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Effect of Treated Wastewater (TWW) on soils and crops: the rationale for TWW quality upgrading

Dr. Jorge Tarchitzky

Department of Soil and Water Science

Faculty of Agriculture, Food and Environment

The Hebrew University of Jerusalem

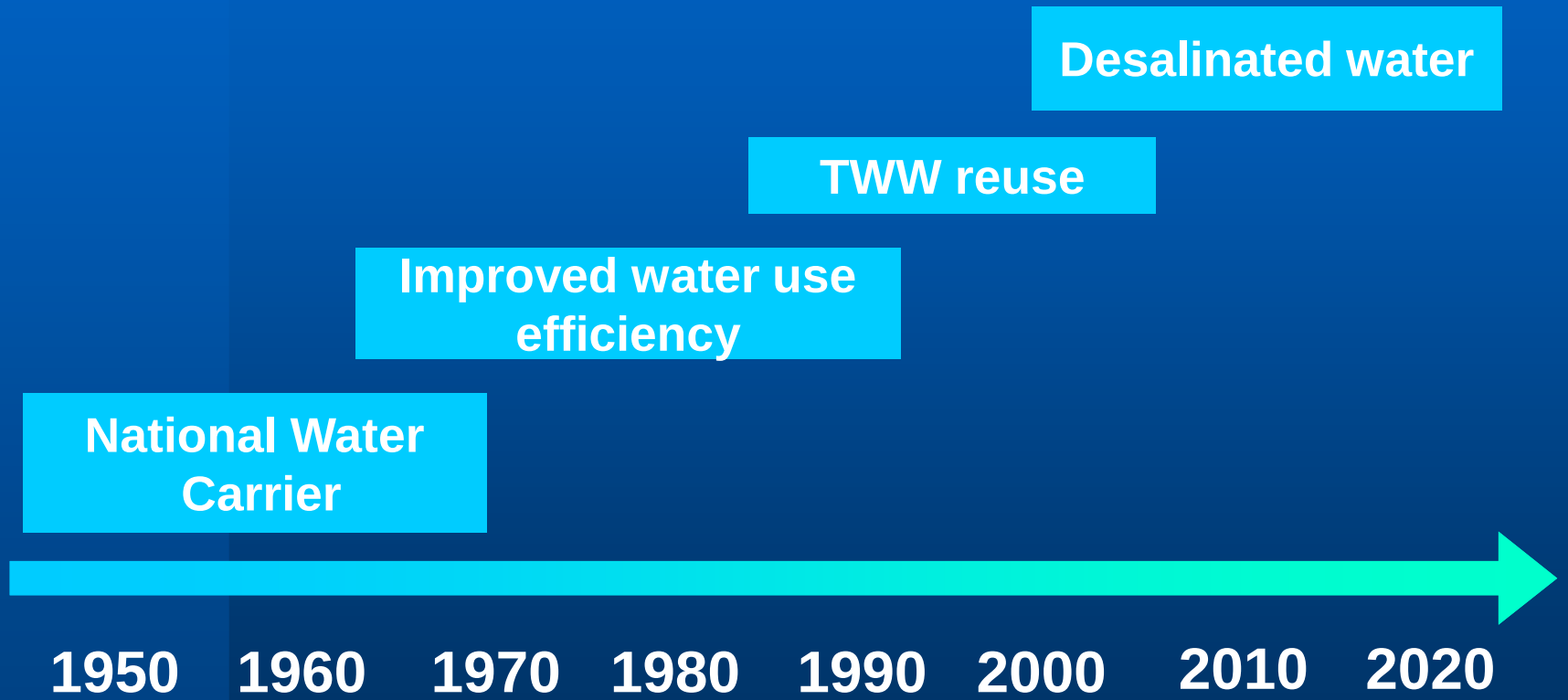
tarchitz@agri.huji.ac.il

Introduction

- **Wastewater treatment and reuse is part of national water strategic plans, in order to:**

1. **Protect public health, water sources and environment**
2. **To develop a renewable water source, mainly for agricultural use (70-80% of the total water consumption in most of the countries)**

