

Assessing Options for On-site Leachate and Groundwater Management Strategies at Florida Landfills

A Project Funded by the
Hinkley Center for Solid and Hazardous Waste
Management

TAG Presentation
May 27, 2014
Palm Beach County, Florida

Research Agenda Item 7

What measures can be taken to prevent "reductive dissolution" of iron and arsenic beneath existing lined landfills? What are some low-cost design and construction options for getting oxygen into the soils? What are the options for new landfills that have not yet been constructed? How can we avoid creating new groundwater contamination problems due to "the shadow effect" underneath new lined cells which have not yet been built?

Research Agenda Items 12 and 13

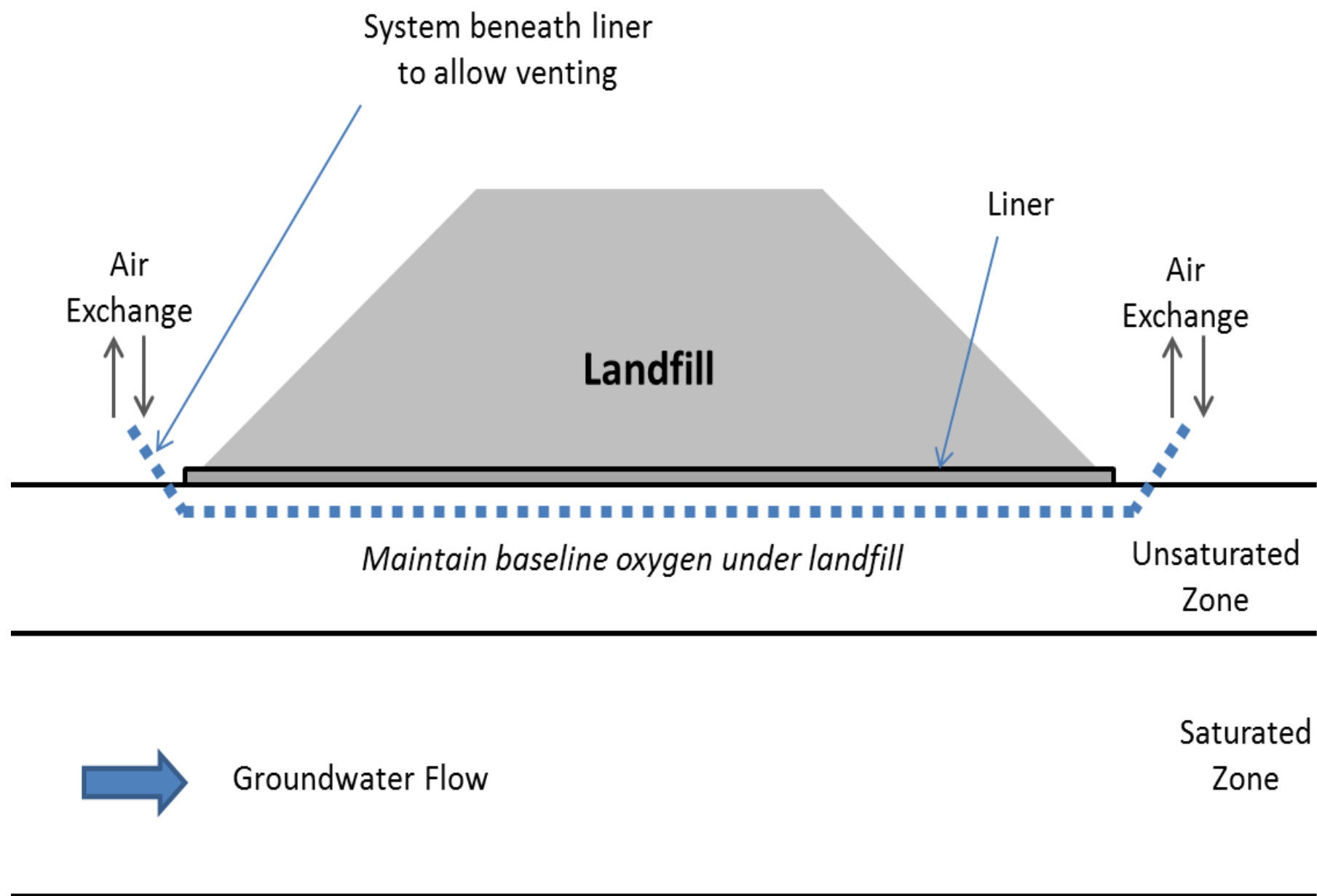
Can constructed wetlands be utilized for onsite leachate treatment?

What are the onsite leachate treatment options for landfills that have high chloride levels in their leachate from waste-to-energy ash?

Options for On-Site Leachate Management

- Leachate recirculation
- Evaporation
- Wetlands
- On-site treatment plant with discharge to surface water or groundwater
 - High salt
 - Low salt





Study Objectives

- Task 1: Update 2007 state of practice information
- Task 2: Critical review of ash landfill leachate management
- Task 3: Develop an engineering cost model for on site leachate treatment
- Task 4: Develop a tool to disseminate on-site leachate assessment
- Task 5: Develop design options for sub-liner vadose zone venting
- Task 6: Vadose zone venting simulation and economic evaluation
- Task 7: Preparation of final report

Task 1

- **Update of current state of practice for leachate management at Florida landfills.** The previous Hinkley Center study on leachate management practices in Florida will be updated (Townsend et al., 2007). Additional sites will be identified. Contact information for the majority of the facility operators already exists from the previous work. A specific objective is to identify all facilities with on-site leachate treatment components; these will serve as probable data sources for economic, energy and treatment efficiency data.

Task 2

- **Critical review of ash landfill leachate management practices.** Given the Center Agenda Item 13, an in depth critical review, beyond those facilities in Florida, will be conducted for ash landfill leachate management. Leachate quality data, treatment experience, economic data and energy consumption information will be gathered from facilities around the country (and internationally if appropriate). The investigator already has contacts with many of the major companies involved in the WTE industry.

Task 3

- **Development of an engineering cost model for on site leachate treatment.** A spreadsheet economics model, one that includes energy consumption, will be developed for major on-site leachate treatment options. The source of the information will be from industry and facility contacts identified in Tasks 1 and 2, the scientific literature, communications with practicing engineers (included as part of the TAG), and consultation with equipment and technology vendors. The goal of the model will be to allow an interested party to enter site specific information, using defaults where necessary, and predict the costs of implementing various forms of on-site leachate treatment.

Task 4

- **Development of a dissemination tool for on-site leachate assessment.** The resulting model and associated information will be used to produce a tool for use by interested parties. The exact nature of the tool will depend on feedback from the TAG, but candidate formats are a spreadsheet, an interactive website, or an app.

Task 5

- **Development of design options for sub-liner vadose zone venting.**
The investigator and his team will develop a set of potential design alternatives for meeting the objectives described earlier in this proposal. These design alternative are anticipated to include either air venting (forced aeration, induced soil venting, passive venting) or the addition of aerated water (possibly with amendments) using configurations/materials such as pipes, rock trenches, geonets, and high permeability soil layers. These configurations will be presented to the TAG for feedback before detailed simulation and costing.

Task 6

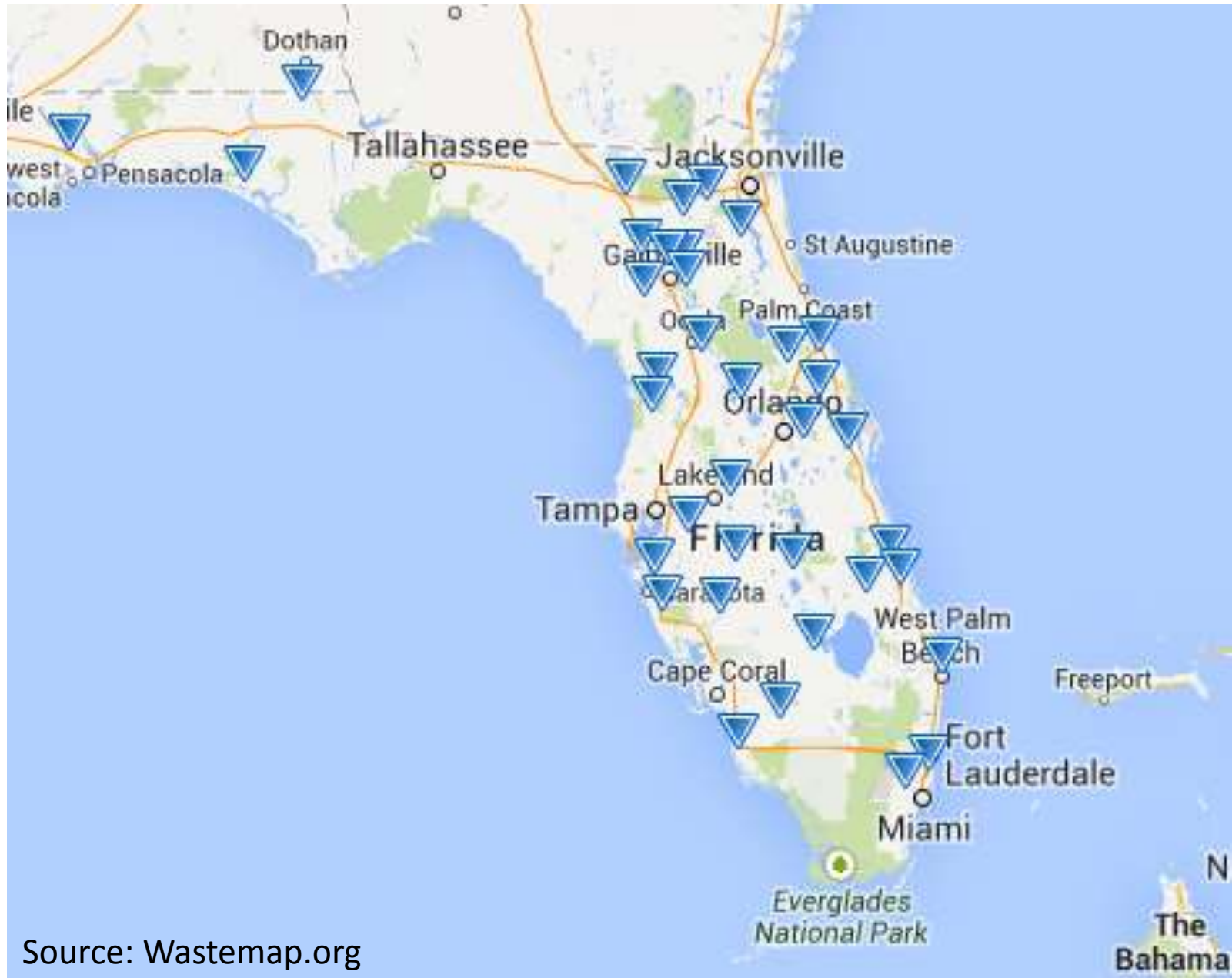
- **Vadose zone venting simulation and economic evaluation.**
Appropriate design configurations developed in Task 5 will be modeled with respect to the potential to maintain baseline oxygen conditions under a landfill liner system. This will be modeled with standard hydraulic engineering techniques as well as multimedia transport models currently used by the investigator for reductive dissolution research. Based on these results, an engineering economic analysis and energy evaluation will be conducted for those scenarios/designs that are believed to suitably meet the desired objectives. The results will be compared to more traditional remedial alternatives.

