Long term operation of onsite volume reduction system to evaluate “water evaporation efficiency” of the same gauze sheet

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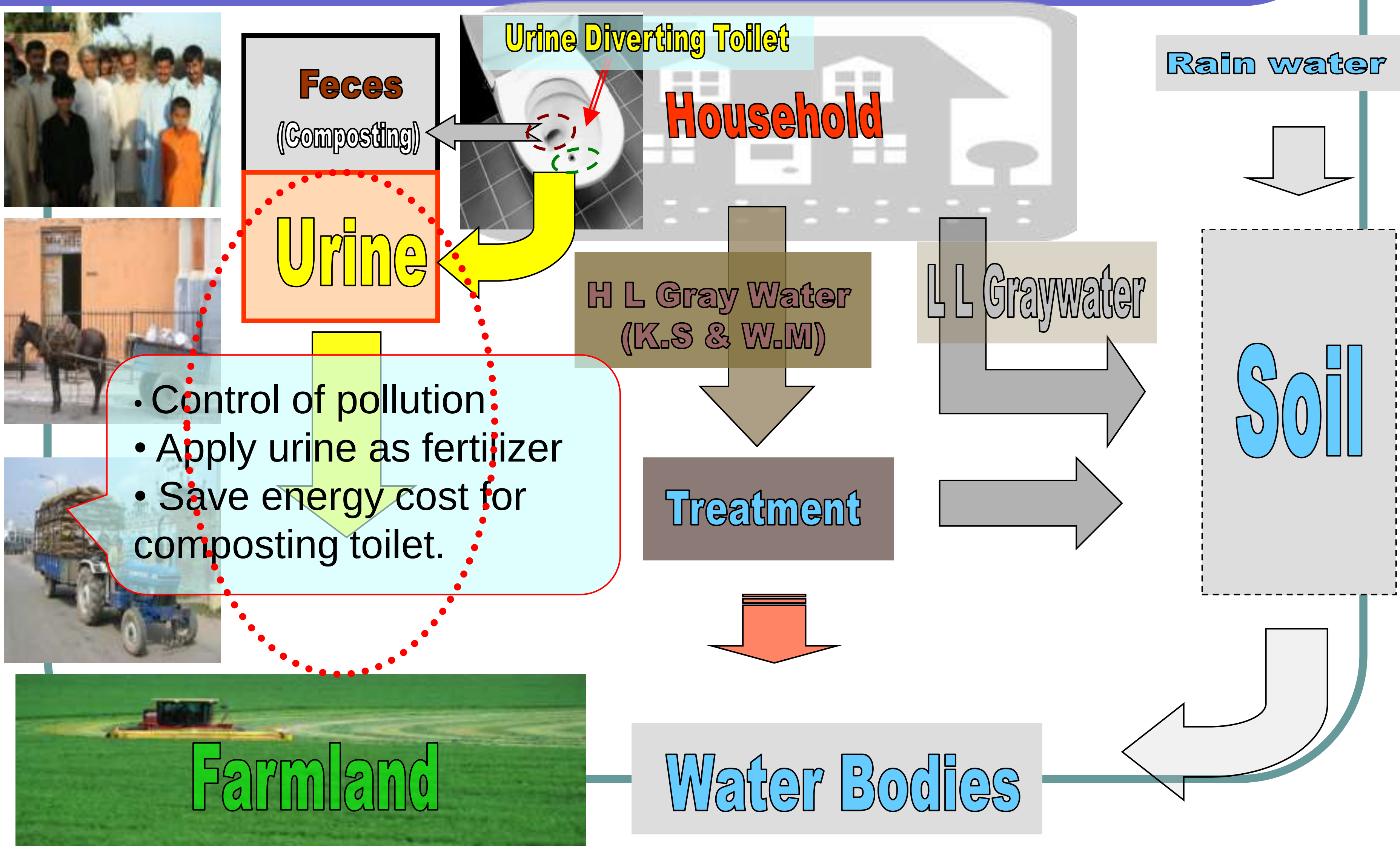
This presentation

- Introduction
- Background
- Material and method.
- Results and discussion
- Summary

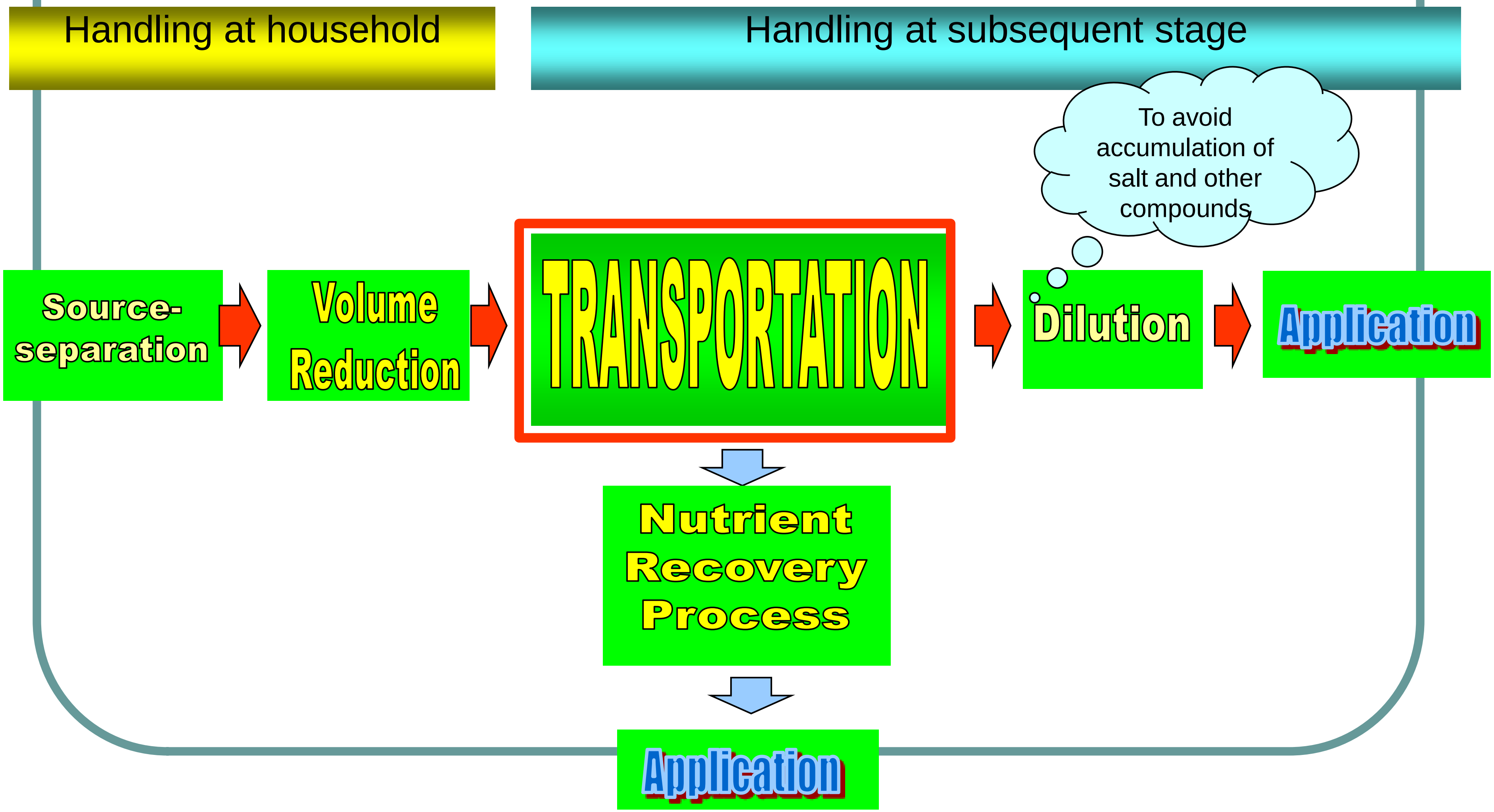
Introduction

Onsite Wastewater Differentiable Treatment System (OWDTS)



Background

(Why the volume of urine should be reduced?)



Background

Design of OVRS based on climate conditions and daily urine discharge

How much volume should be reduced?

Motivation

Specific case study of Southern Pakistan

Compared transp. cost of raw urine with various concentrated urine cases

Compared transp. cost of urine cases with commercial fertilizer cost

How can we reduce the volume or urine?

Research objective

Propose volume reduction method

Review of previous research and drying theory

Prepared experimental unit, performed experiments, design procedures

Background

(Specific case study of Southern Pakistan)

Data required to estimate transportation cost

	Nitrogen	Phosphorus	Potassium
Concentration in urine (g/L)	7-9	0.2-0.21	0.9-1.1
Required fertilizer for cotton (kg/ha)	90-140	60	50
Amount of required raw urine (L)	10,000	300,000	50,000
Proposal	10,000 L		
Nutrient recovery (kg)	90	2	11
Addition of commercial fertilizer (kg)	0	58	40
Unit Transport cost (US $/km/1000L)	0.1374		