Israel - Milestones in a short water history



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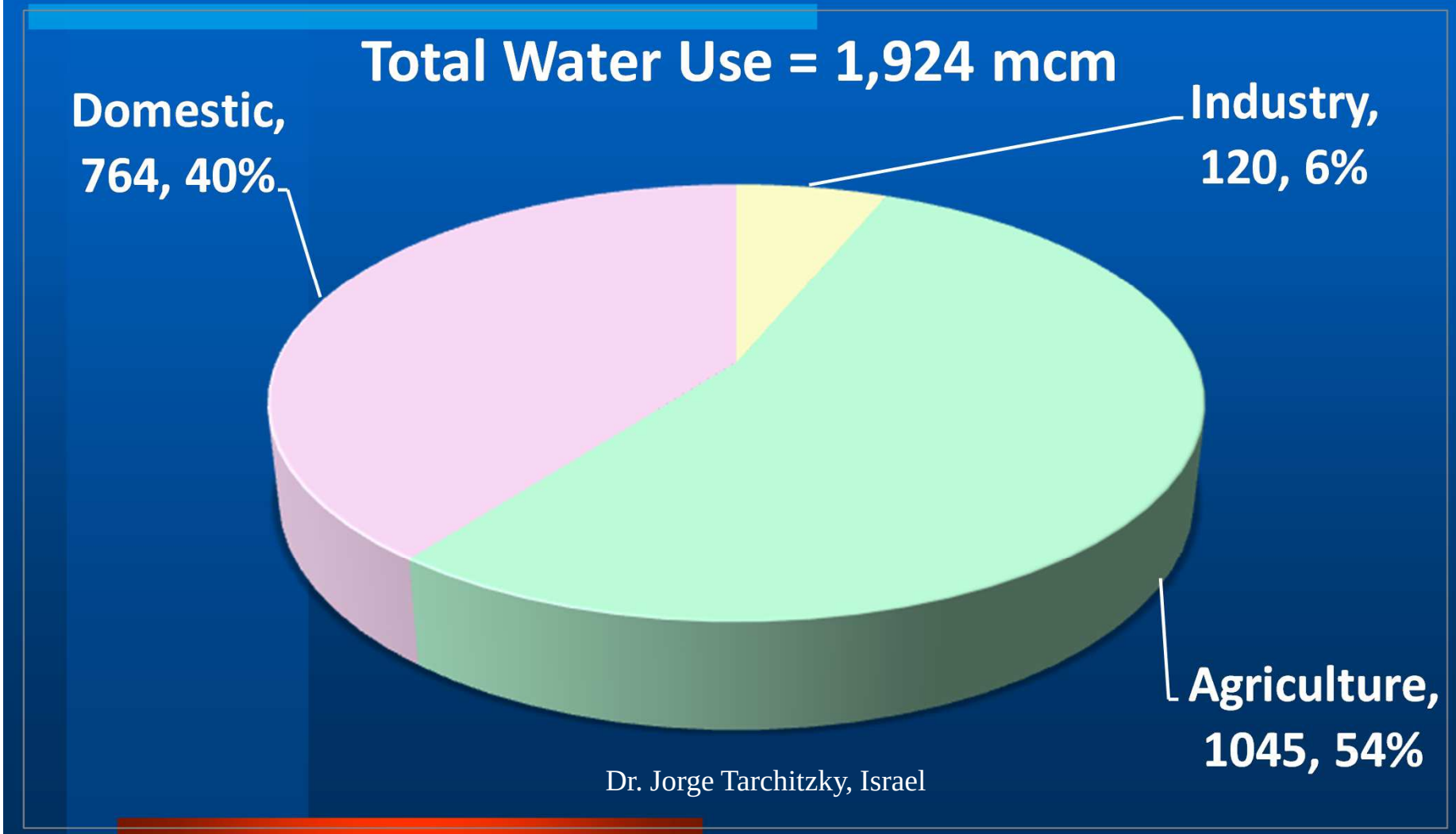
Water Use in Israel - 2010



Manufactured Water 2002-2015 (MCM/Year)

	2008	2009	2010	2011	2012	2013	2014	2015
Sea water desalination	140	160	280	300	400	500	700	700
Brackish water desal.	11	15	22	31	37	43	47	51
Water import	-	-	-	-	-	-	-	-
Additional amounts of potable water	151	175	302	331	437	543	747	751
Treated waste water	340	355	370	385	400	415	430	445

40% of the total supply will be manufactured by 2010

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Wastewater Balance - Data = 2007

