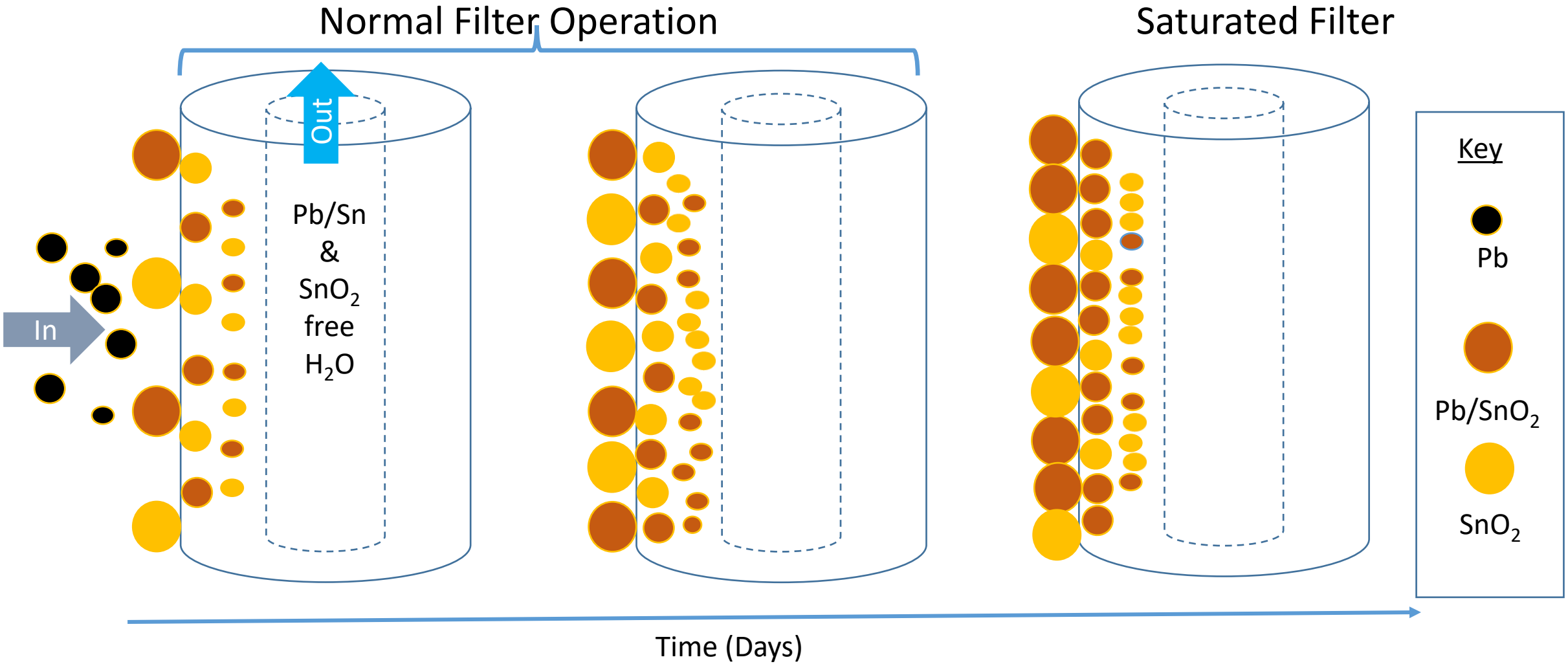
Mechanism 3: Dynamic Lead Filtration

Household water supplies containing dissolved and insoluble Lead as well as Tin Dioxide particles pass through a series of filters.

The filtration system is set to retain the particles of different size (several micron to sub micron).

The filters efficiently retain Tin Dioxide colloidal particles of different sizes and, thus, acquire a ‘self assembled’ layer of ‘colloidal sludge’ on their surface. This sludge serves as an ‘active mass” which efficiently removes remaining dissolved Lead species.