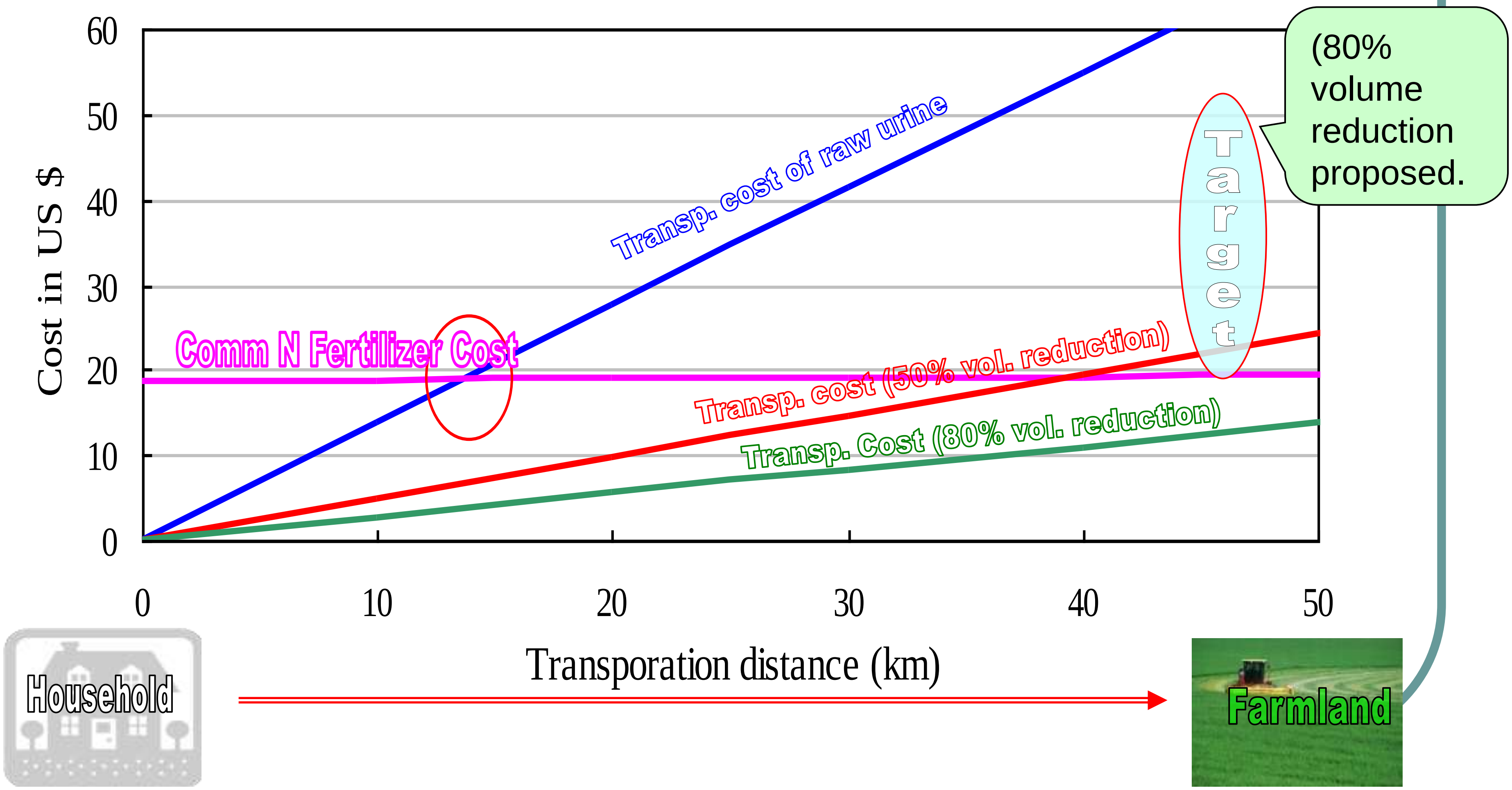
References:

1. A. Guyton, Textbook of Medical Physiology, W. Saunders Co., Philadelphia, USA,1986.
2 Food and Agriculture Organization of UN, Rome, Fertilizer use by crops in Pakistan
3. World Bank Report, Road Transport Service Efficiency Study, India, November, 1, 2005.

Background

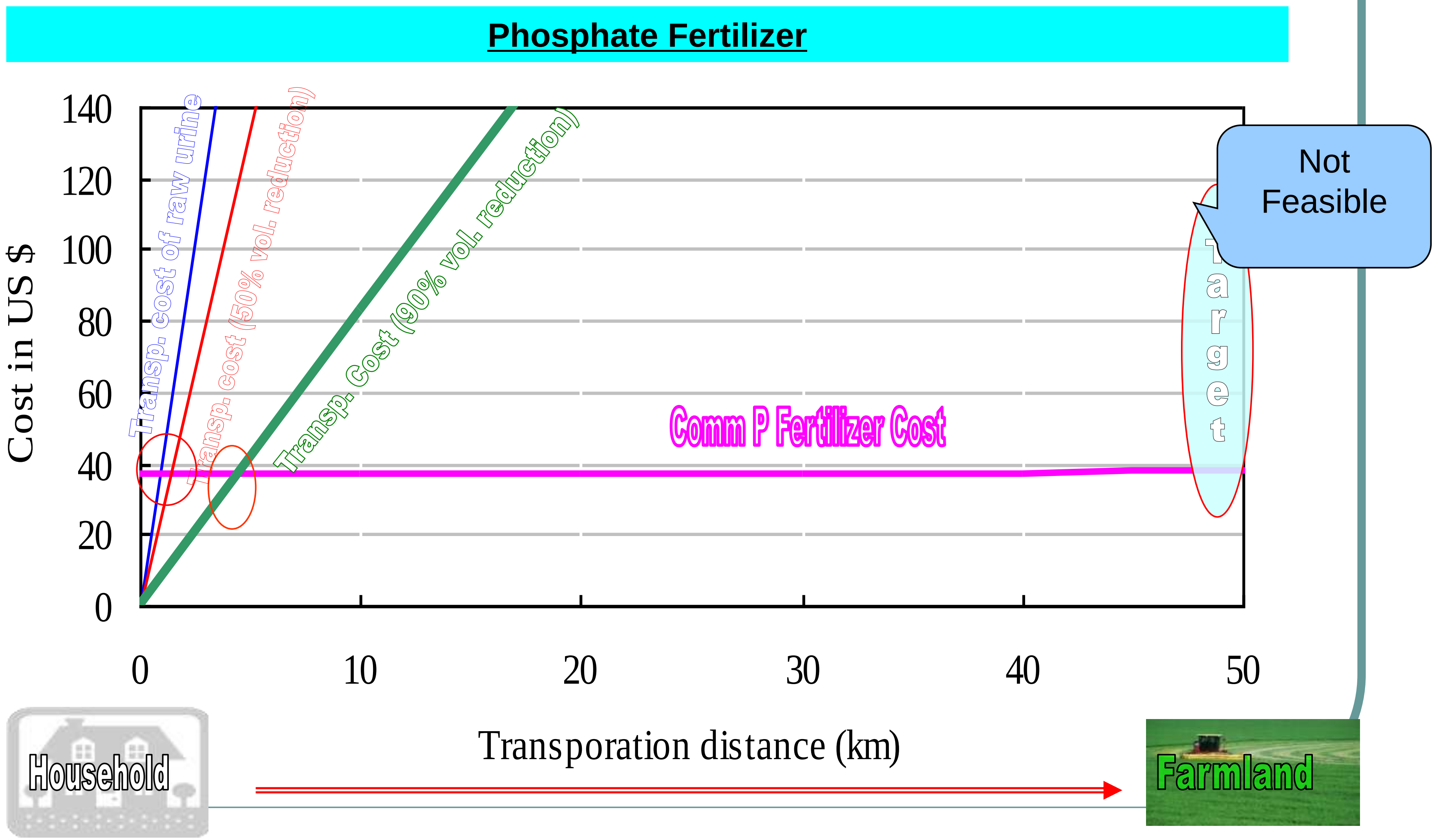
(Transp cost of urine vs. cost of commercial N fertilizer)

Nitrogen Fertilizer



Background

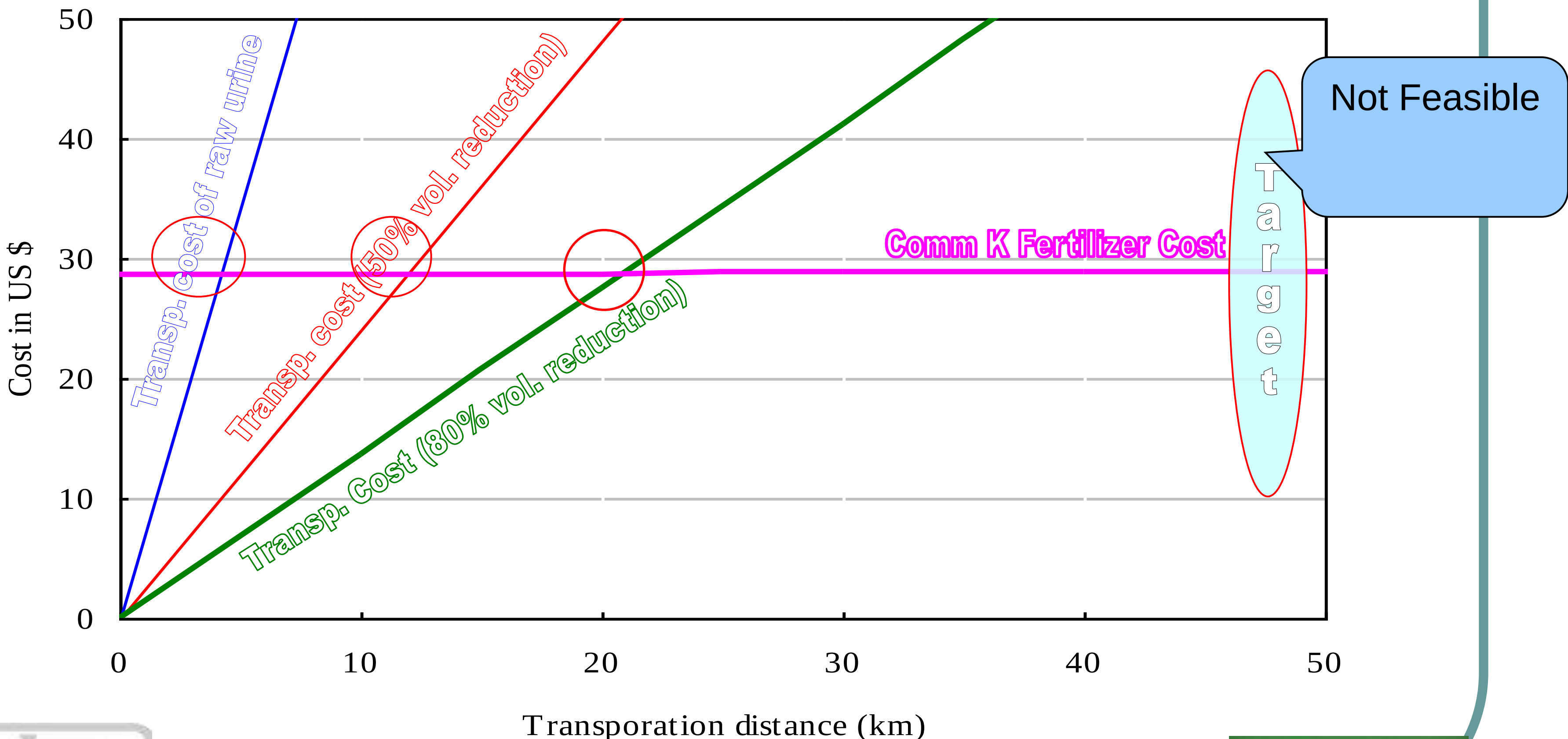
(Transp cost of urine vs. cost of commercial P fertilizer)