Total Wastewater = 516 million cubic meter (100%)

492 million cubic meter (95.4%) are collected and treated in 76 treatment plants

356 million cubic meter (70%) are reused in agriculture

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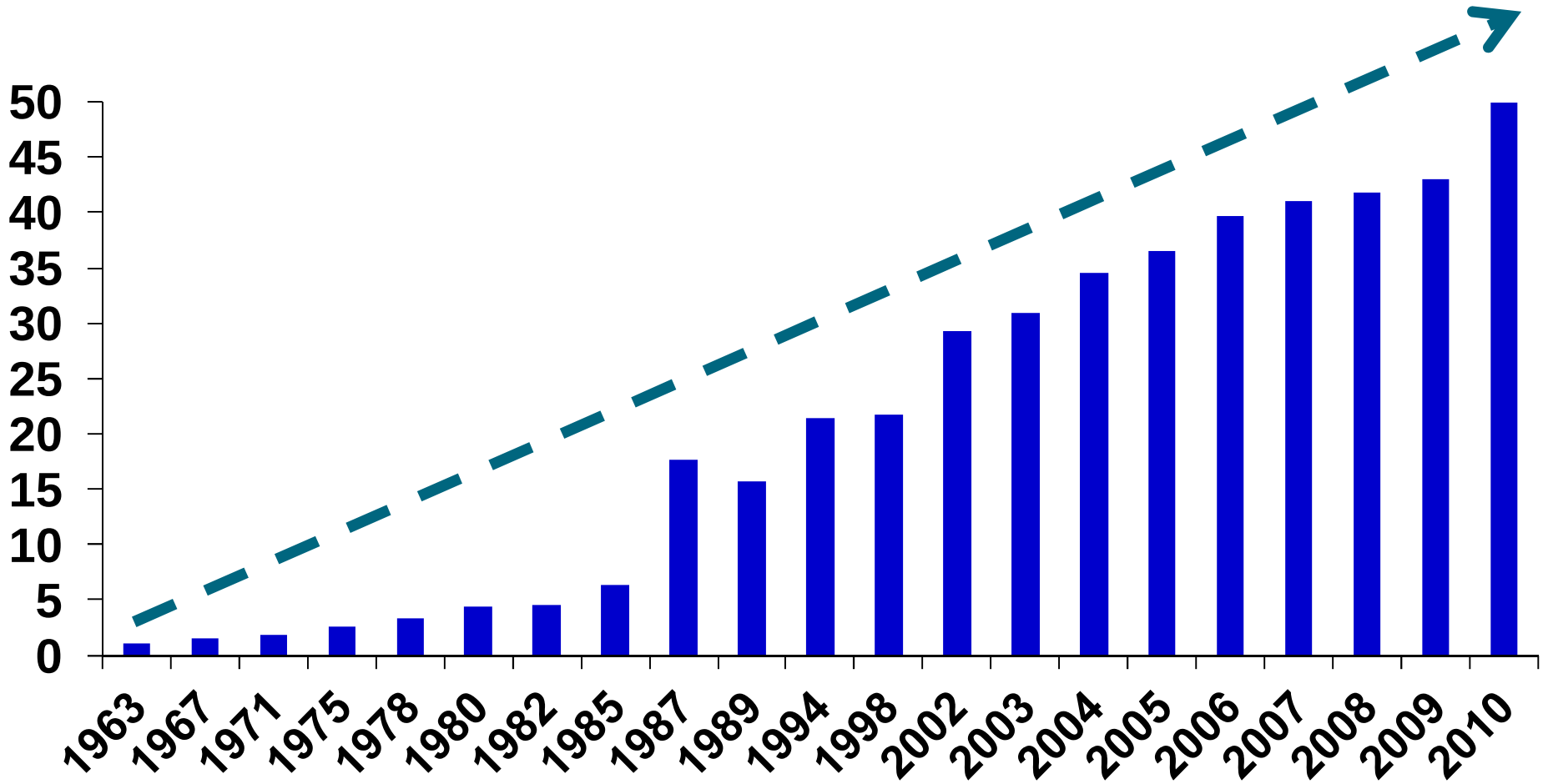
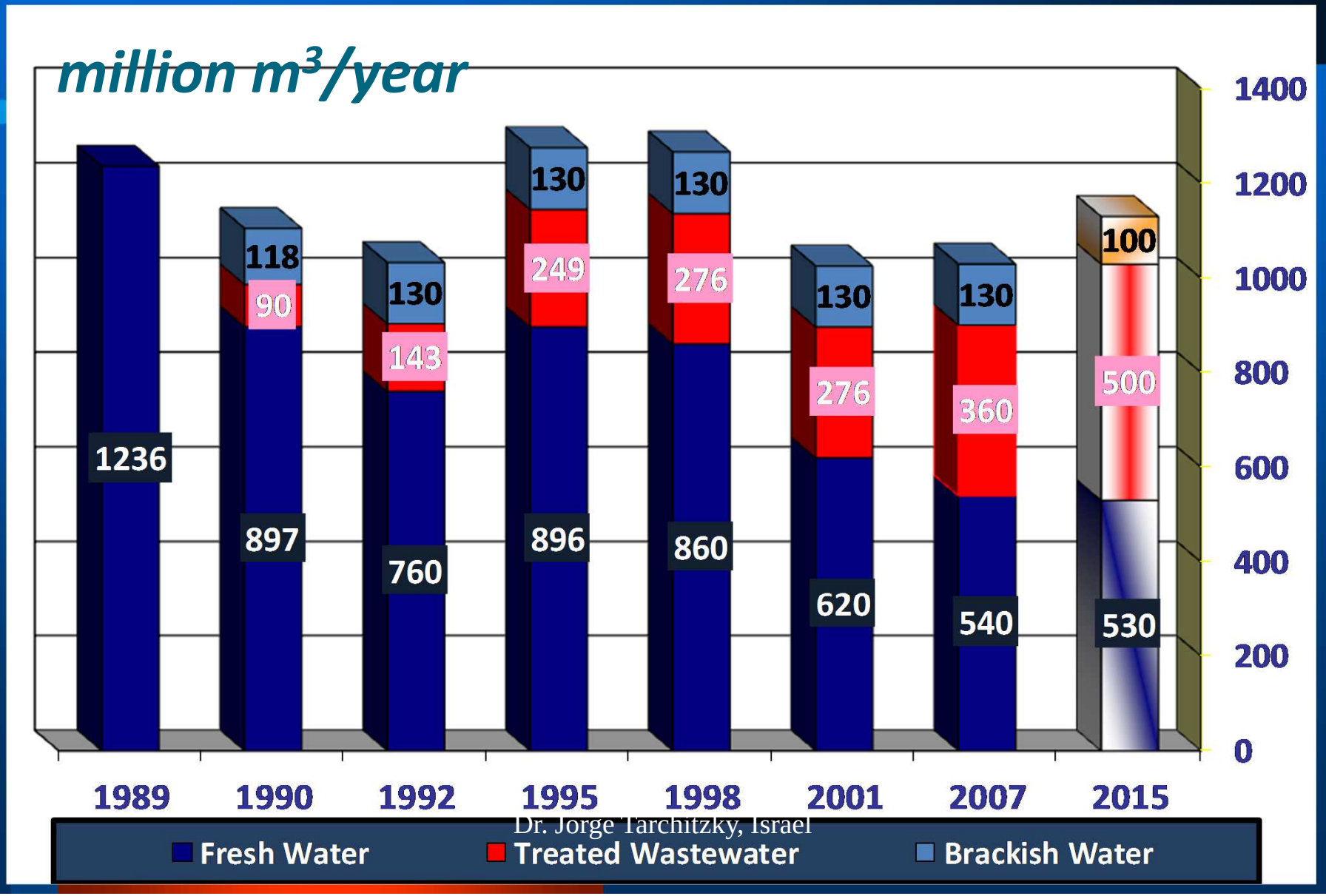
Irrigation with Treated Wastewater (% of total water use in agriculture)