Lead Removal: Point-of-Entry/Point-of-Use Filter



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SafeGuard™ H2O Lead Treatment System

Feature	Benefit
Protects	The system removes/inhibits biofilm formation and significantly inhibits dissolved and particulate lead corrosion
Retains	The system effectively addresses both dissolved and total Lead species retention through stannous reagent water treatment
Point-of-Use Filters	The “active mass” of the dynamic composite filter increases continuously as Tin Dioxide is deposited and this increases its capacity to retain dissolved Lead

Industrial Wastewater Treatment, Airborne Contaminant Removal & Resource Recovery

Coal Plants, Refining, and Process Industries

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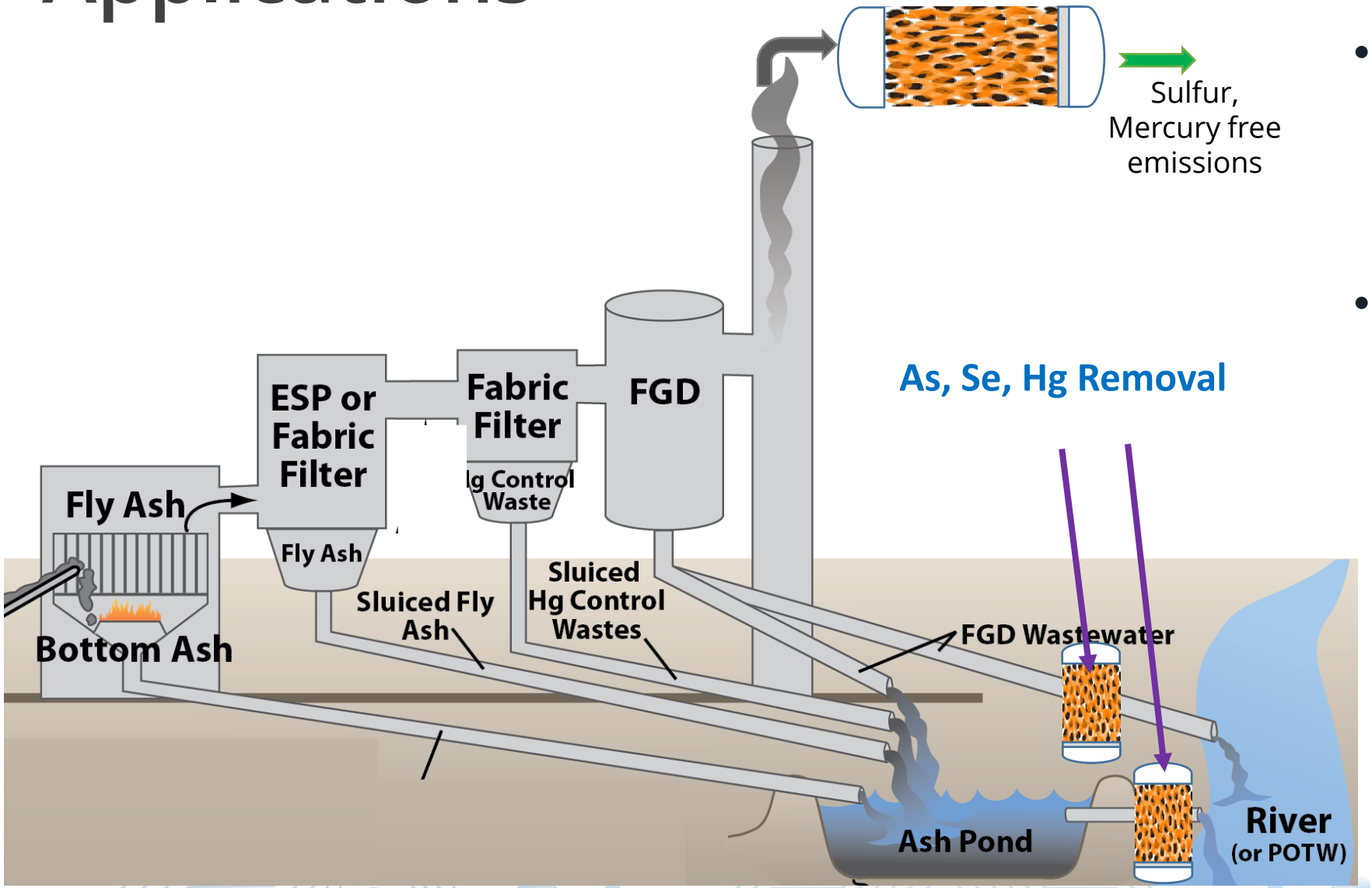
Coal-Fired Power Plants – Multiple Applications



- Tin Dioxide adsorption media for stack gas desulfurization and mercury removal
- Tin Dioxide composite filter remediates multiple metal contaminants from plant wastewater