Background

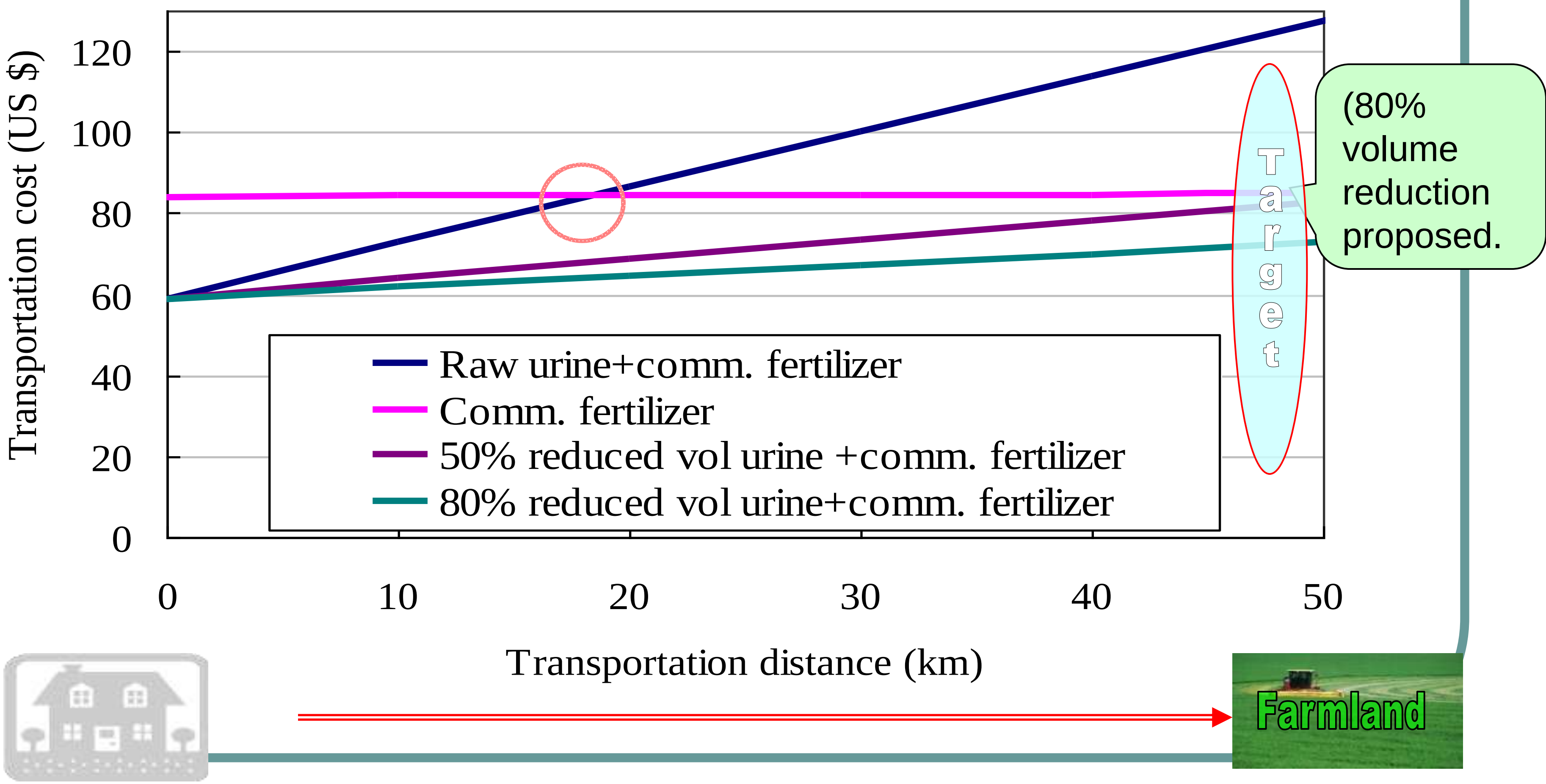
(Transp cost of urine vs. cost of commercial K fertilizer)

Potassium Fertilizer



Background
(Case Study of Southern Pakistan)

Total NPK Fertilizer



Background

(Case Study of Southern Pakistan)

How much volume should be reduced?

- 80% volume reduction would be feasible for farmers

How much nutrients would be recovered?

- 100% N (90 kg)
- Partial P and K (2 and 11 kg respectively)
- Commercial P and K fertilizer need to be added.

How much cost reduction can be expceted?

- Transp. cost of urine + cost of deficit comm. fertilizer = 71 US$/ha
    - Cost of comm. fertilizer alone = 84.14 US$/ha
    - Result: 20% cost reduction per ha.

Material and Method

Currrent volume reduction processes

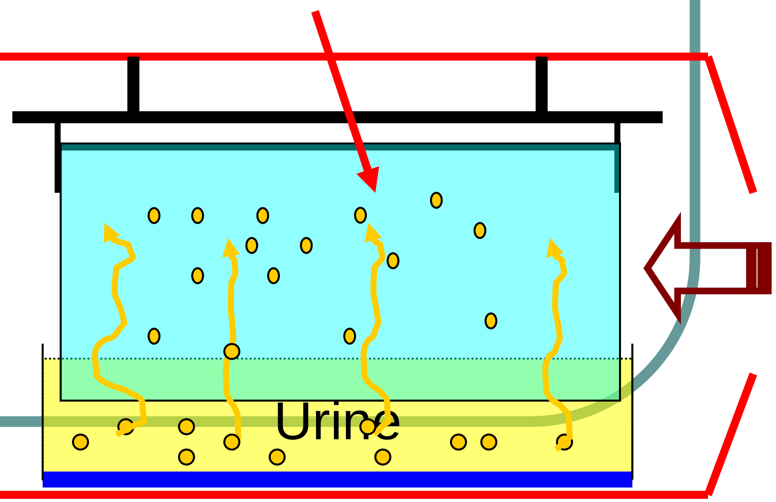
- **Reverse Osmosis Process**
- **Electro Dialysis Process**
- **Freezing and Thawing Process**
- **Conventional Drying by Heating**

Energy Intensive
Cost Intensive

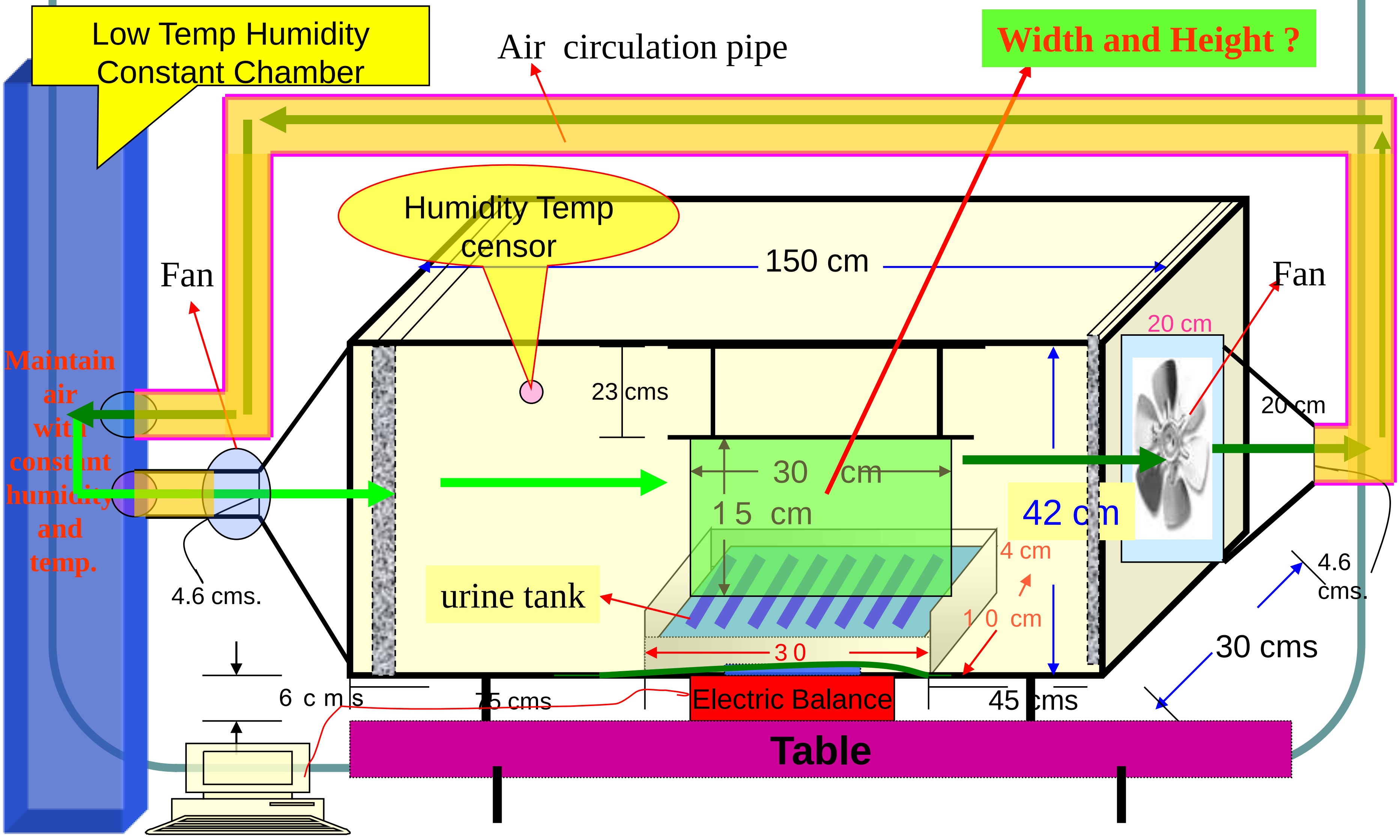
Salient features of OVRS

- **Vertical Cloth Sheet**
  - *Capillary Pressure*
- **Evaporation**
  - Influenced by
    - *air temperature*
    - *air humidity*
    - *air flow rate*