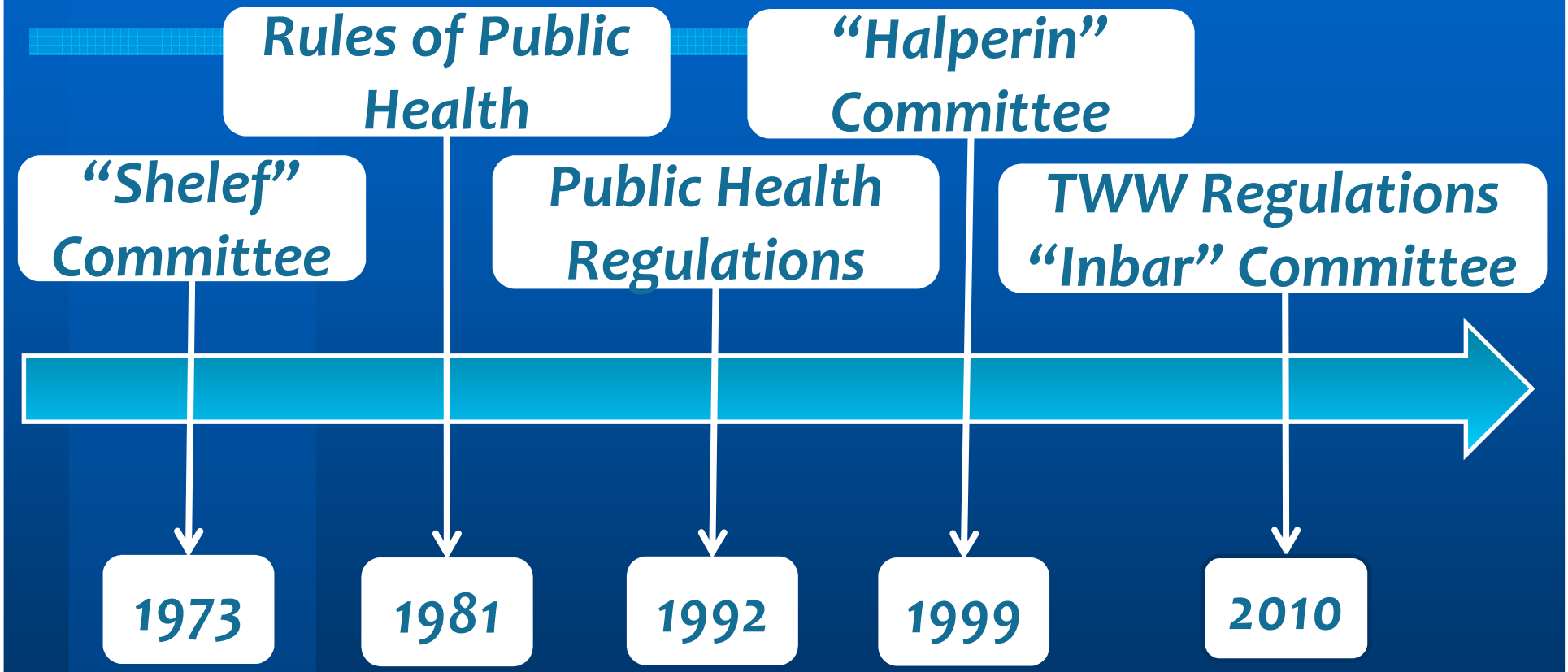
Water Use in Agriculture
Decreases in Fresh Water Use and increases in TWW Use