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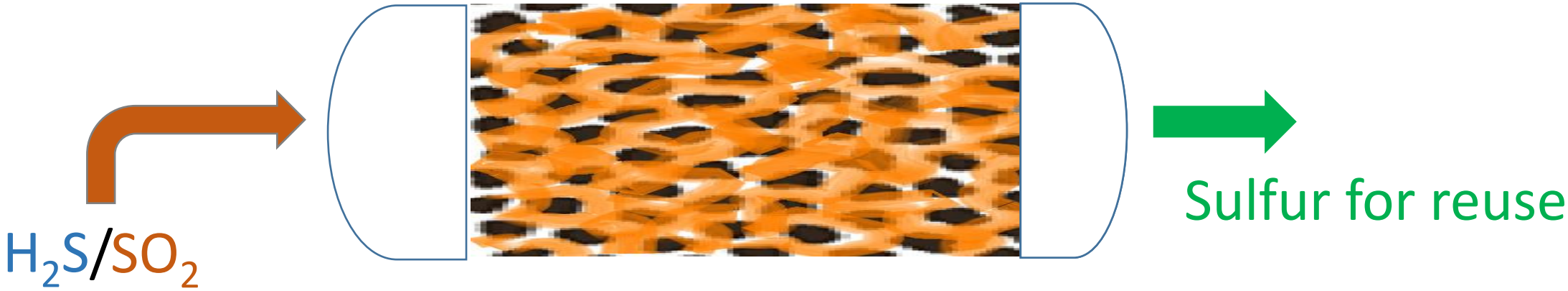
Flue Gas Desulfurization, Media Regeneration & Sulfur Recovery