Concept of onsite volume reduction system



Material and method

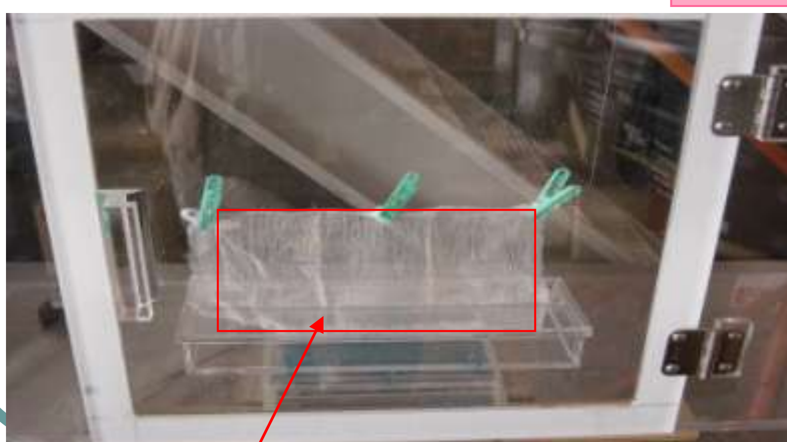


Material and Method

Constant Temp Humidity Chamber

Fan

Wind Tunnel



Vertical Sheet and Evaporation Tank

PC connected with Elec. Balance

Material and method

(Experiment conditions for short term experiments)

Short term operation of OVRS

Constants			**Variables**						**Find.**
Wind Velocity (m/sec)	Air Temp (-C)	Air Hum. (%)	**RUN-1** (Liquid Sample)						
1	25	70	D.W	D.U (10%)	S.Urine	S.Ux2	S.Ux3	S.Ux4	Xi, H
Wind Velocity (m/sec)	Sample	Air Hum. (%)	**RUN-2** (Air Temperature (-c))						
3	S.Ux2	60	20	-	30	-	40	-	Xi, H
Sample	Air Temp (-C)	Air Hum. (%)	**RUN-3** (Wind Velocity (m/sec))						
S.Ux2	20	70	1	-	3	-	4	-	Xi, H

Material and method

(Experiment conditions)

Long term operation of OVRS

Air conditions			Exp Time	Parameters			
W (m/sec)	T (ºC)	H (%)	(day)	g/day	mg/cm2	g water/g dry air	cm
2	25	60	60	ER	Salt concent.	Xi	H

Material and method

$$\downarrow ER = M_{air}\, Ky\, (Xi-X)\, W\, H$$

Should we consider that ~~accumulated salt~~ **in the sheet surface may affect** ~~saturated vapour pressure~~ **required to evaluate Xi?**

Experiment

Operation Time = 90 h

Effect on water evaporation rate:

Can we have steady-state evaporation or inhibition ?