Treated Wastewater Reuse

- Government objective: replacement of fresh water use in agriculture by TWW reuse (up to 50%)
- New strict regulations
- Upgrading all the TWW to tertiary treatment level
- Quality improvement by salt pickup prevention during fresh water use

Evolution of TWW Regulation in Israel



TWW – Unlimited Irrigation Quality

(new regulation)

		Irrigation
BOD	*mg/L*	10
TSS	*mg/L*	10
COD	*mg/L*	100
Fecal *coliforms*	*MPN/100 mL*	10
Residual chlorine (contact time 30 minutes)	*mg/L*	1
Filtration		

Type of treated wastewater	BOD		TSS		Turbidity		Residual chlorine		Fecal coliforms		Intestinal Nematodes		Recommended uses without barriers
	mg L-1		mg L^{-1}		NTU		mg L^{-1}		no./100 ml		Egg L^{-1}		
	Ave.	Max	Ave.	Max	Ave.	Max	Ave.	Max	Ave.	Max	*	**	
High quality treated wastewater	20	40	30	60							1	0.1	Irrigation of fruit trees with 2 barriers or irrigation of vegetables after disinfection and an additional barrier
Very high quality treated wastewater	10	20	10	20	5	10	1	0.5	10	20	1	0.1	Unrestricted agricultural irrigation, and for the irrigation of public gardens where public entry thereto is restricted during irrigation