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Past Work

- Leachate Database
- Leachate Management in Florida



Treatment Options for Landfill Leachate:

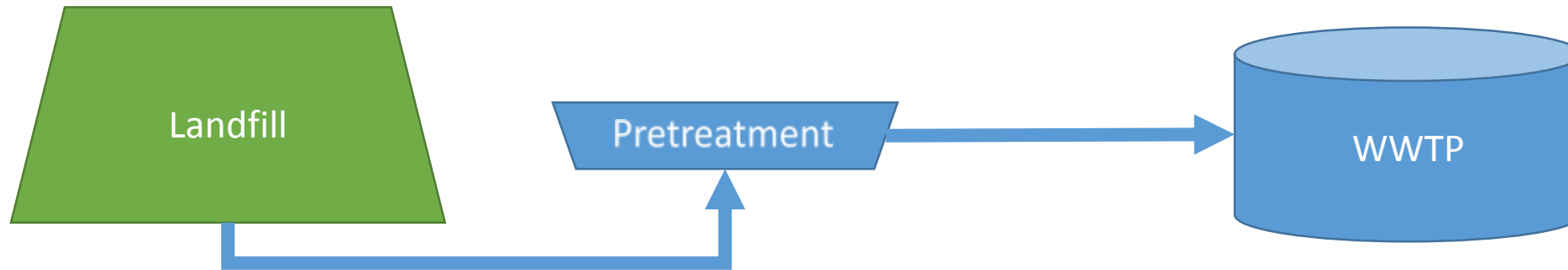
1. Discharge to WWTP



61% of landfills surveyed in 2007

Treatment Options for Landfill Leachate:

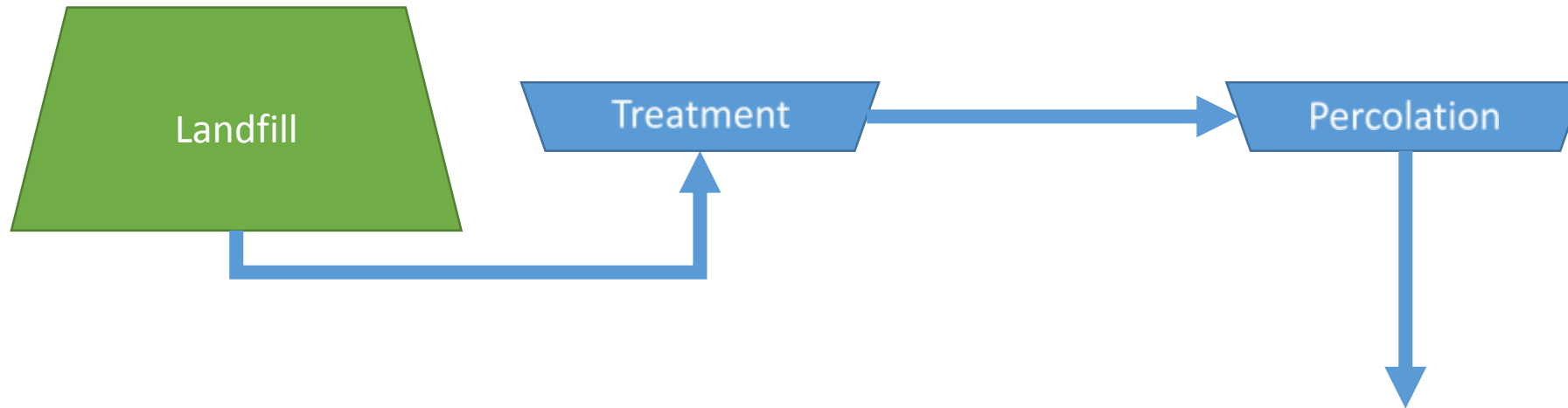
2. Pretreatment, Discharge to WWTP



22% of landfills surveyed in 2007

Treatment Options for Landfill Leachate:

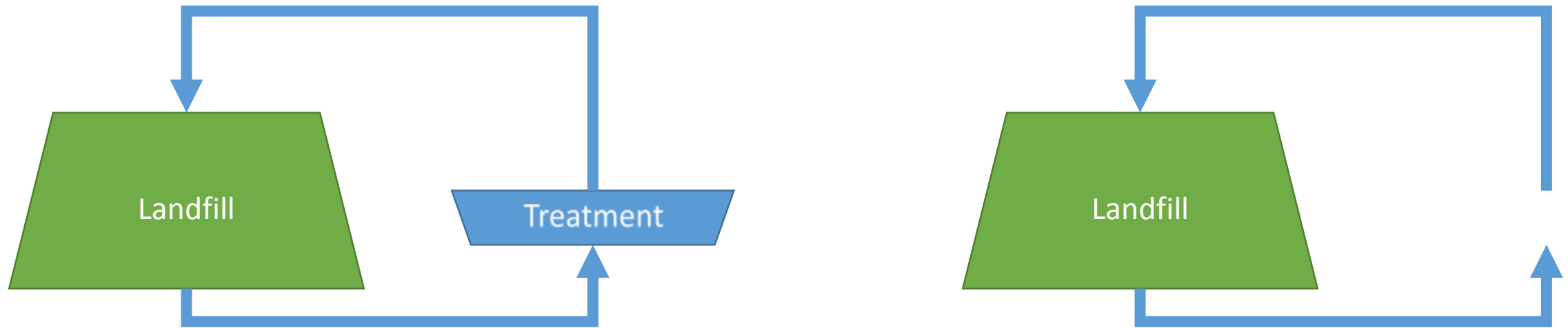
3. Pretreatment, Onsite Discharge



7% of landfills surveyed in 2007

Treatment Options for Landfill Leachate:

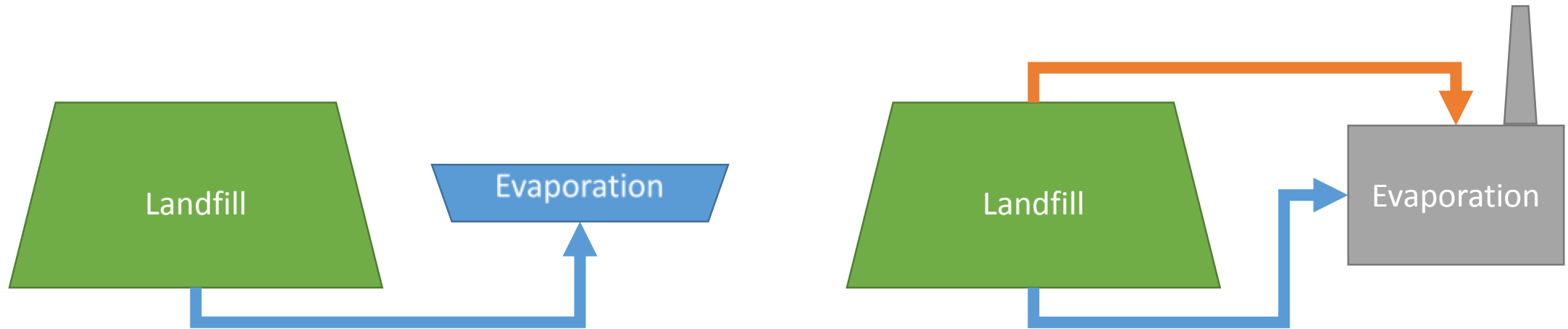
4. Recirculation



19% of landfills surveyed in 2007 recirculated leachate
9% managed all leachate through recirculation

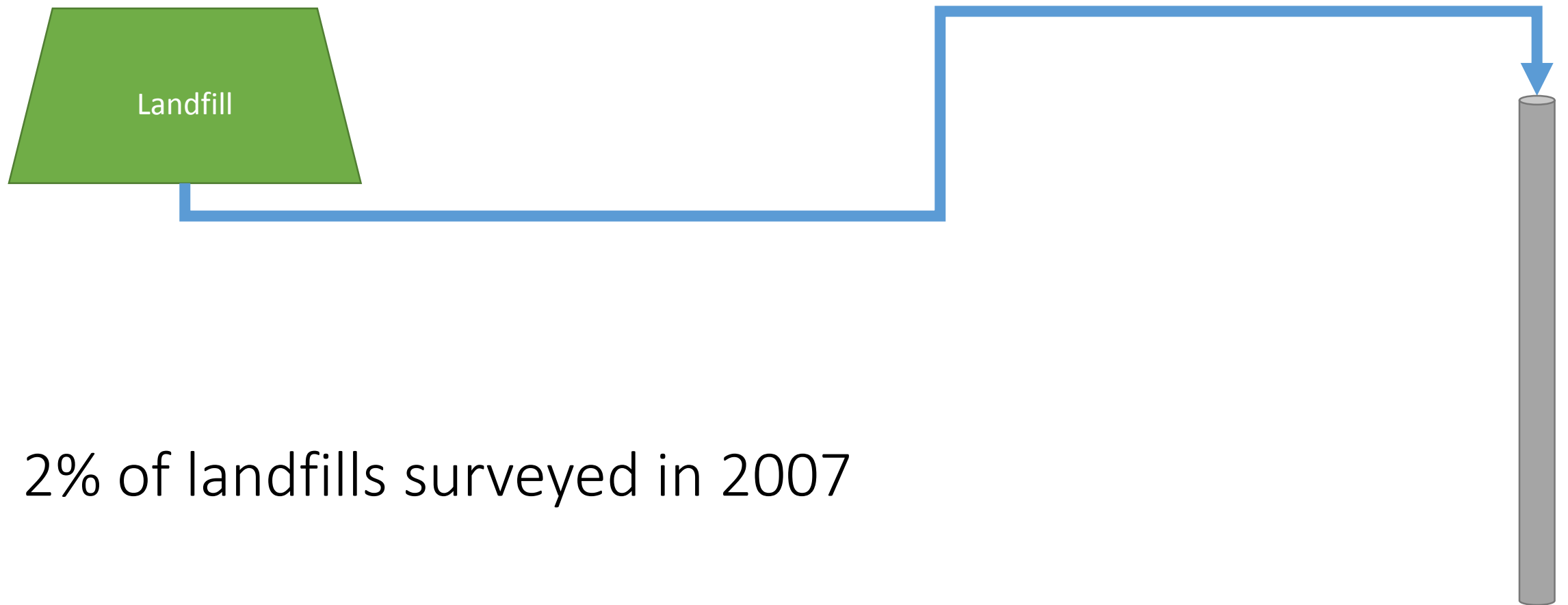
Treatment Options for Landfill Leachate:

5. Evaporation



Treatment Options for Landfill Leachate:

6. Deep Well Discharge



2% of landfills surveyed in 2007

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Waste to Energy Ash

- Burning municipal solid waste (MSW) creates ash which must be disposed of
- Ash can be placed in a landfill by itself (ash monofill) or with MSW (co-disposed)
- This can create leachate with very different characteristics than MSW leachate



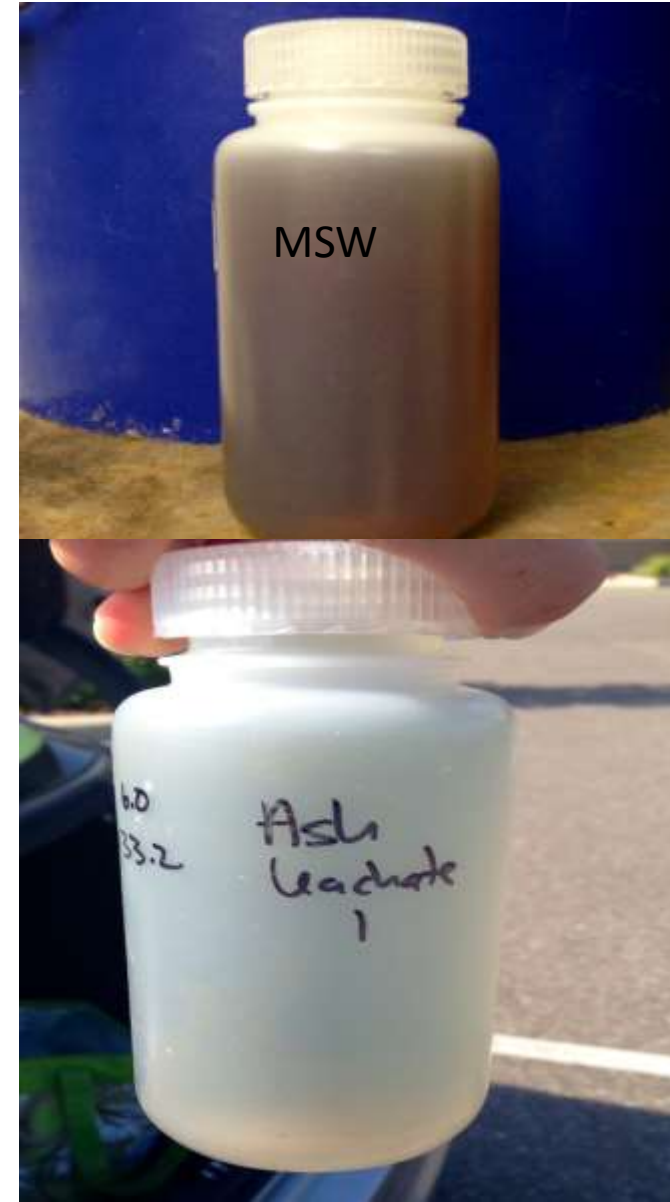
Leachate Database

- Contains various parameters over multiple years for 95 different lined landfills in Florida
 - pH, ammonia, VOCs, heavy metals, TDS, conductivity, alkalinity, etc.
- Data from:
 - Landfill operators
 - FDEP files (including WACS)
- Allows us to compare leachate characteristics from different landfills over a desired time span