Investigate

Saturated interface air humidity Xi

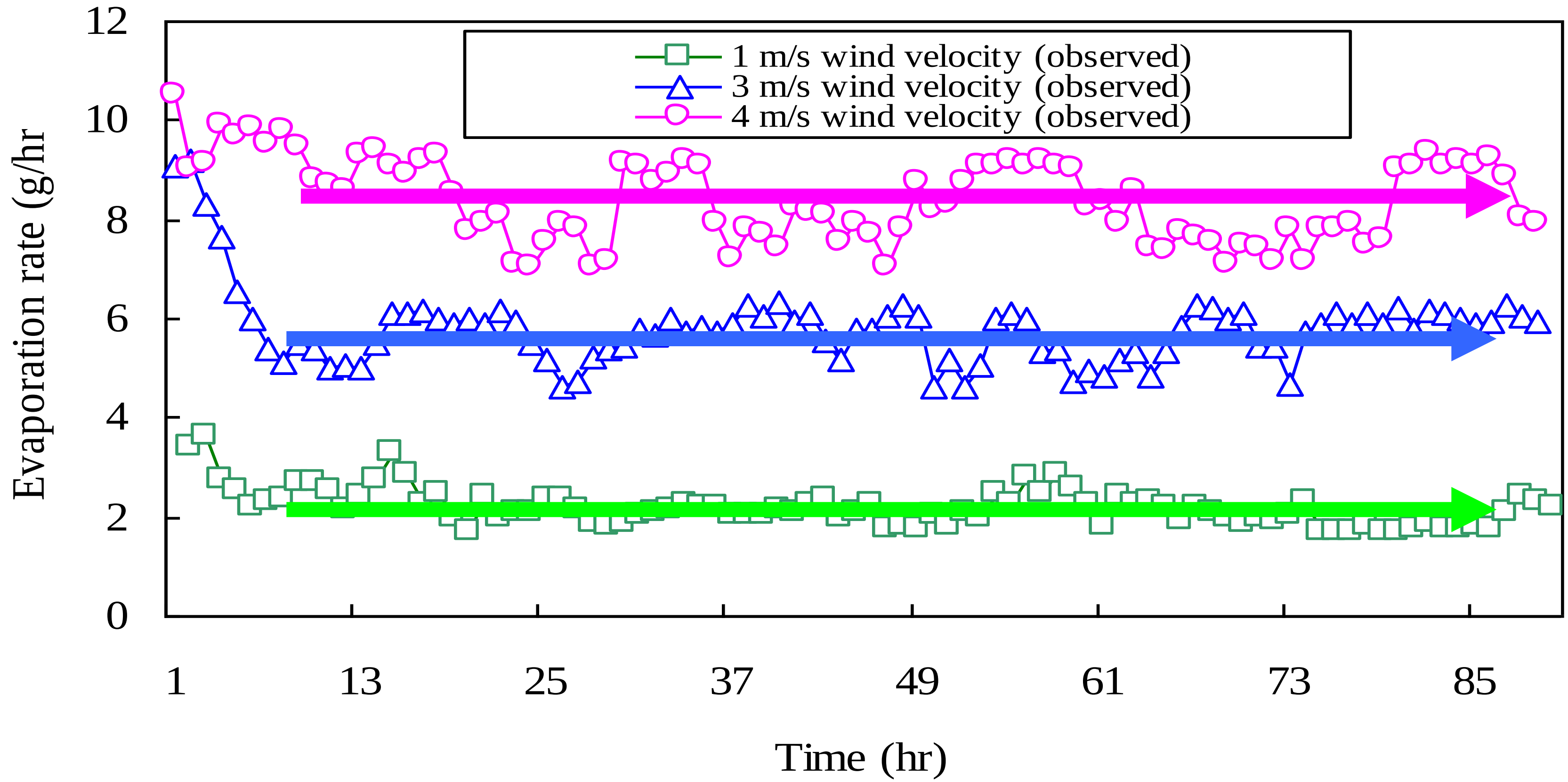
Water level in sheet, WL

Salt concentration in the sheet

How can we estimate the value of saturated vapour pressure

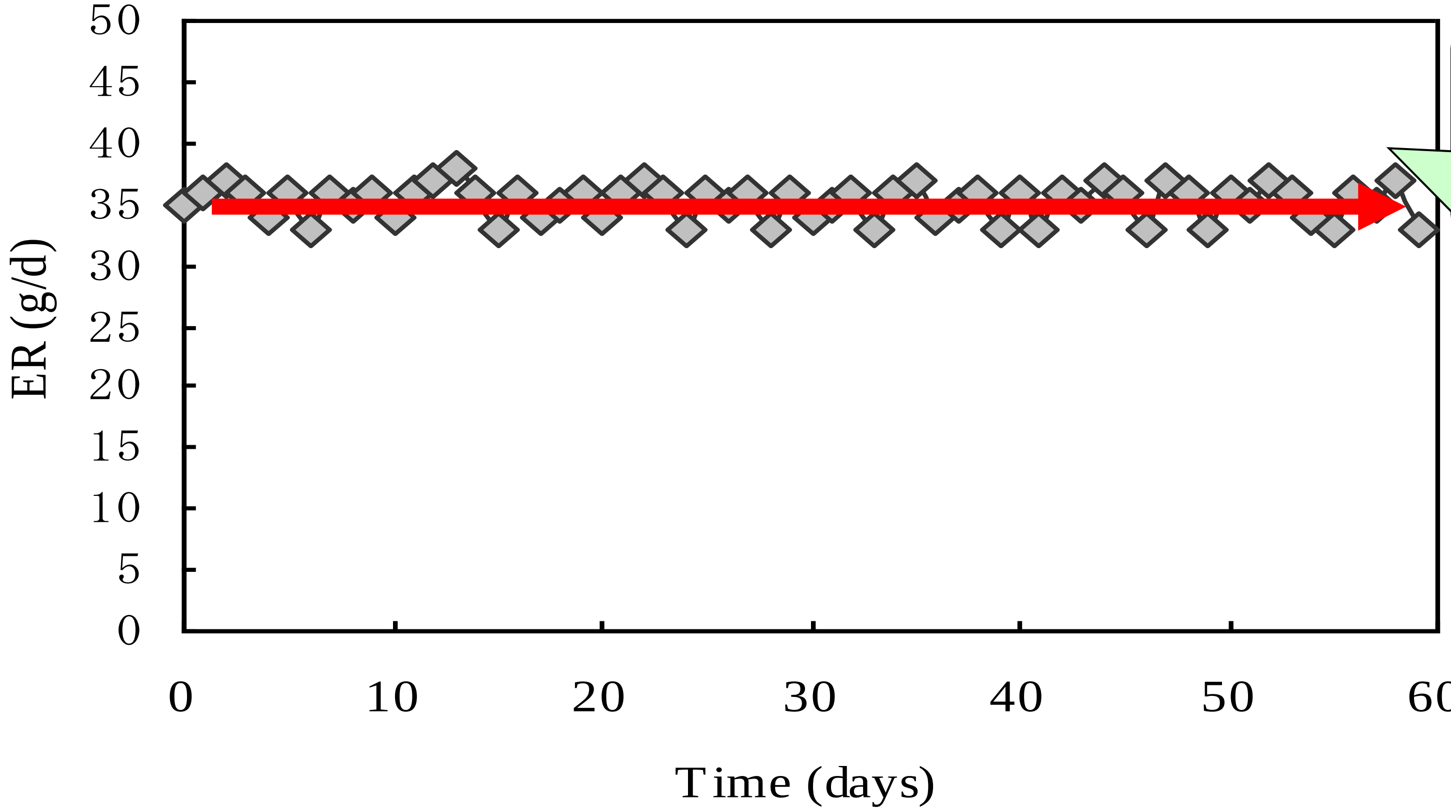
Experiment results

Evaporation rate
(RUN-3 for short term experiment)



- Steady state evaporation maintained
- High wind velocity make strong turbulent air flow to increase ER