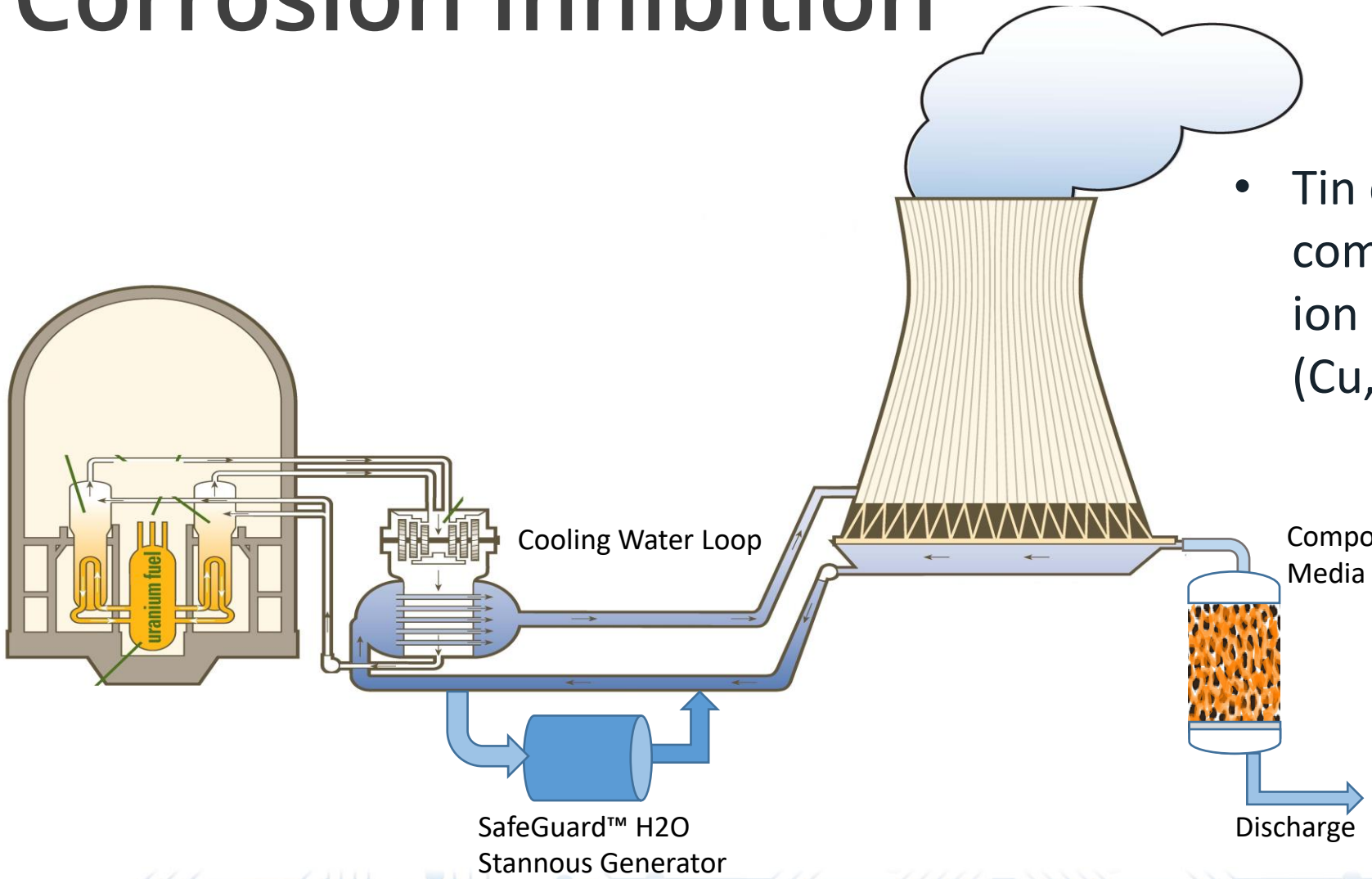


$SnO_2 + H_2 + H_2S \rightarrow SnS + 2H_2O$ – Hydrogen Sulfide removal

$SnS + SO_2 \rightarrow SnO_2 + S_2$ – media regeneration with Sulfur Dioxide

$SO_2 + H_2 + H_2S \rightarrow S_2 + 2H_2O$ – combined Claus process

SafeGuard™ H2O: Cooling System Corrosion Inhibition



- Tin dioxide self-assembled composite filter remediates metal ion corrosion process by-products (Cu, Fe, Ni, etc…) prior to discharge

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Stannous & Tin Dioxide

A safe, non-toxic metal for drinking water treatment, industrial wastewater treatment and airborne contaminant removal.

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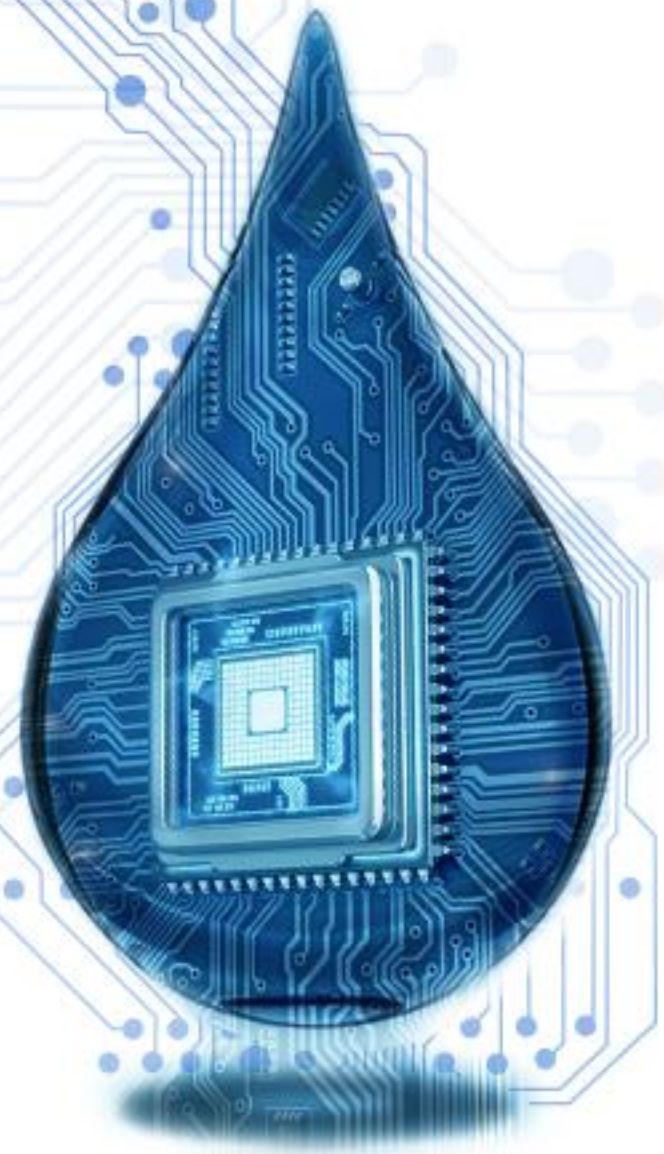

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