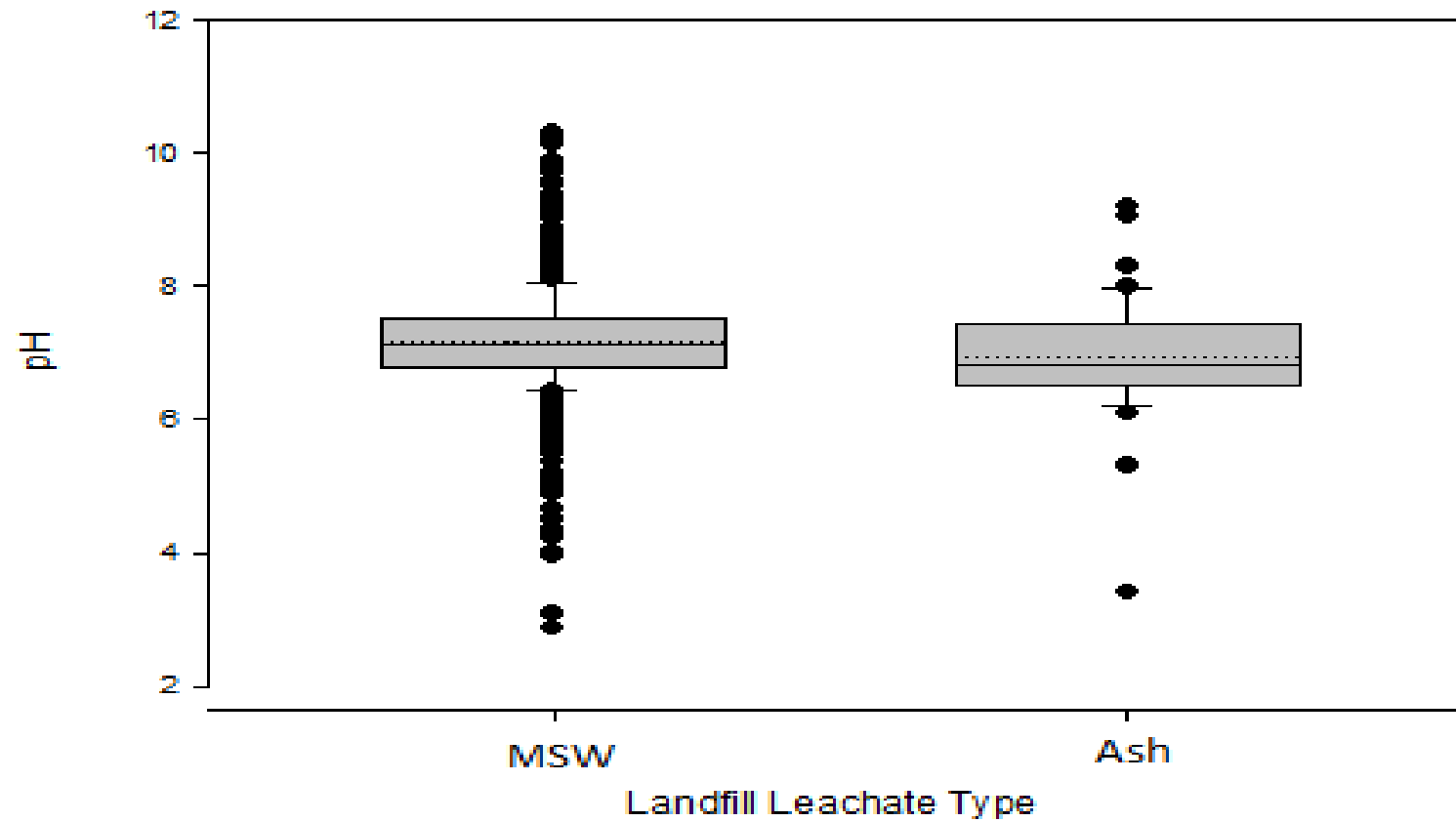
FINAL LEACHATE DATABASE										
DISTRICT	LANDFILL_NAME	SAMPLE DATE	COUNTY	YEARS	TYPE OF LANDFILL	LOCATION	PARAMETER	Values included	UNIT	VALUES
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	TEMPERATURE	25	DEG C	25
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	SPEC. CONDUCT	6600	UMHOS/CM	6600
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	PH	6.8	STD UN	6.8
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	NITRATE (NO3)	0.11	MG/L	0.11
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	NITROGEN, KJEL	710	MG/L	710
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	SODIUM (NA)	60	MG/L	60
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	CHLORIDE	190	MG/L	190
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	SULFATE (SO4)	0.89	MG/L	0.89
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	ETHYLBENZENE	2	UG/L	2
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	SOLIDS TOT DIS	2200	MG/L	2200
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	IRON (FE) TOT	35	MG/L	35
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	TURBIDITY, FIEL	130	NTU	130
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/13/1996	GADSDEN	1996		L-4 LIFT STATION #	MANGANESE (M)	5.8	MG/L	5.8
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/1/1995	GADSDEN	1995		L 1 LEACHATE LIFT	TEMPERATURE	17	DEG C	17
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/1/1995	GADSDEN	1995		L 1 LEACHATE LIFT	SPEC. CONDUCT	20000	UMHOS/CM	20000
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/1/1995	GADSDEN	1995		L 1 LEACHATE LIFT	PH	7.1	STD UN	7.1
NWD	QUINCY BYRD LANDFILL/ LAND CLE	2/1/1995	GADSDEN	1995		L 1 LEACHATE LIFT	NITROGEN, KJEL	1900	MG/L	1900

Ash leachate vs. MSW leachate

- Compared leachate data from ash monofill landfills and MSW landfills
- Looked at pH, TDS, COD, BOD, Chloride, Sodium TOC, Arsenic, Iron, and Lead

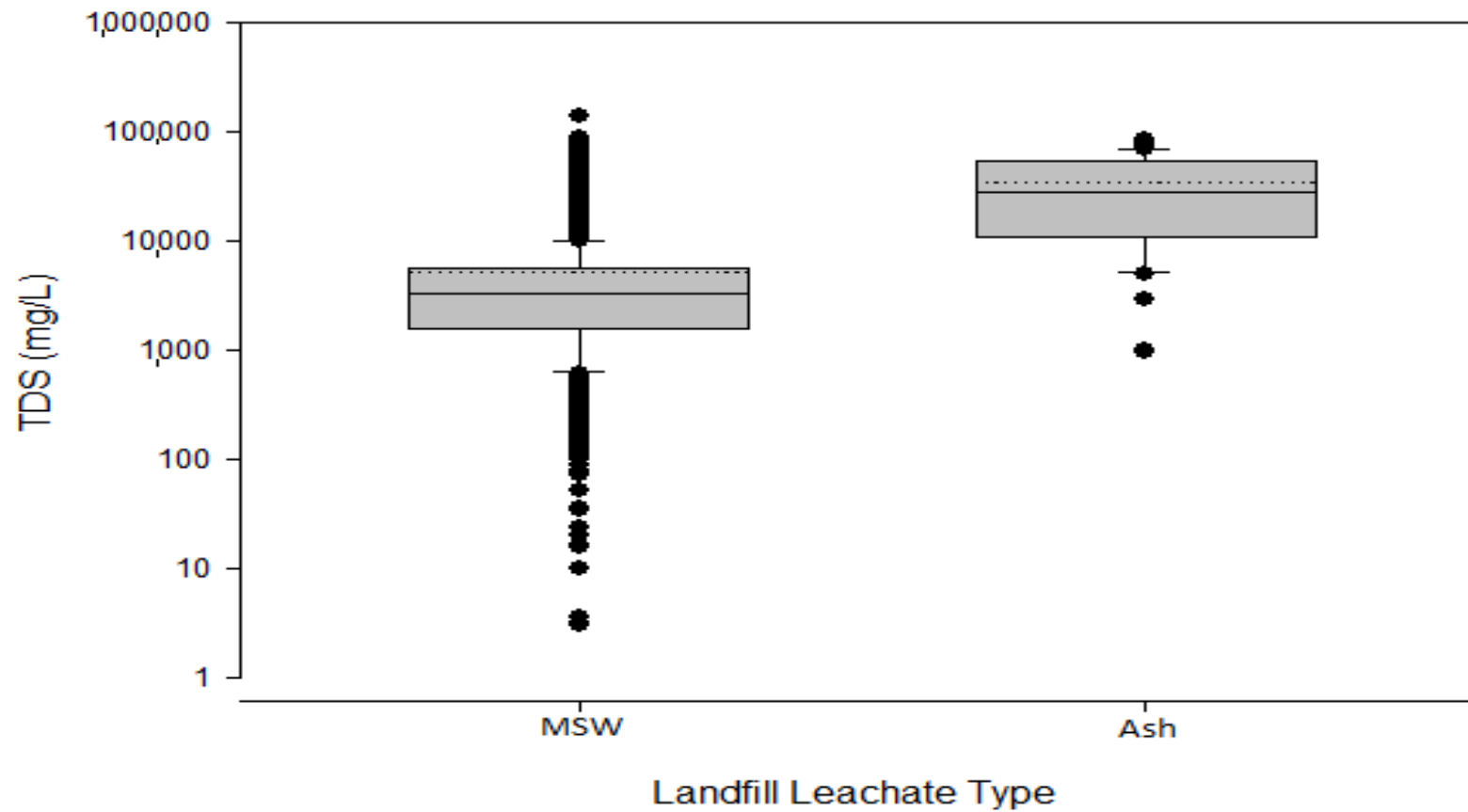


pH



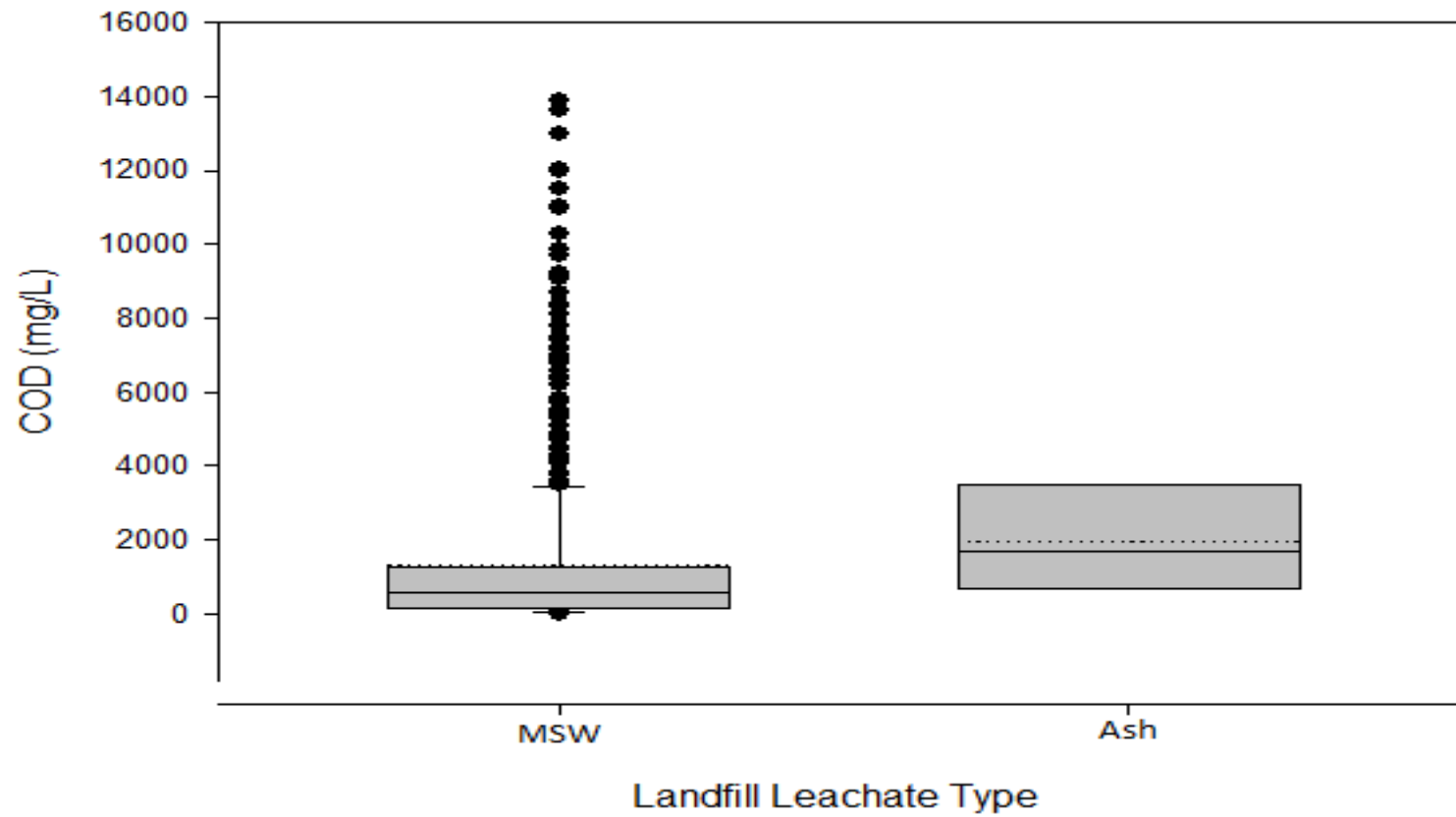
- MSW data included 1925 data points from 88 landfills
- Ash data included 47 data points from 4 landfills