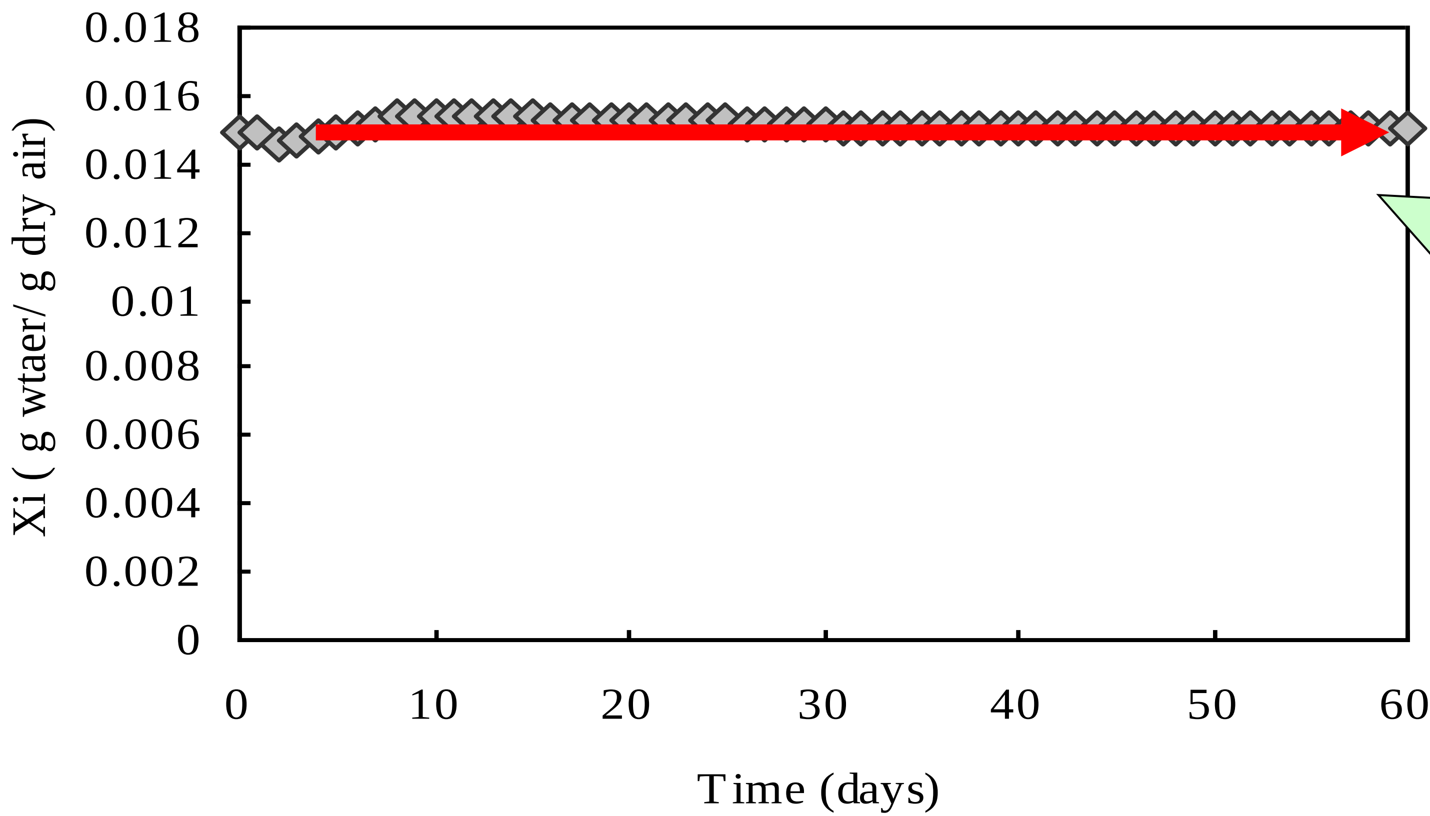
Water evaporation rate, ER



Same sheet can be used for 60 days

Steady-state evaporation maintained
No inhibition

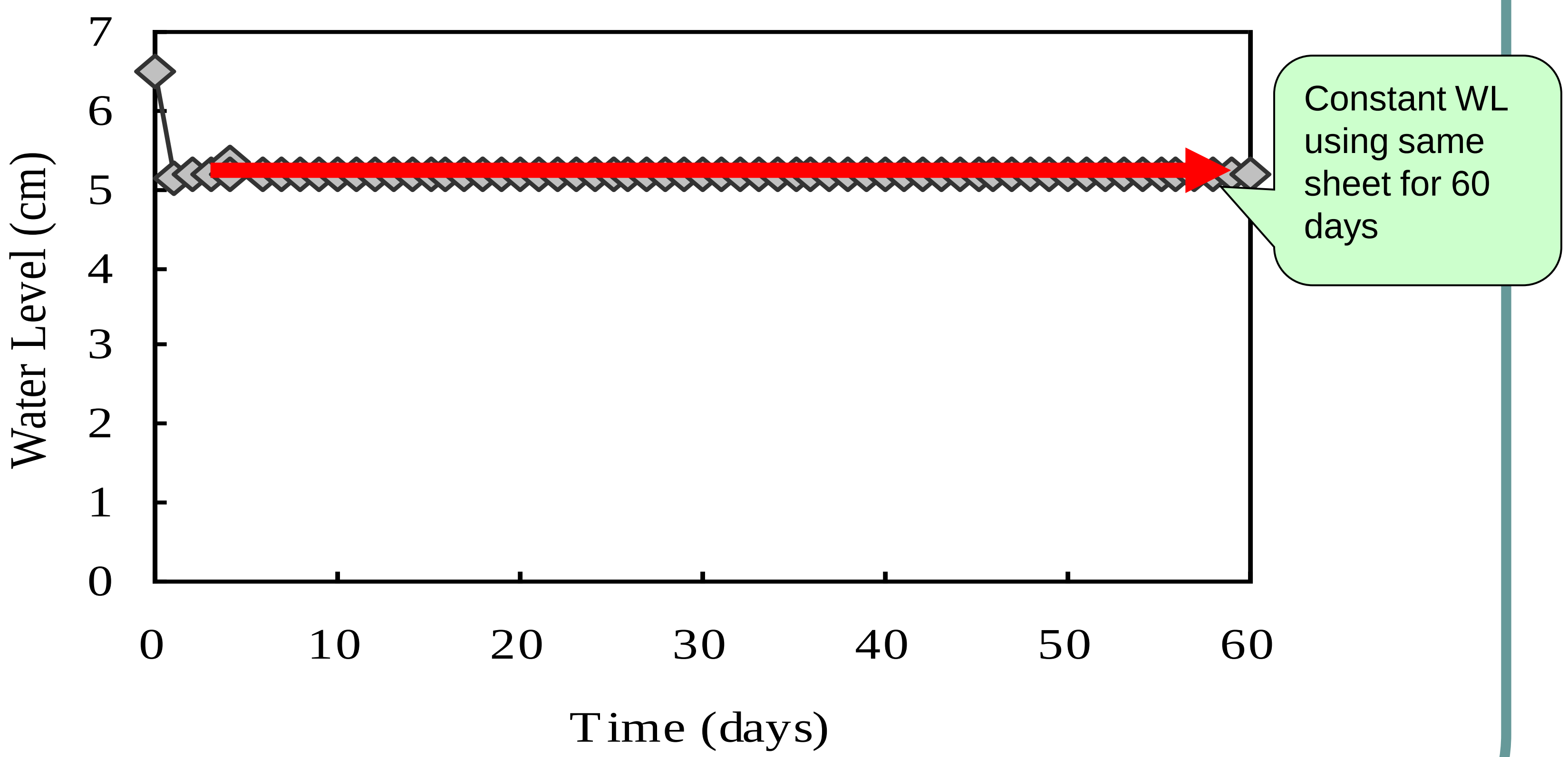
Saturated interface air humidity, Xi



Constant Xi using same sheet for 60 days

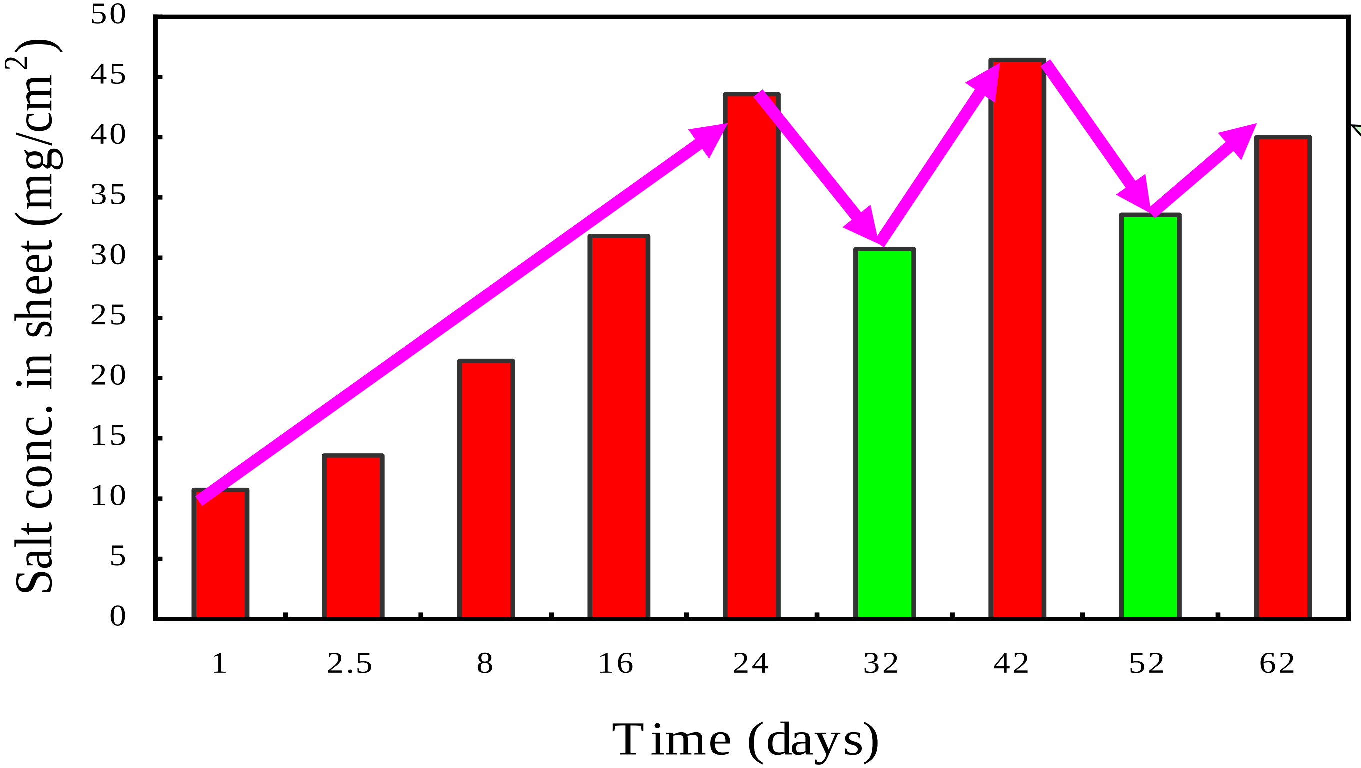
No change in Xi during steady-state condition

Water Level in the Sheet, cm



No change in WL during steady-state condition

Salt concentration in the Sheet, mg/cm^2

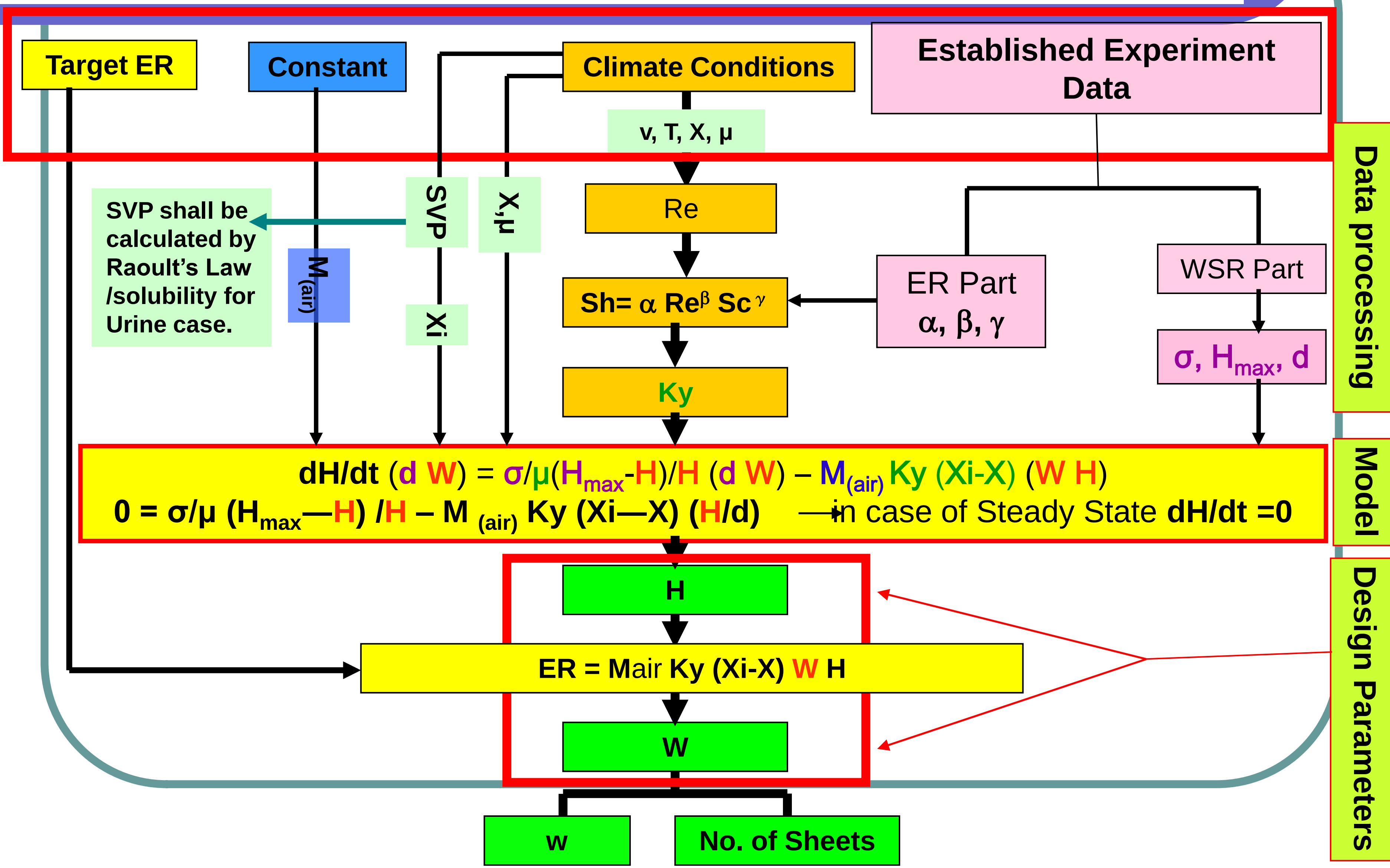


Accumulation and falling of salt conc.

Initial part shows increasing trend of salt in the sheet
Subseqbtently, cycles of accumulation followed by falling continues

Comprehensive Design Procedure

(For designing gauze sheet of OVRS)



Estimated size of gauze sheet

- 80% volume reduction of 10 L urine per day for a family of 10 members
- Conditions as shown in RUN-3

Given Data		Dimensions of Gauze Sheet		
Wind velocity (m/s)	Target ER (g/day)	Water Level (cm)	Width (cm)	Size of sheet (cm^2)
1	8000	8.8	1400	13000
3		5.5	900	5000
4		4.5	800	3600