Type of treated wastewater	BOD		TSS		Turbidity		Residual chlorine		Fecal coliforms		Intestinal Nematodes		Recommended uses without barriers
	mg L^{-1}		mg L^{-1}		NTU		mg L^{-1}		no./100 ml		Egg L^{-1}		
	Ave.	Max	Ave.	Max	Ave.	Max	Ave.	Max	Ave.	Max	*	**	
Extra high quality treated wastewater	10	20	10	20	2	5	At end of disinfection: 1; At user connection: 0.5	At end of disinfection: 1; At user connection: 0.25	0 at median	10	1	0.1	Unrestricted agricultural irrigation, and for the irrigation of public gardens where public entry thereto is unrestricted
Excellent quality wastewater									0 at median	3	1	0.1	Unrestricted use for all purposes

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TWW water quality– Agronomic aspects

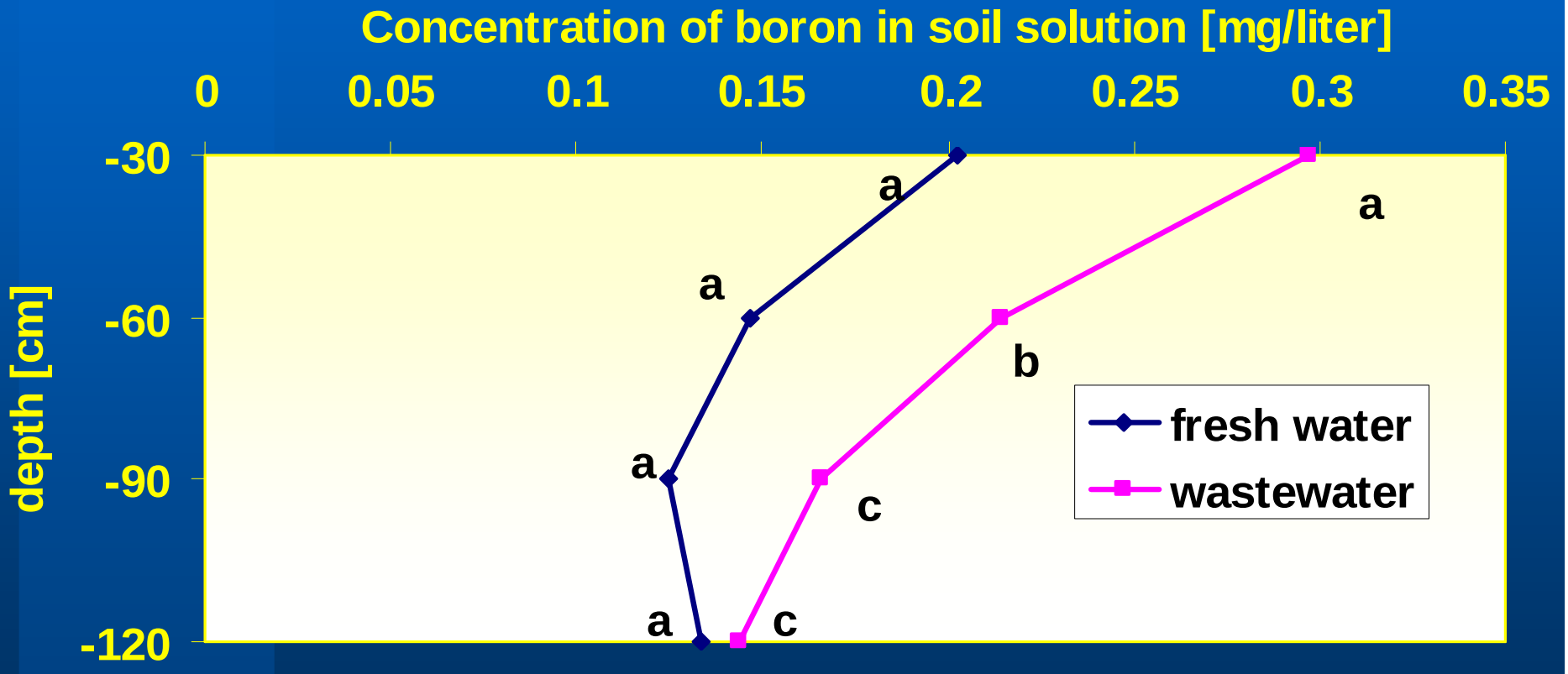
- Potential damage to crop, soil and irrigation equipment
- Regulatory and technologic means to avoid the potential negative effects of TWW use