TDS



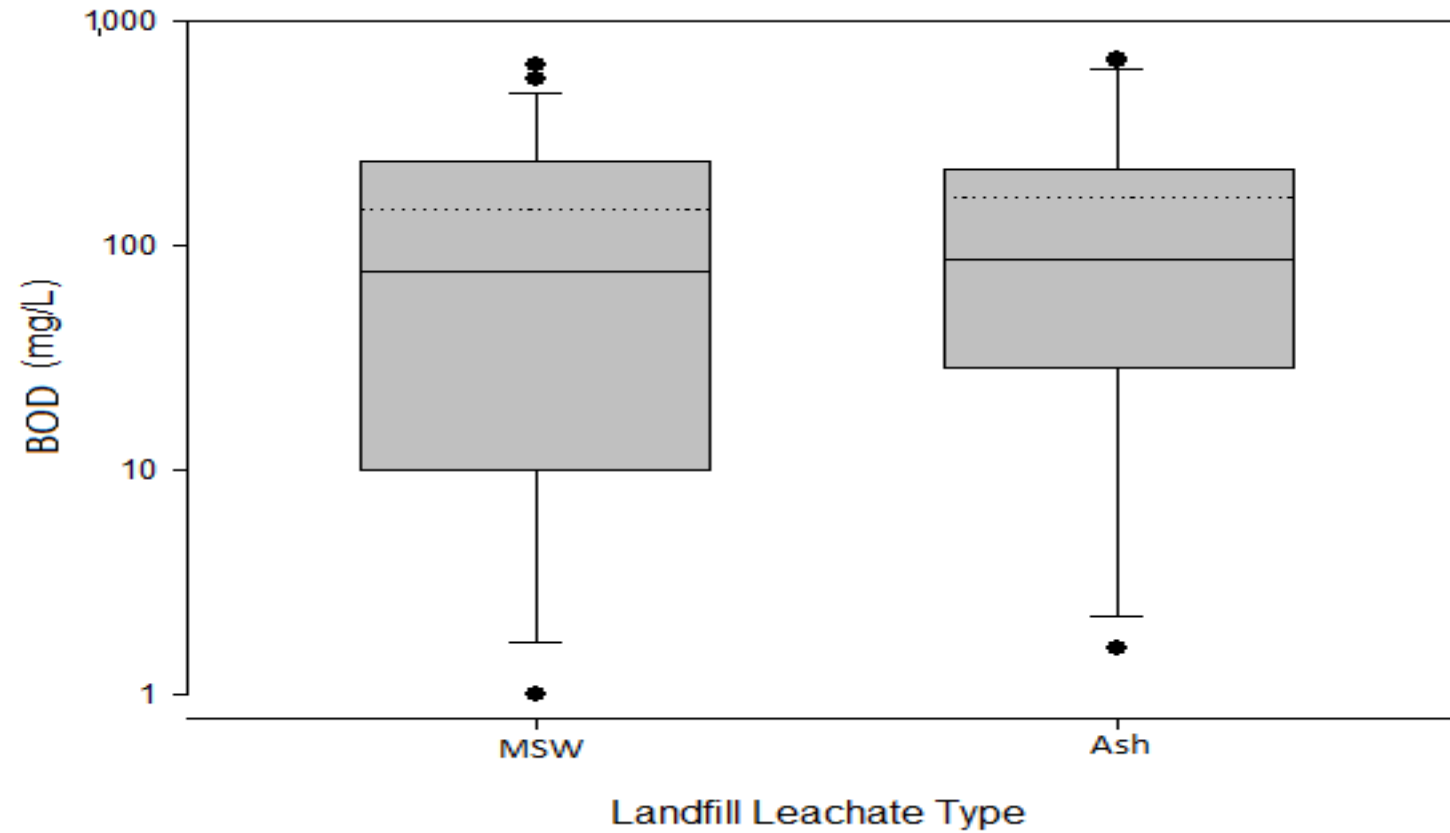
- MSW data included 2517 data points from 95 landfills
- Ash data included 41 data points from 4 landfills

COD



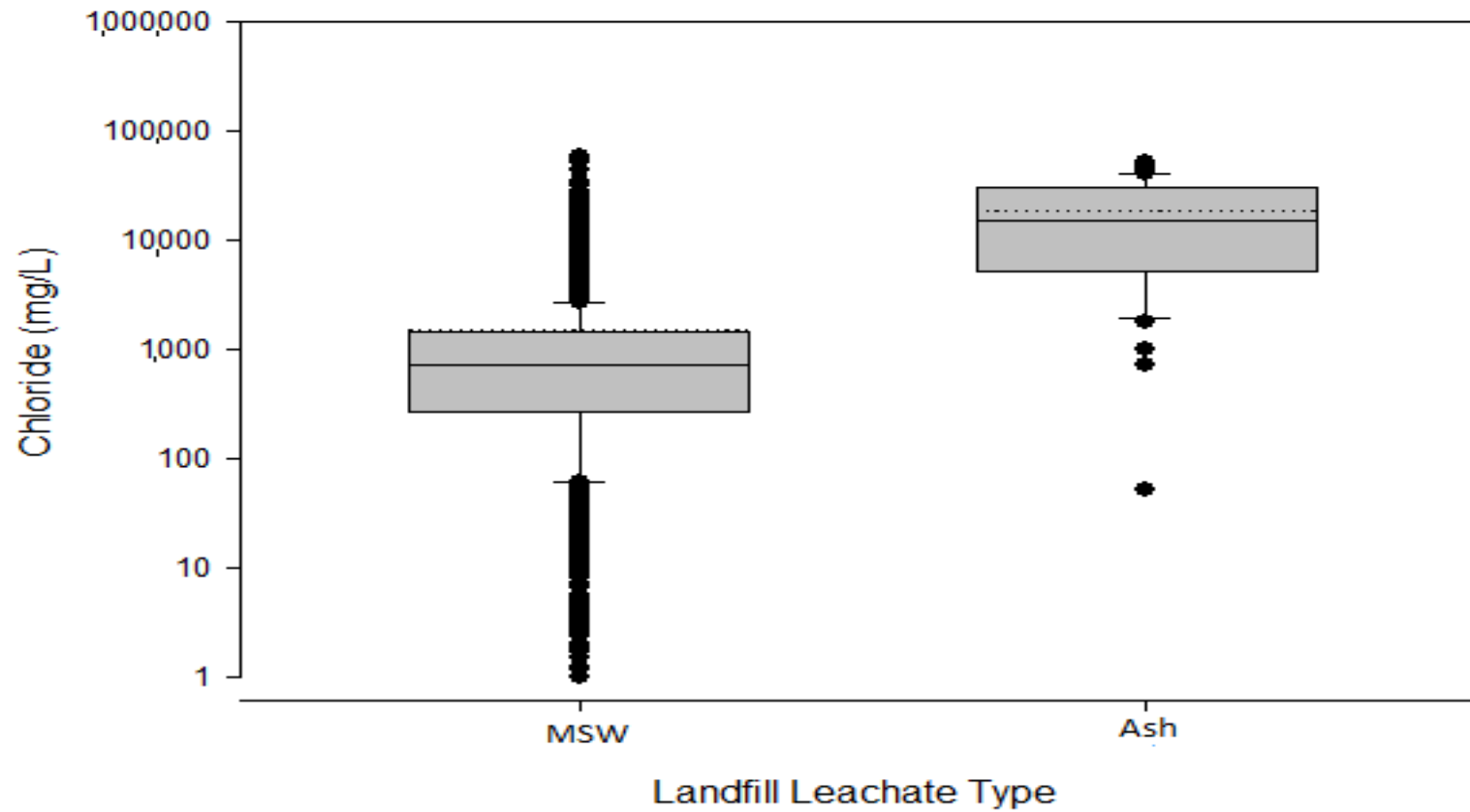
- MSW data included 567 data points from 47 landfills
- Ash data included 6 data points from 2 landfills

BOD



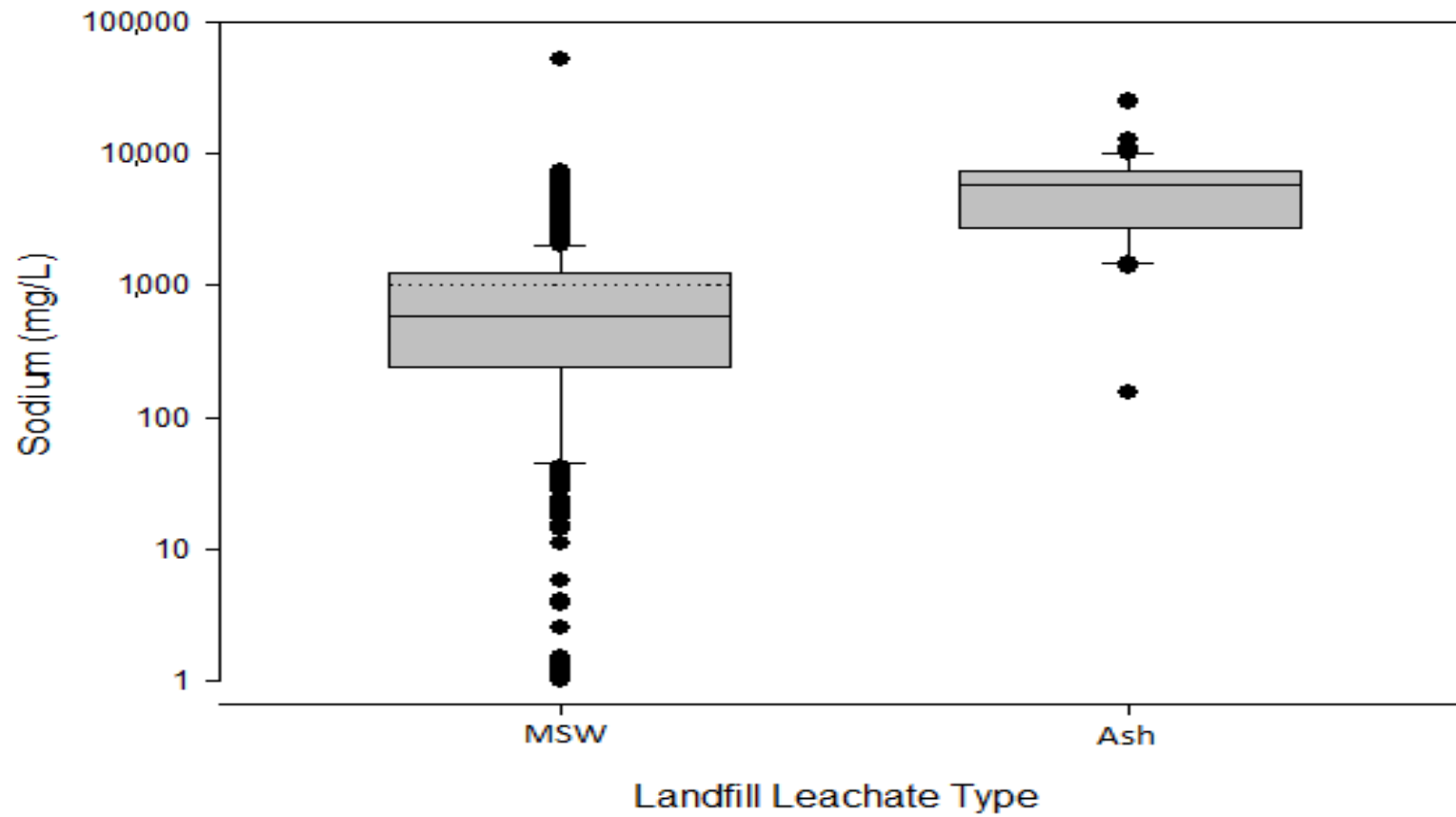
- MSW data included 24 data points from 7 landfills
- Ash data included 12 data points from 2 landfills

Chloride



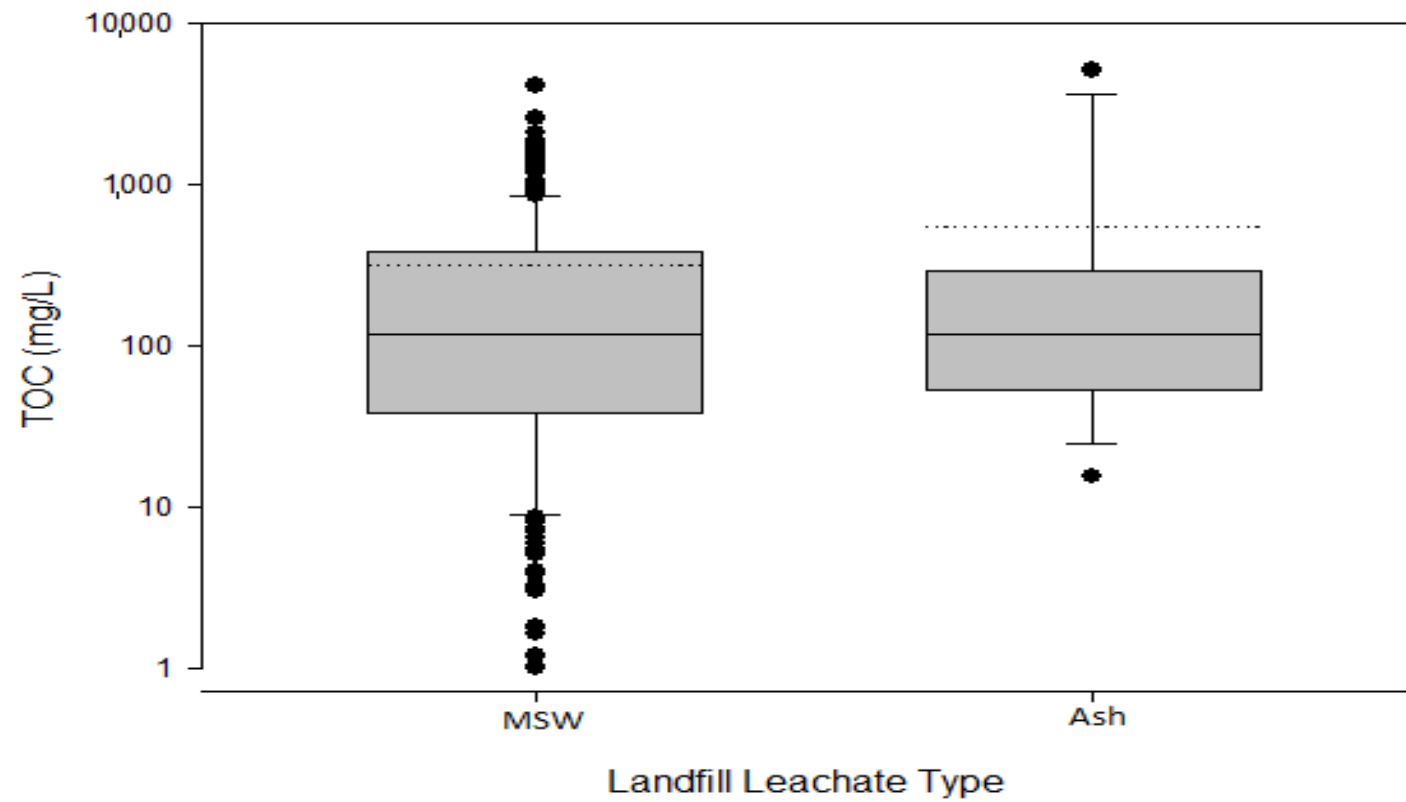
- MSW data included 2757 data points from 86 landfills
- Ash data included 42 data points from 4 landfills