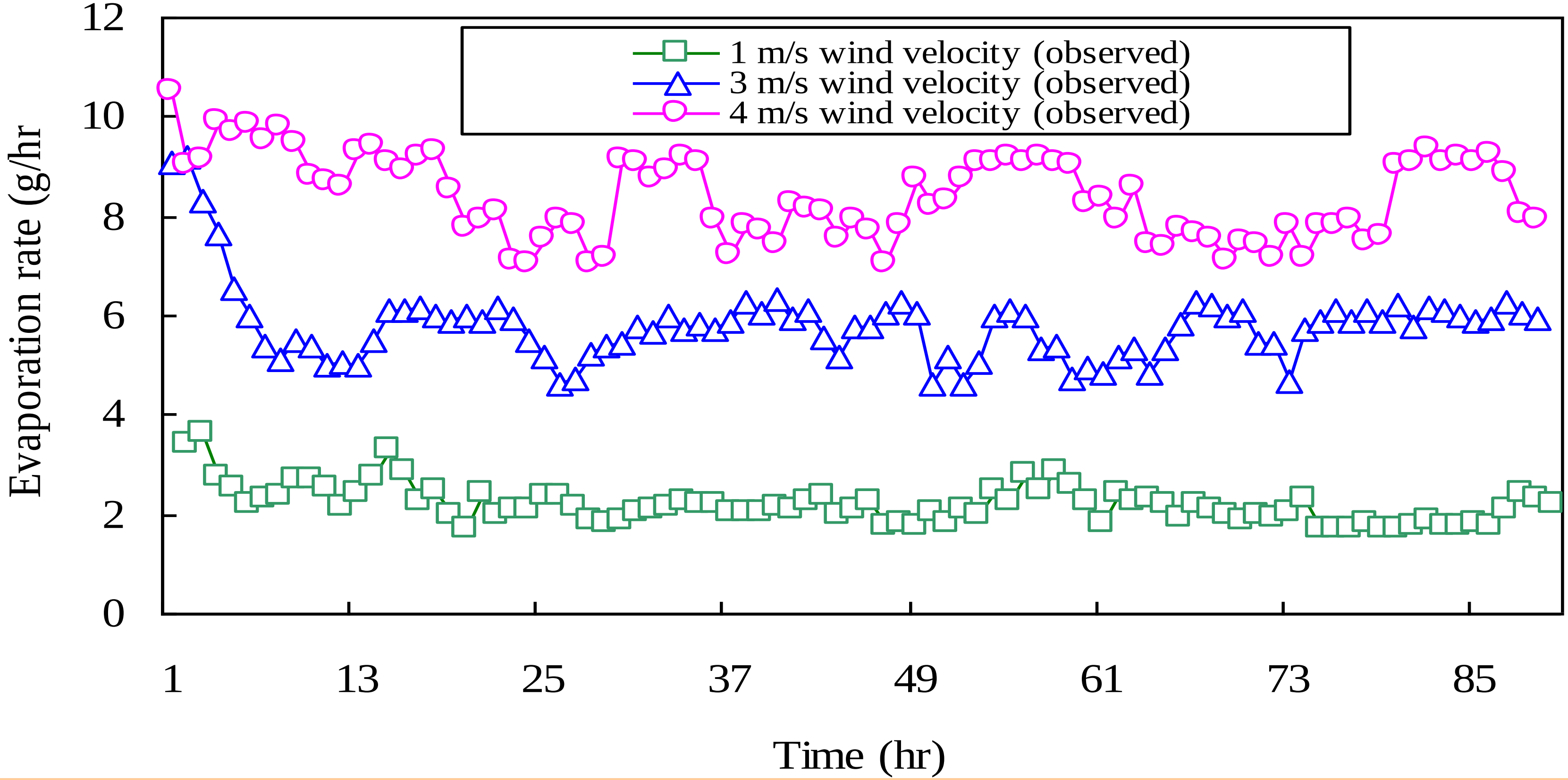
Summary

- Steady-state evaporation maintained without any inhibition.
- Values of Xi, WL and Salt Conc. in the sheet were found constant.
- Same gauze sheet can be used for a Long term operation of OVRS
- Required size of the sheet for 80% volume reduction is not so large.

Thank You

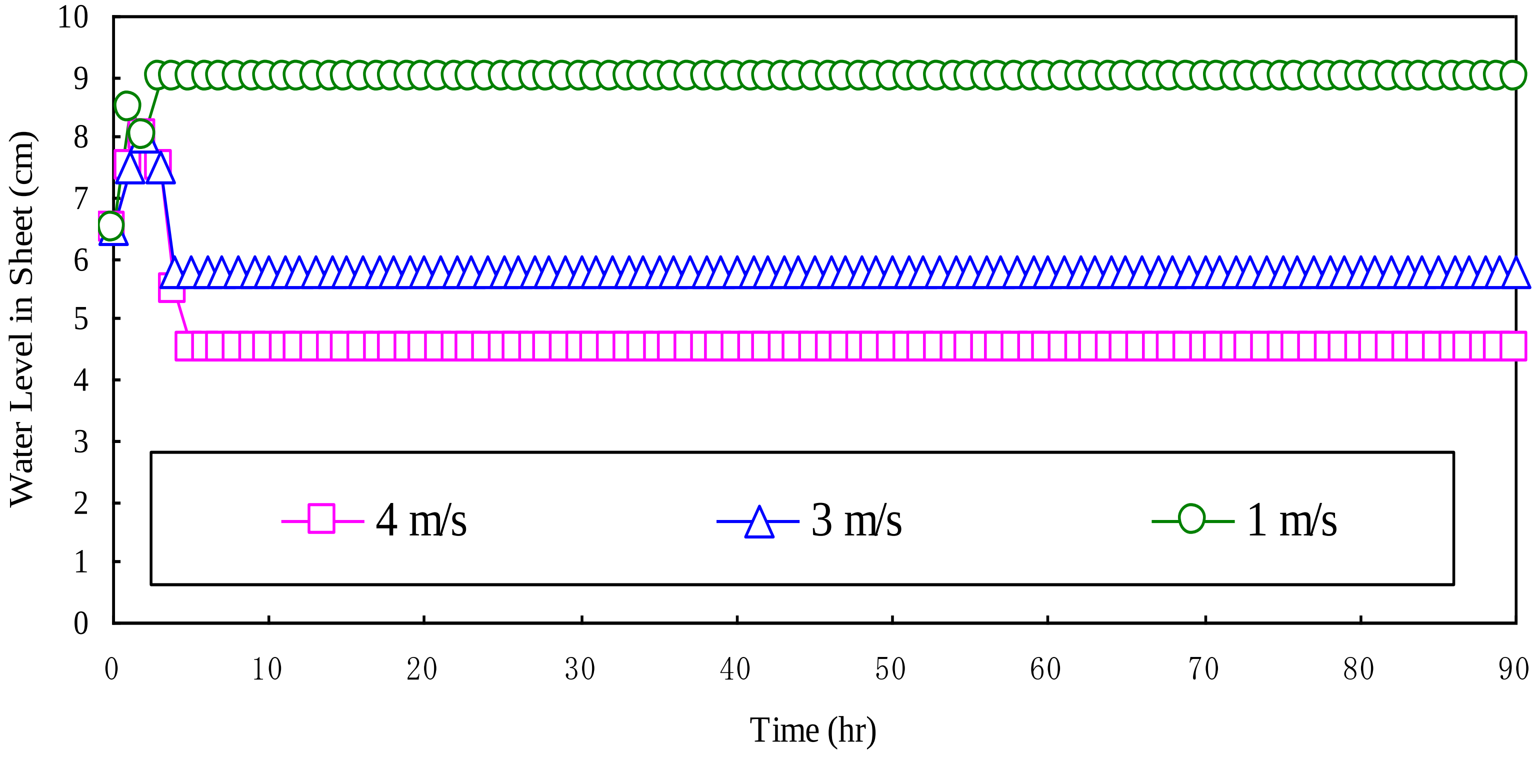
Evaporation rate

(RUN-3 for various wind velocities)



- Steady state evaporation after about few hr operation
- Steady state: High wind velocity make strong turbulent flow and increase ER than low wind velocity.

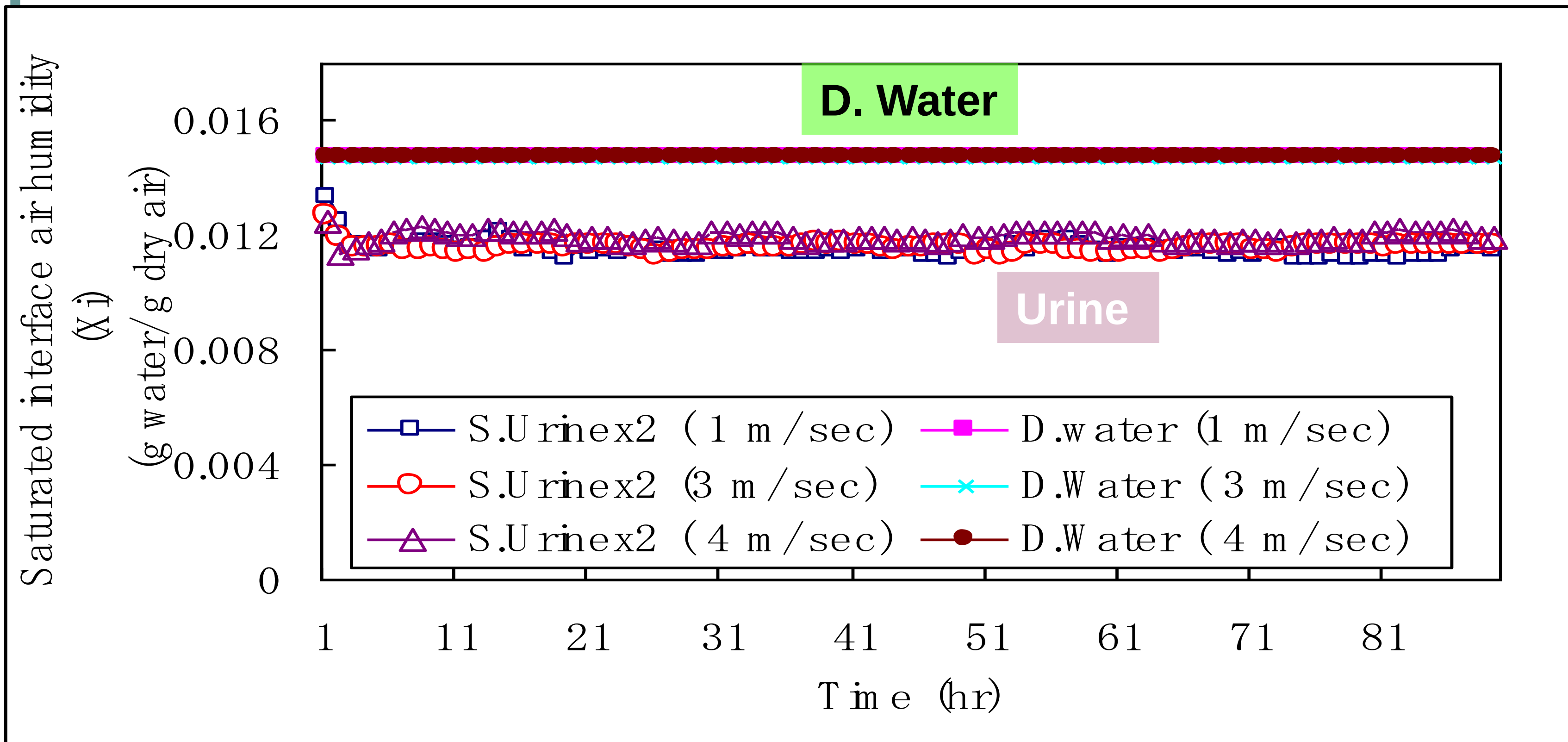
Water level in the sheet
(RUN-3: various wind velocities)



- Steady state was observed after few hr time.
- High wind velocity cause high evaporation with low water level in sheet.