Potential damage to crop

- **Total Salt Content (TDS; Electrical Conductivity)**
  - **Osmotic effect**
- **Specific Toxicity**
  - **Chloride**
  - **Boron**
  - **Sodium**

Israel Ministry of Agriculture - National Wastewater Survey

Fall 1998- Water Source comparison



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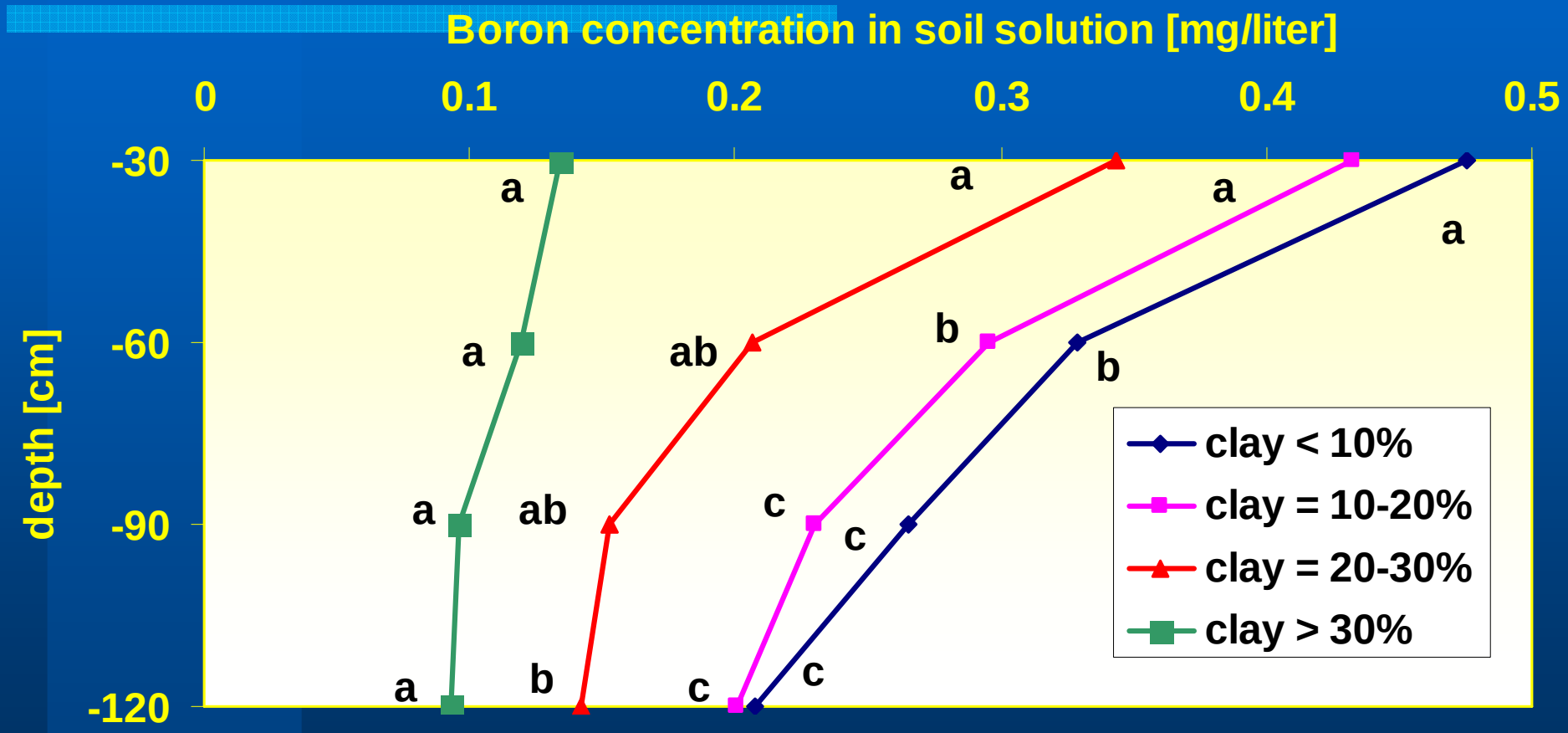
Israel Ministry of Agriculture - National Wastewater Survey