Sodium



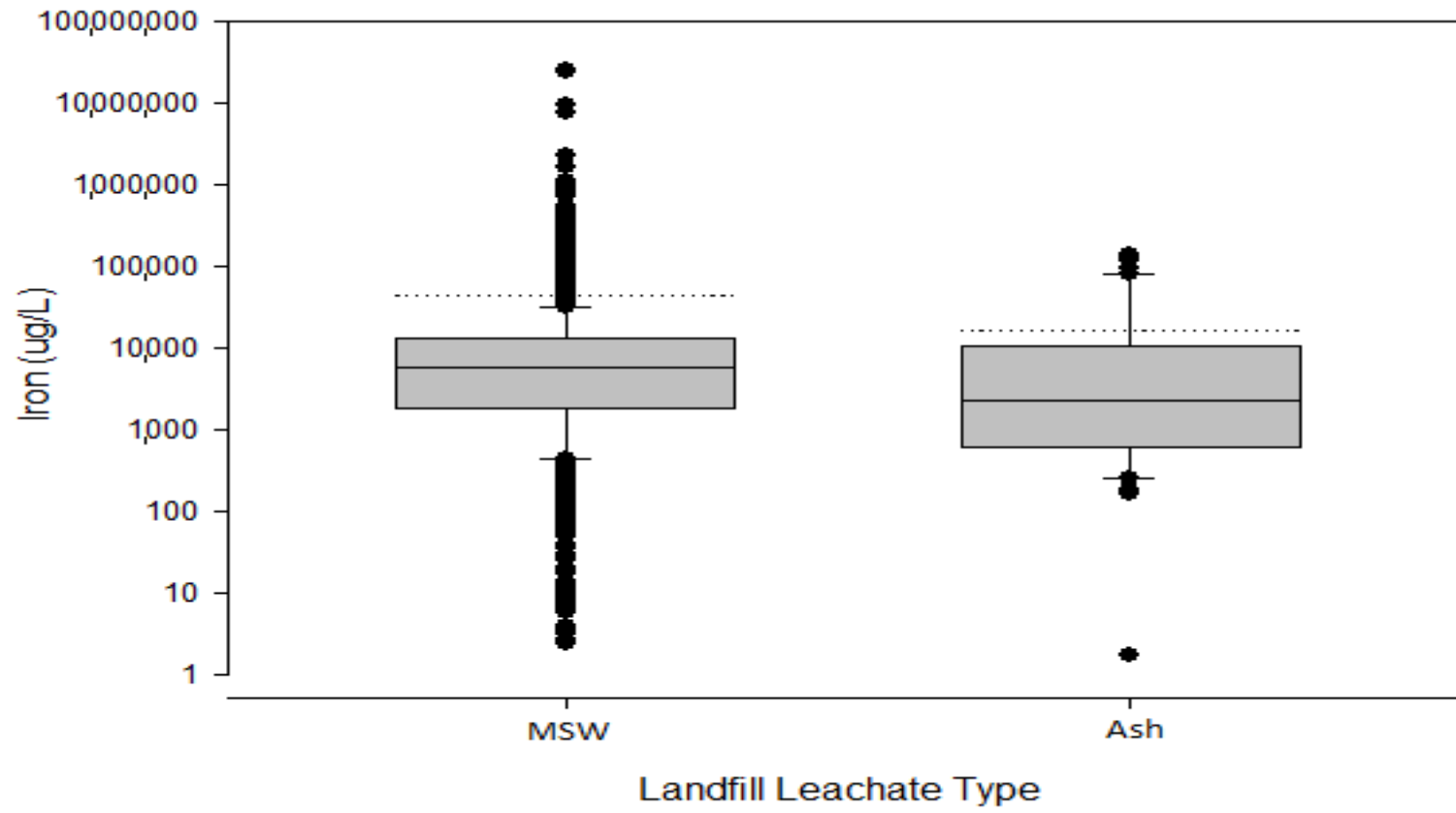
- MSW data included 787 data points from 56 landfills
- Ash data included 39 data points from 4 landfills

TOC



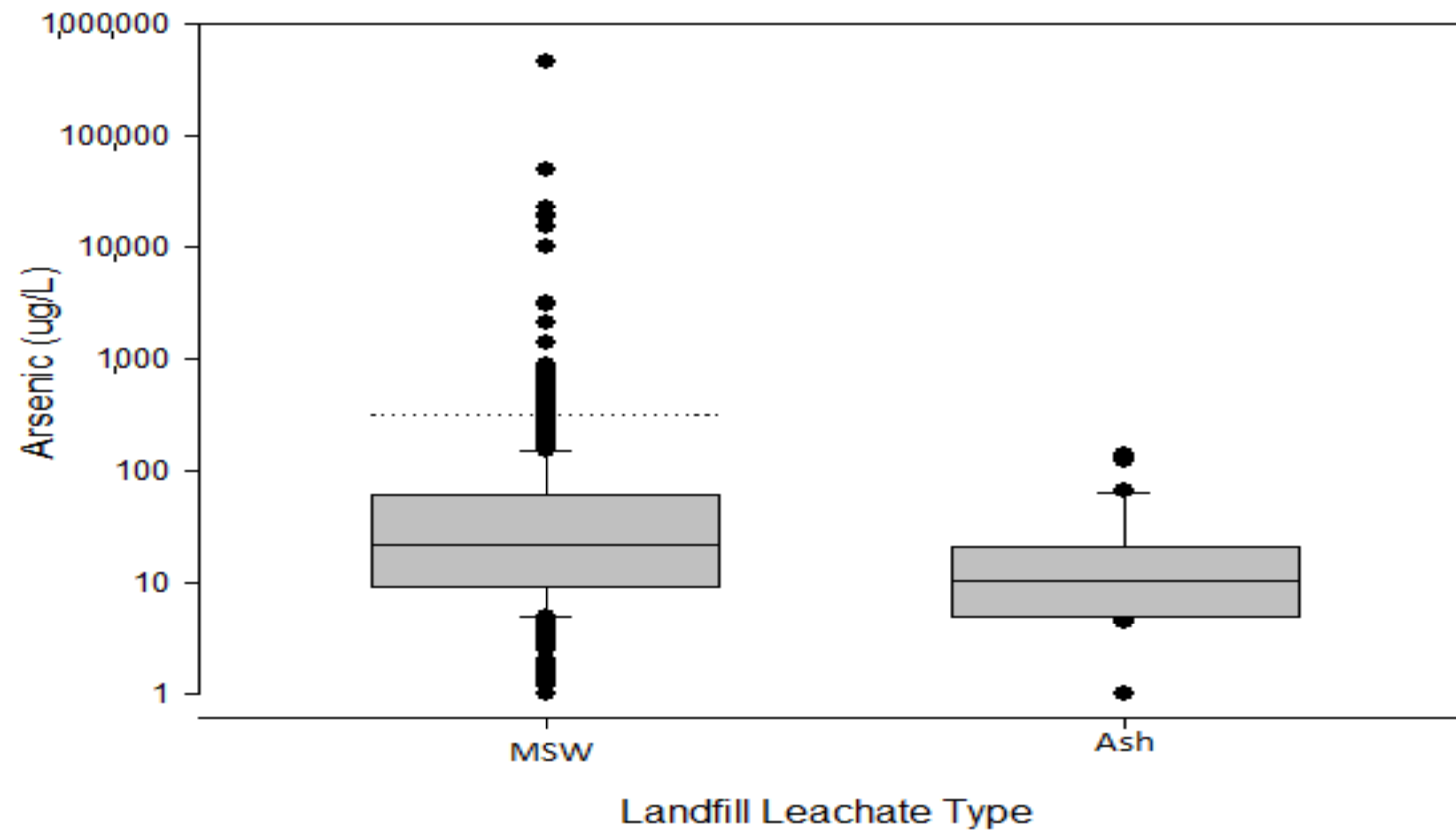
- MSW data included 396 data points from 43 landfills
- Ash data included 11 data points from 1 landfills

Iron



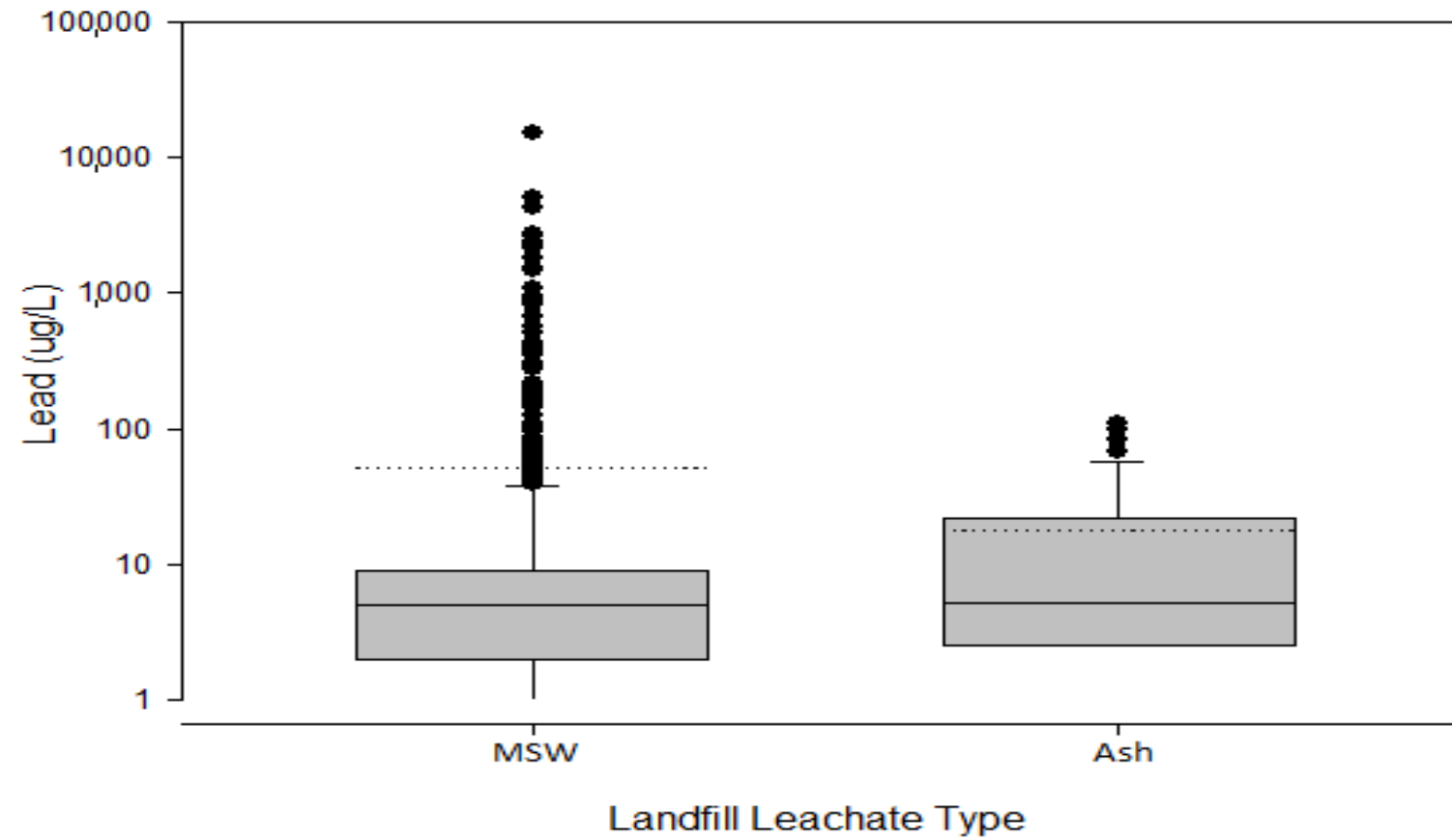
- MSW data included 782 data points from 55 landfills
- Ash data included 40 data points from 4 landfills

Arsenic



- MSW data included 803 data points from 55 landfills
- Ash data included 40 data points from 4 landfills

Lead



- MSW data included 748 data points from 54 landfills
- Ash data included 43 data points from 3 landfills

Calcium Precipitation

- Calcium precipitation from leachate can clog leachate collection systems
- Want to calculate a calcium precipitation index for different types of landfill leachates
- There are many different calcium precipitation indices
 - Langelier Saturation Index, Ryznar Index, Aggressiveness Index, Momentary Excess, Calcium Carbonate Precipitation Potential (CCPP), etc.