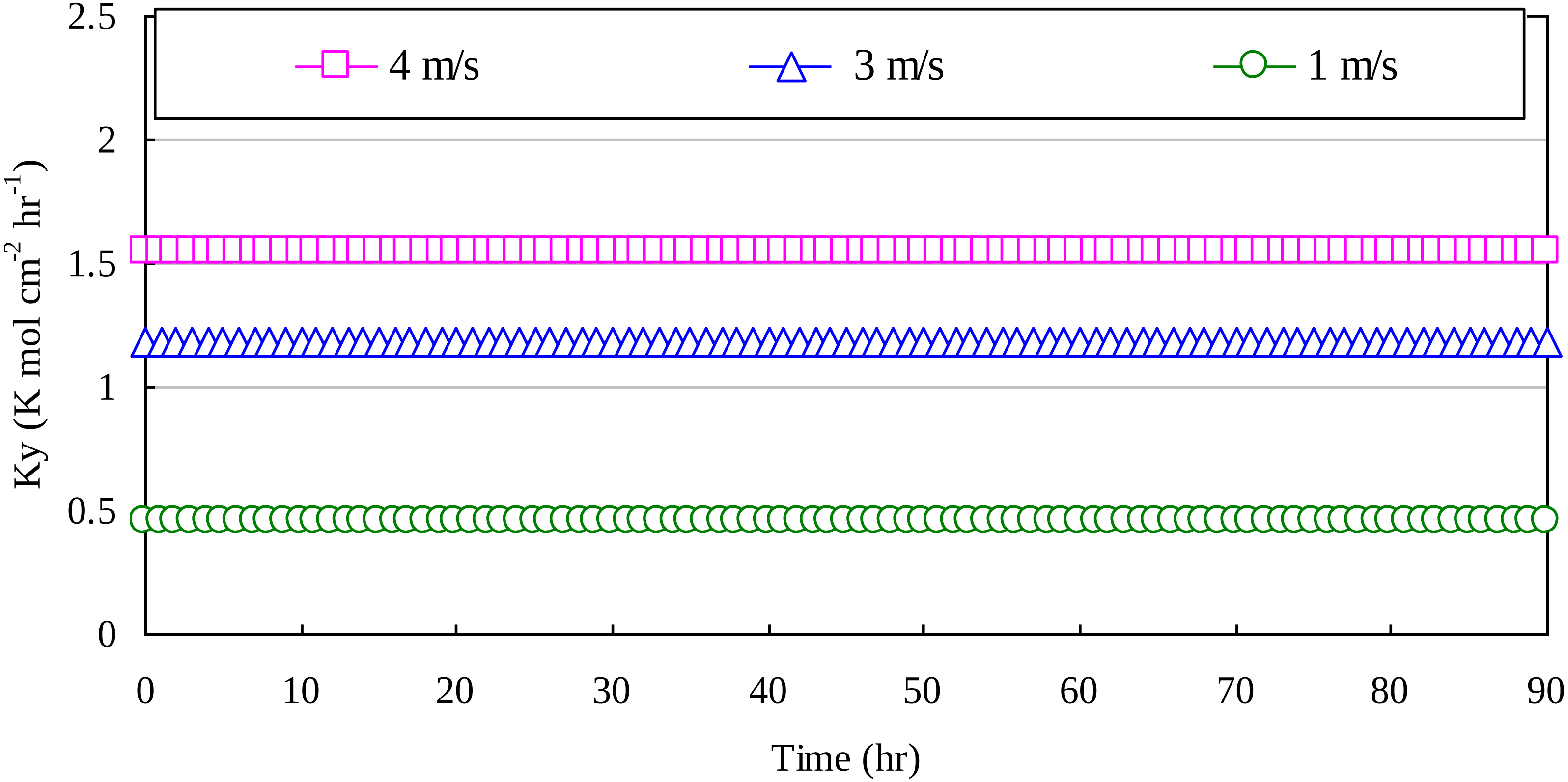
Saturated interface air humidity

(RUN-3 for urine and de-ionized water)



- Xi is smaller for urine than de-ionized water.
- Steady-state reveals that constant Xi means accumulated salt does not increase in the evaporation zone of the sheet. Thus, salt dropping from the sheet may have occurred.

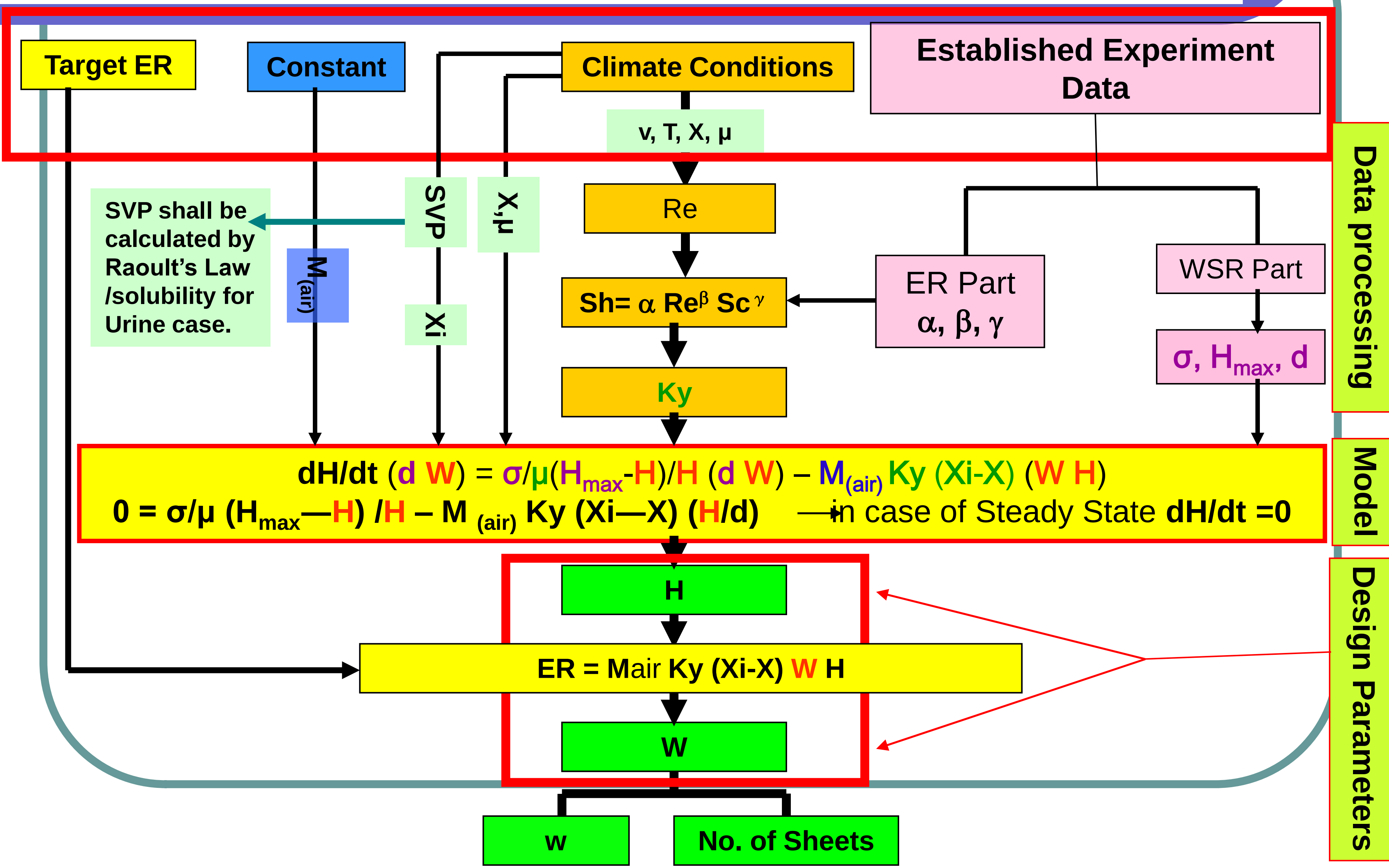
Mass transfer coefficient



High wind velocity cause high mass transfer whereas low wind gave lower mass transfer coefficient.

Comprehensive Design Procedure

(For designing gauze sheet of OVRS)



Estimated size of gauze sheet

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- For a family of 10 members
- Conditions as shown in RUN-3

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- Steady-state evaporation after about few hr operation
- Steady-state: High wind velocity make strong turbulent flow and increase ER than low wind velocity.
- Required size of the sheet for 80% volume reduction is not so large.

Estimated size of gauze sheet

Climate	Operation Time	Air conditions		Synthetic Urine		Comments
		Temp (-C)	Humidity (%)	Height (cm)	Width (cm)	
DRY	**12 hr (day)**	**30**	**39**	**3.2**	**860**	**Suitable**
	24 hr	**15**	**66**	**8.4**	**1260**	
TROPICAL	**12 hr (day)**	**25**	**66**	**7.2**	**2150**	
	24 hr	**15**	**77**	**16**	**3600**	
TEMPERATE	**12 hr (day)**	**20**	**56**	**5.8**	**1570**	
	24 hr	*10*	*80*	*22*	*8560*	*Not effective*
CONTINENTAL	**12 hr (day)**	**7**	**57**	**8**	**2450**	**Suitable**
	24 hr	***0***	***89***	**-**	**-**	**Unsuitable**