Langelier Index for different types of leachate

Type of leachate	Landfill that samples were taken from	Langelier Index
Ash Monofill	West Pasco County	0.45
Co-Disposal	Palm Beach County NCRRF Class I Landfill	2.97
C&D	West Pasco County	0.88
Mature Leachate	New River Regional Landfill	1.31
Fresh Leachate	New River Regional Landfill	- 0.71

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Cost Variables

- Volume
- COD and BOD
- Ammonical Nitrogen
- pH
- Total Dissolved Solids



Metal Concentrations

- Many exceed GWCTLs
- No direct removal route in biological processes
- Just diluting leachate in conventional WWTPs

Source: 2007 Hinkley Center Report: Lined Landfill
Leachate Management in Florida

Analyte	% Exceeding GWCTL
As	41.5
Ba	0.0
Be	2.4
Cd	7.3
Cr	9.8
Ni	24.4
Pb	19.5
Sb	41.5
Se	0.0
Hg	2.4
Na	85.4
Al	53.7
Cu	2.4
Fe	100.0
Mn	90.2
Zn	2.4
Mo	7.3
B	92.7
Co	0.0
Sn	0.0
Sr	17.1
V	17.1

2007 Report: Biological

Biological Treatment	Advantages	Disadvantages
Aerobic processes	○ Removes biodegradable organic materials ○ Removes ammonia ○ Less retention time ○ Easy to operate	○ Energy requirement ○ Sludge production ○ Low organic loading rate
Anaerobic processes	○ Less sludge production ○ Less energy required ○ Methane recovery ○ Removes heavy metal by forming metal sulfides	○ Limit ammonia removal ○ Long retention time ○ Sensitive to toxic compounds and pH
Constructed wetland	○ Low operation and maintenance cost ○ Various contaminant removal mechanisms	○ Land intensive ○ Low quality of effluent
Leachate recirculation	○ Removes biodegradable organic materials ○ Accelerate waste stabilization ○ Methane recovery ○ Reduced post-closure monitoring	○ Leachate seeps ○ Reduced landfill slope stability ○ Odor problems ○ Field plumbing problems

2007 Report: Physical/Chemical

Physical/Chemical Treatment Processes	Advantages	Disadvantages
Coagulation-flocculation	○ Mature wastewater treatment process	○ Limited removal of organics
Chemical precipitation	○ Easy to operate	○ Sludge production ○ Cost of chemicals
Chemical Oxidation	○ Effectively removes refractory organic materials	○ Cost of oxidants ○ Extra energy may be required for AOPs
Membrane filtration	○ High removal of COD and dissolved solids	○ Membrane fouling ○ High cost
Air stripping	○ High removal of ammonia and VOCs	○ Air pollution of ammonia and VOCs ○ Sensitive to pH and temperature
Adsorption	○ High removal of refractory organic materials	○ High cost ○ Need regeneration
Ion exchange	○ High removal of dissolved ions/cations	○ High cost ○ Leachate must be pretreat.

Key Treatment Parameters

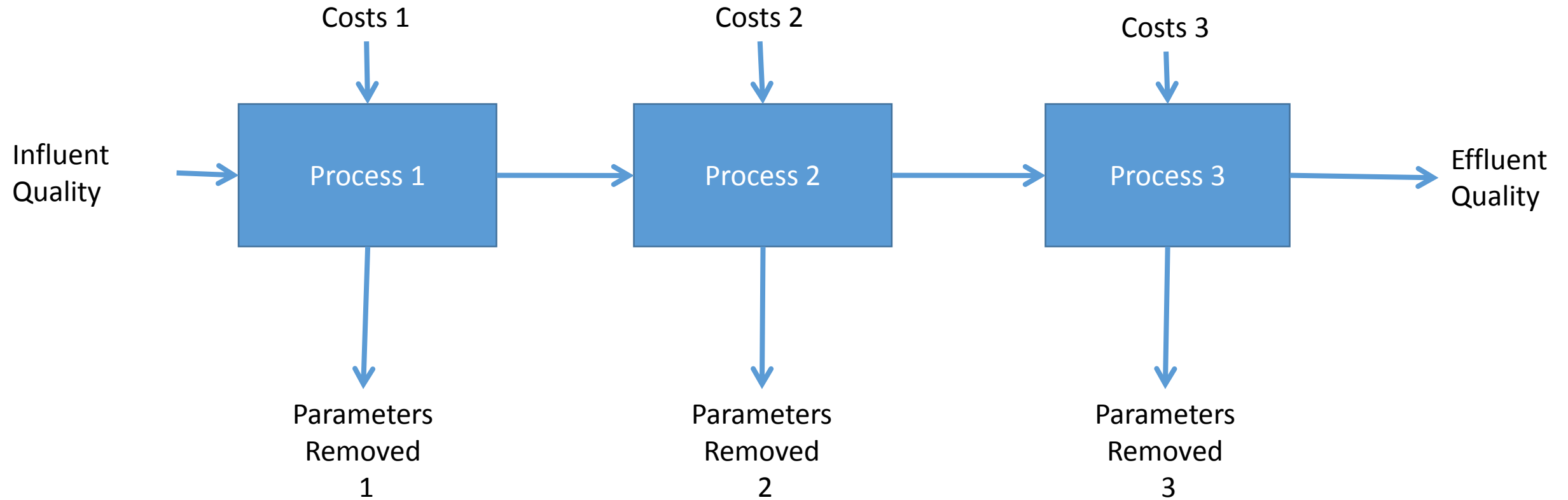
Table 1 Physicochemical characteristics of raw and biologically-pretreated municipal solid waste (MSW) leachates

Parameters	Raw leachate	Biological effluent
COD (mg/L)	17000 $\pm$ 200	680 $\pm$ 10
BOD (mg/L)	9200 $\pm$ 100	60 $\pm$ 2
NH ₃ (mg/L)	660 $\pm$ 10	20 $\pm$ 1
pH	7.2 $\pm$ 0.3	8.4 $\pm$ 0.4
Conductivity (mS/cm)	13.4 $\pm$ 0.1	17.1 $\pm$ 0.1
Chloride ion (mg/L)	4300 $\pm$ 100	4000 $\pm$ 100
Alkalinity (CaO mg/L)	4700 $\pm$ 100	1200 $\pm$ 100
Suspended solids (mg/L)	1700 $\pm$ 100	150 $\pm$ 10
Dissolved solids (mg/L)	23800 $\pm$ 200	13600 $\pm$ 200

Data are presented as average value of three measurements $\pm$ standard deviations.

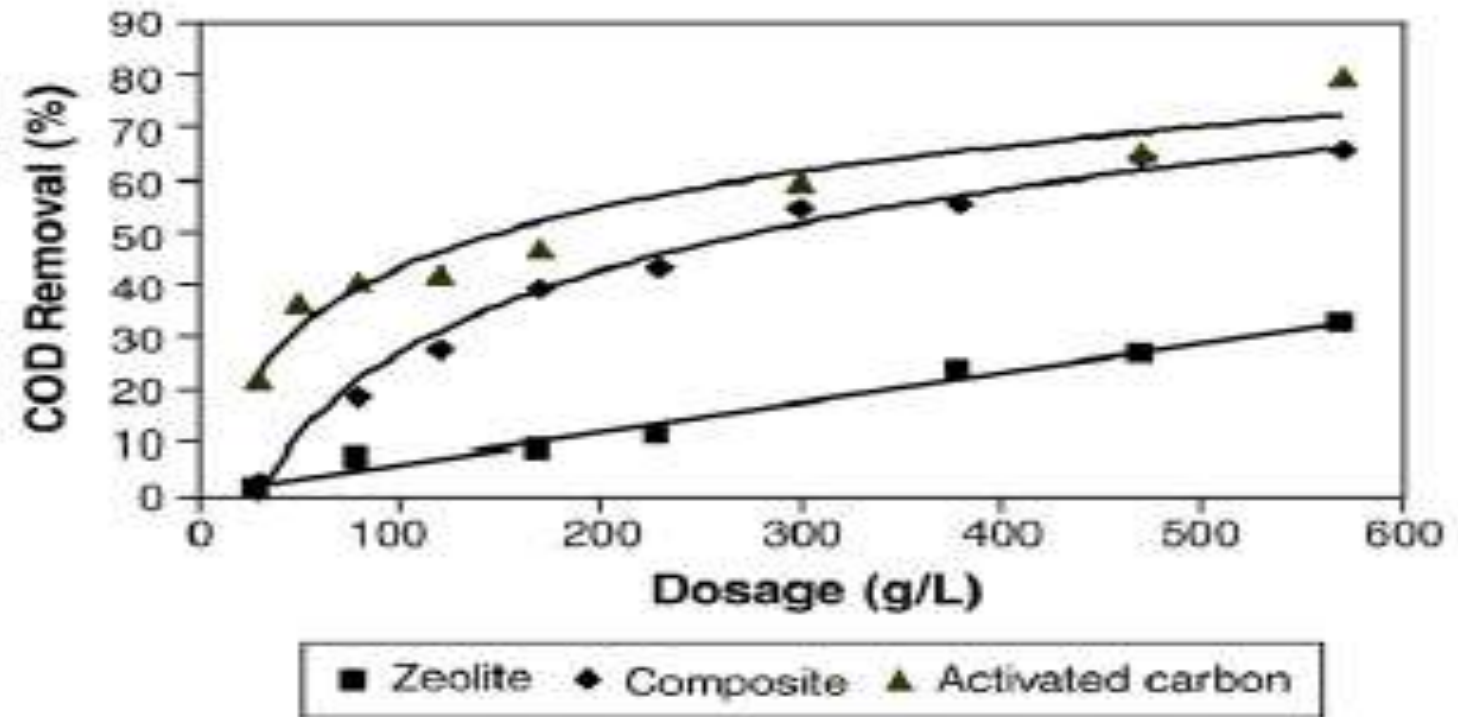
Source: Quan et al., 2013 – Electrochemical oxidation of....Biologically Treated Municipal Solid Waste Leachate in a Flow Reactor

Engineering Cost Model



Adsorption

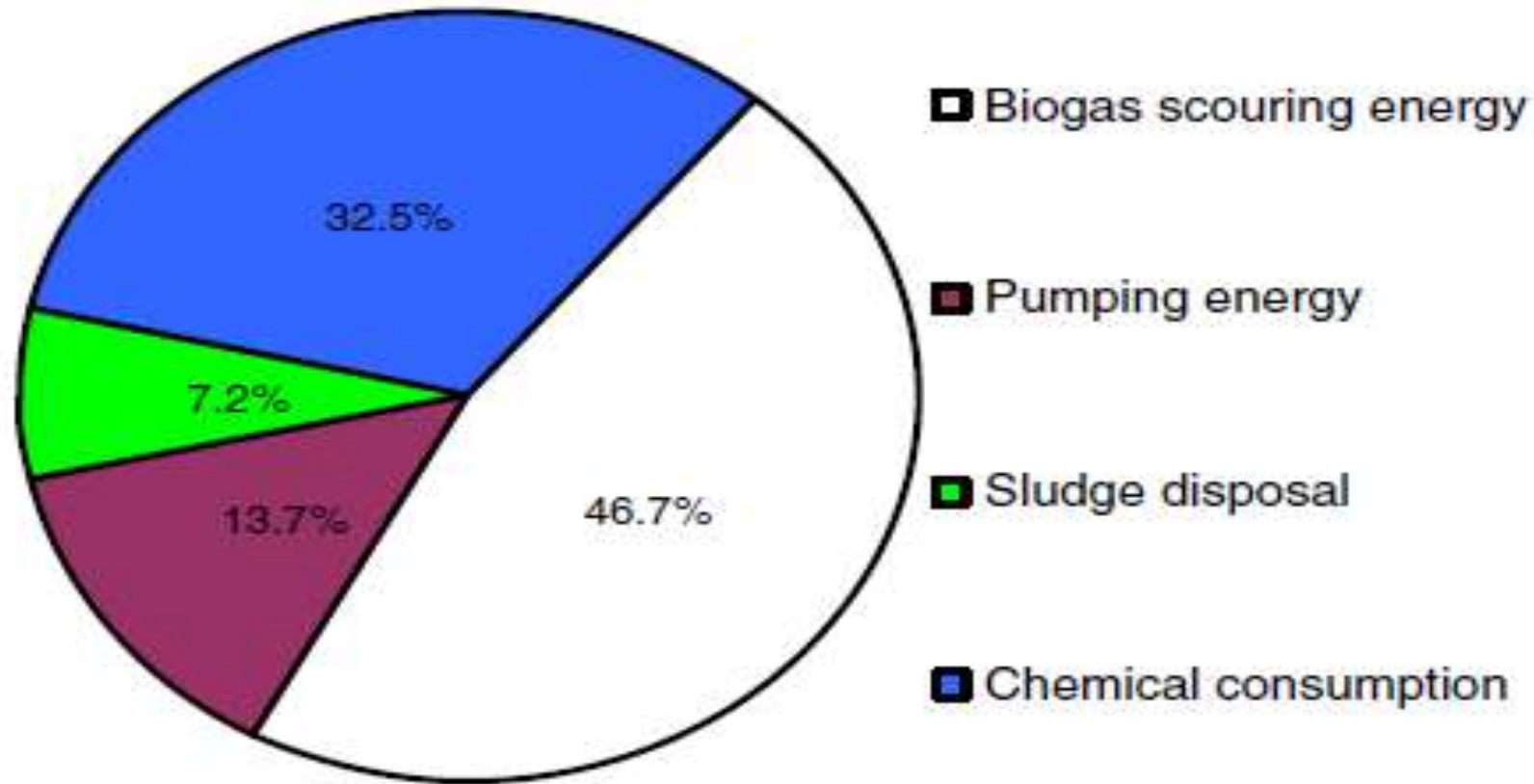
- Adsorption media requirements



COD removal using composite media, zeolite and activated carbon as adsorbent.

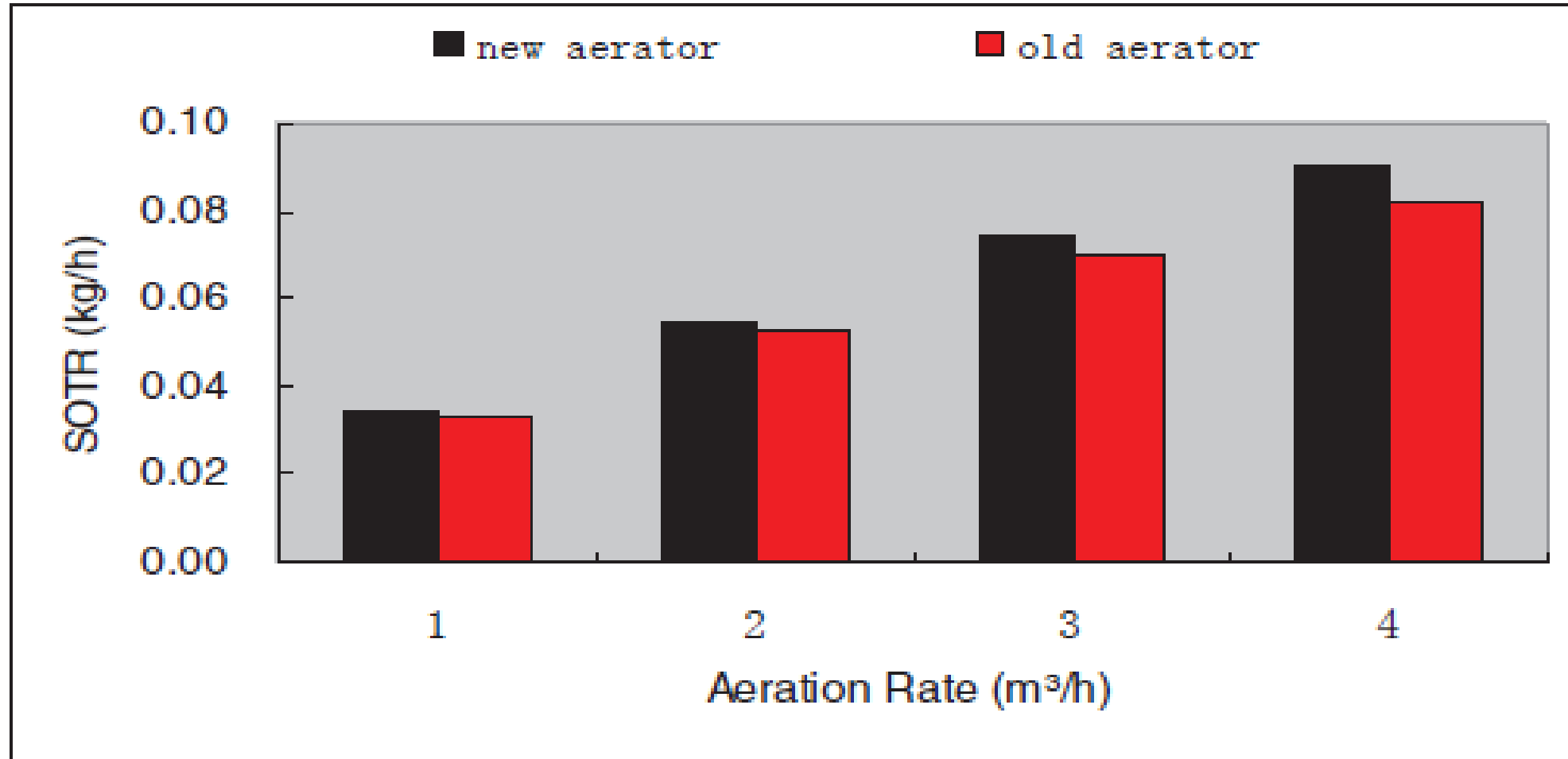
Source: Halim et al., 2010

Membranes



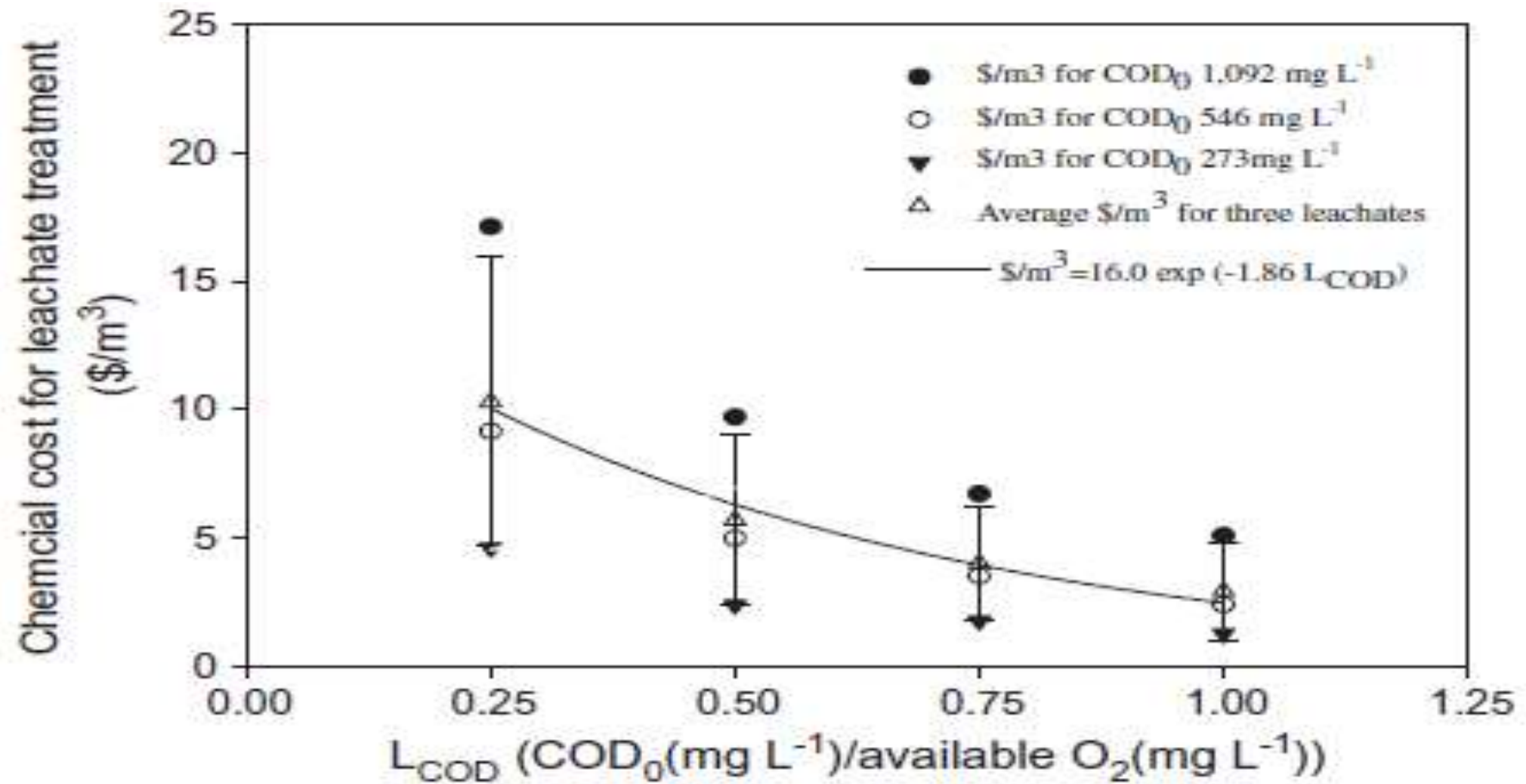
Operational costs of an AnMBR
Source: Lin et al., 2011 *Desalination*

Biological - Aerobic



Source: Liu et al., 2011

Oxidation



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Task 5:

**Develop design options for sub-liner vadose zone venting
&**

Task 6:

Vadose zone venting simulation and economic evaluation

*Presented by Jaeshik Chung
(PhD student)*

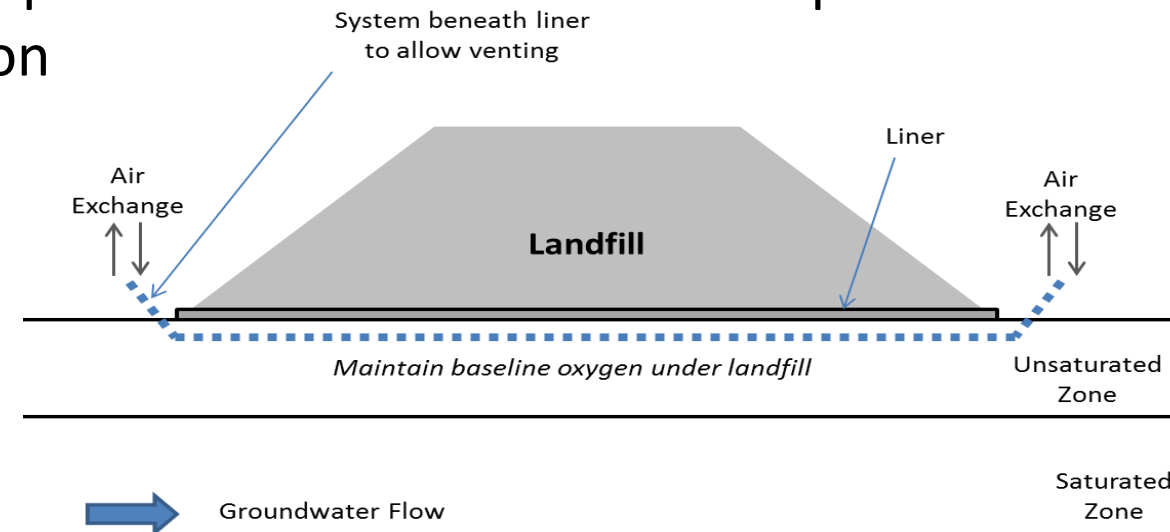
Introduction

Sub-Liner Vadose Zone Venting

- ✓ Prevent plume migration especially developed under reducing condition (Mn(II) , Fe(II) ..)
- ✓ Oxidation of residual organic matter, ammonium-nitrogen
- ✓ Reducing risk of some contaminants via transformation to less hazardous form (As(III) → As(V) ..)
- ✓ Cost-benefit analysis is required..

Simulation of Vadose Zone Venting using Numerical Simulation

- ✓ Assuming predictable and continuous spatial-temporal variation across discrete points
- ✓ Can incorporate various initial/boundary condition



*Fig. Scheme of
sub-liner vadose zone venting*

Simulation tool used in this study



AIR/W 2012 air flow analysis.

AIR/W is a finite element CAD software product for analyzing groundwater-air interaction problems within porous materials such as soil and rock. Its comprehensive formulation allows you to consider analyses ranging from simple, saturated steady-state problems to sophisticated, saturated/unsaturated time-dependent problems

Features (from GEOSLOPE web page)

- Analysis types include steady-state confined and unconfined flow, transient flow, 2-D flow in a cross-section or in plan view, and 3D axisymmetric flow.
- Boundary condition types include total head, pressure head, or flux specified as a constant or a function of time; pressure head; transient flux as a function of computed head; review and adjustment of seepage face conditions.
- Volumetric water content and conductivity functions can be estimated from basic parameters and grain-size functions.
- Adaptive time stepping to ensure the use of optimal time steps in transient analyses with sudden changes in boundary conditions.
- Flow path deliniation.

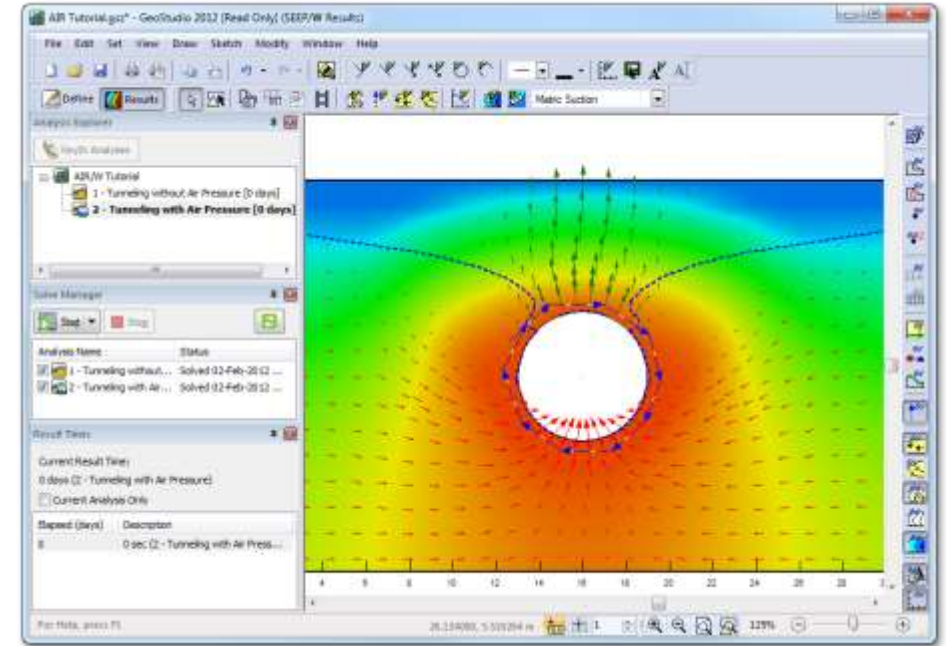
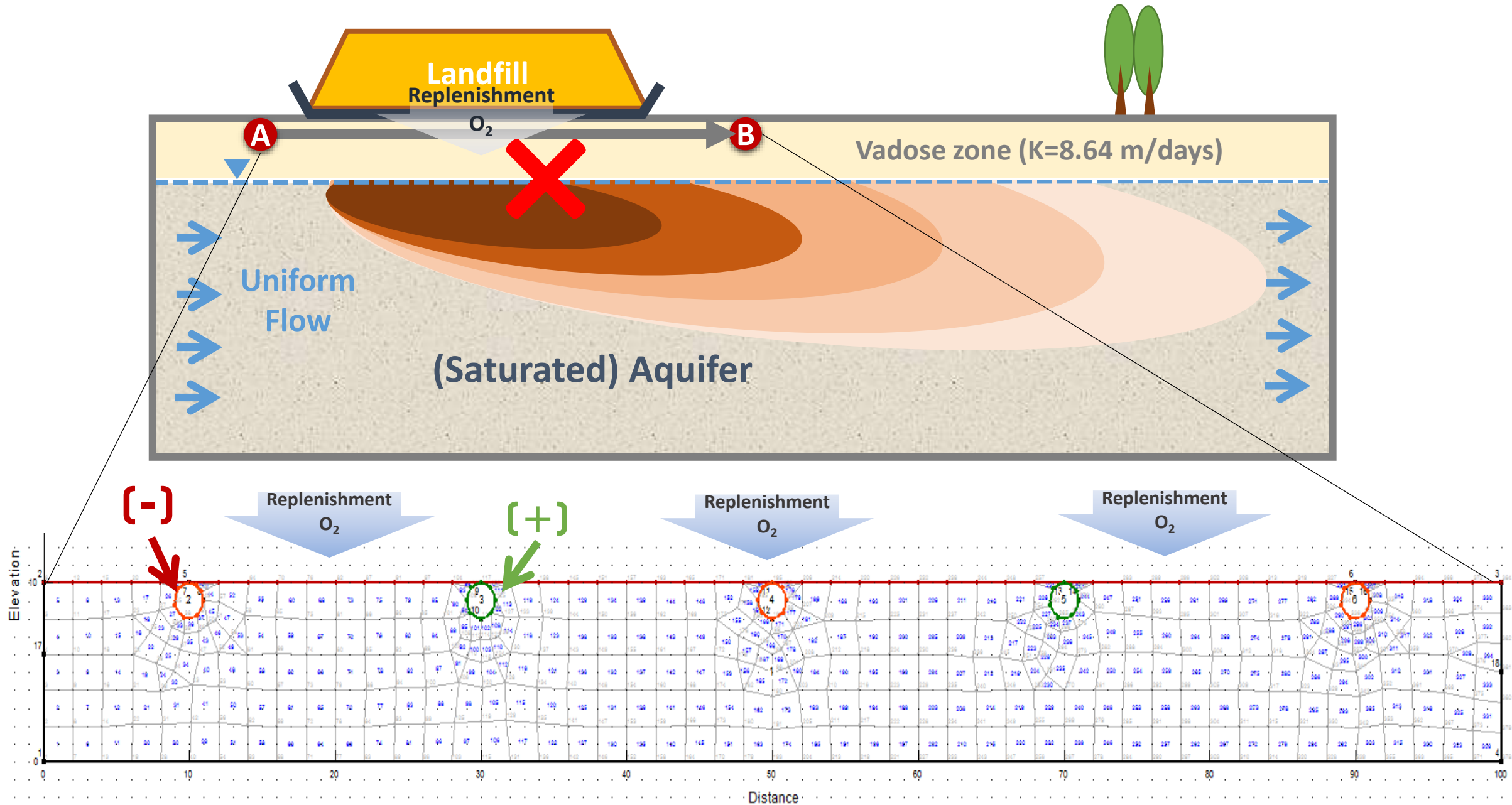


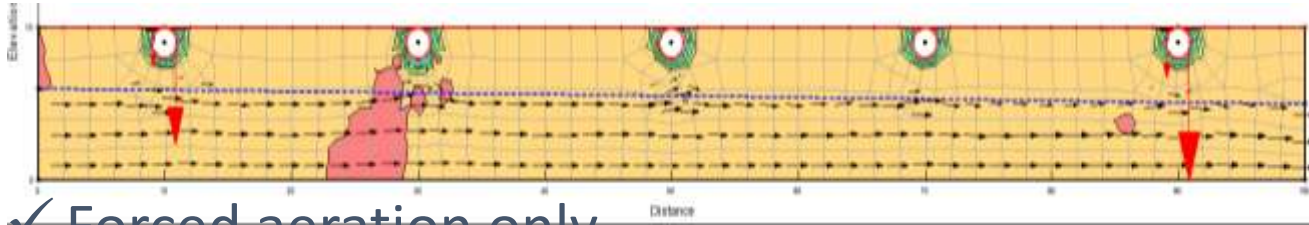
Fig. Example of air-flow modeling into a tunnel

Conceptual 2-D Model for Sub-Liner Venting

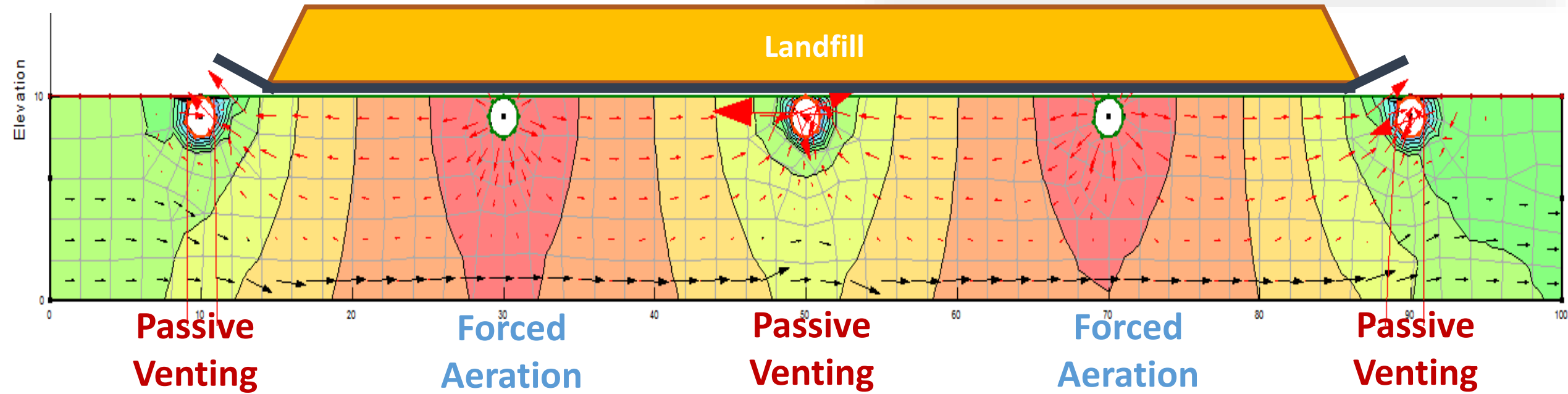
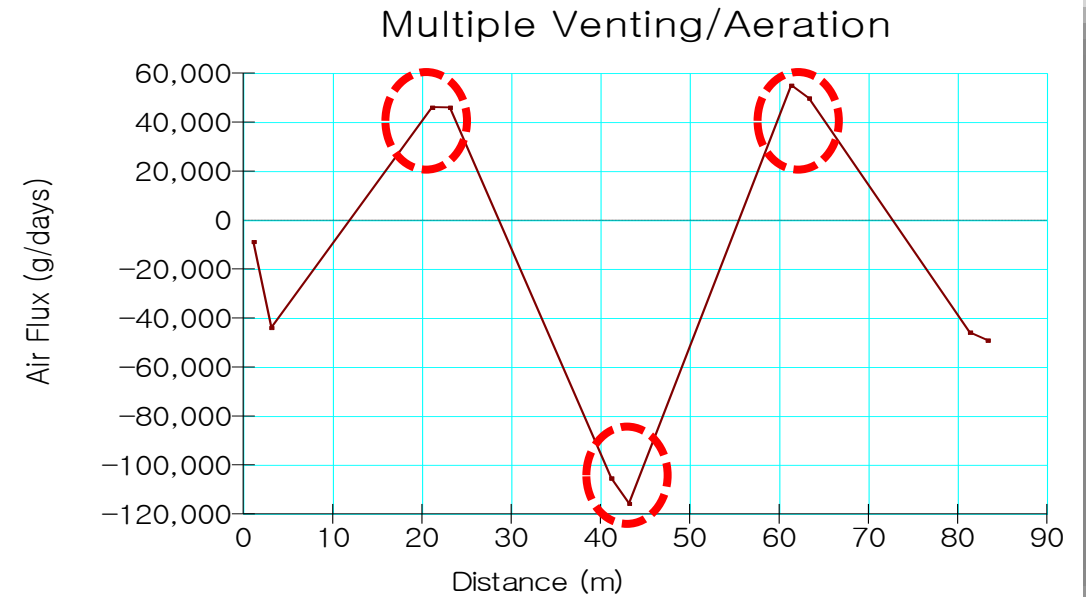
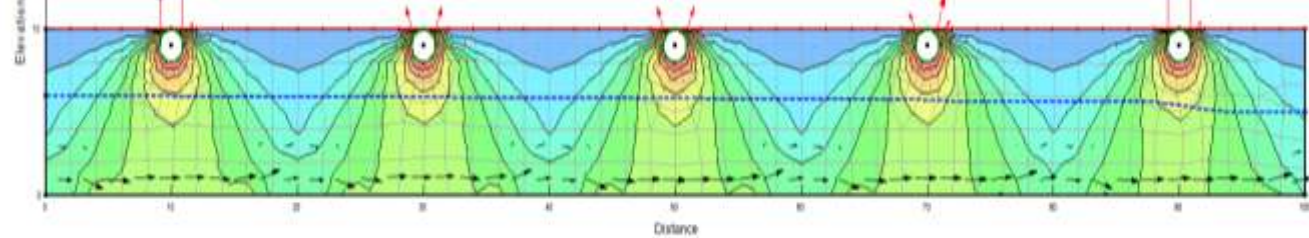


Effect of the combined Passive-venting/Forced aeration in vadose Zone

✓ Passive venting only

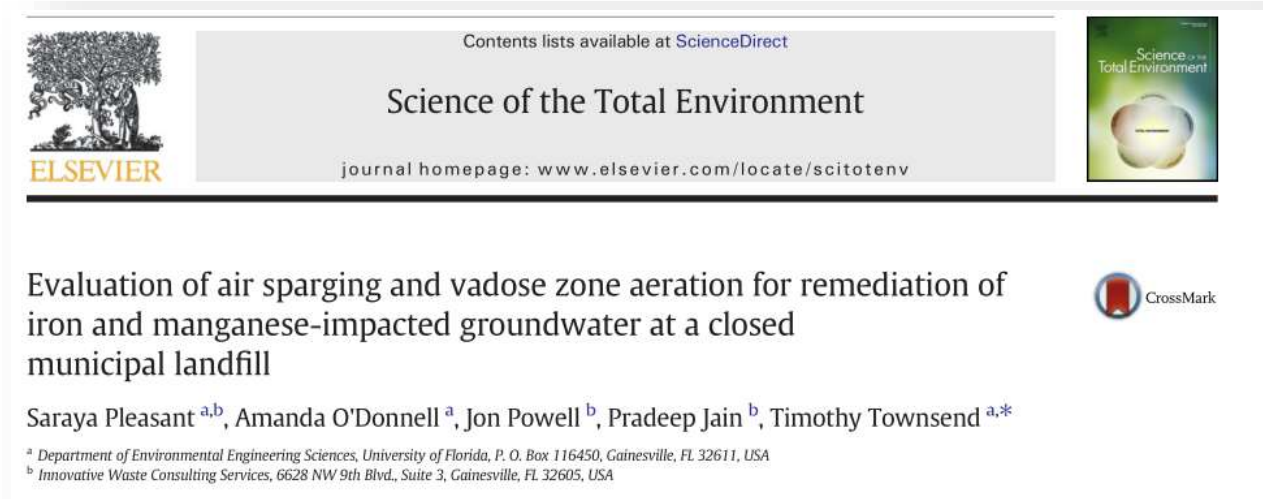


✓ Forced aeration only



Summary & Further Study

- ✓ **Sub-Liner Vadose Zone Venting can be effective in preventing vadose zone from reducing condition**
 - can prevent secondary contamination (e.g. reductive dissolution) in advance
- ✓ **Dimension and configuration of the venting/aeration pipes should be considered**
 - Distance between pipes, amount of pressure should be optimized
- ✓ **Verification of the model using lab(field) data**



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