Boron concentration in soil



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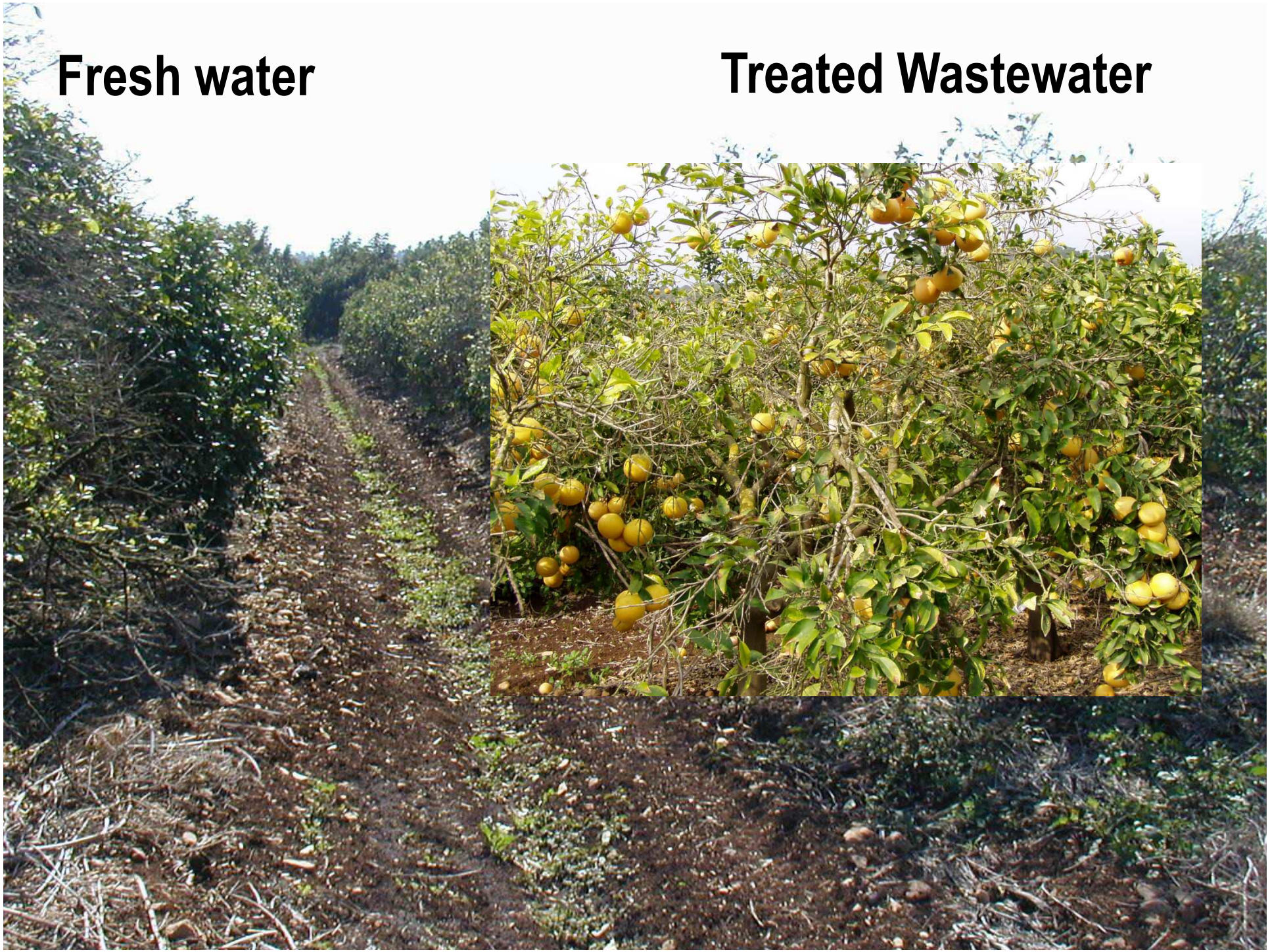
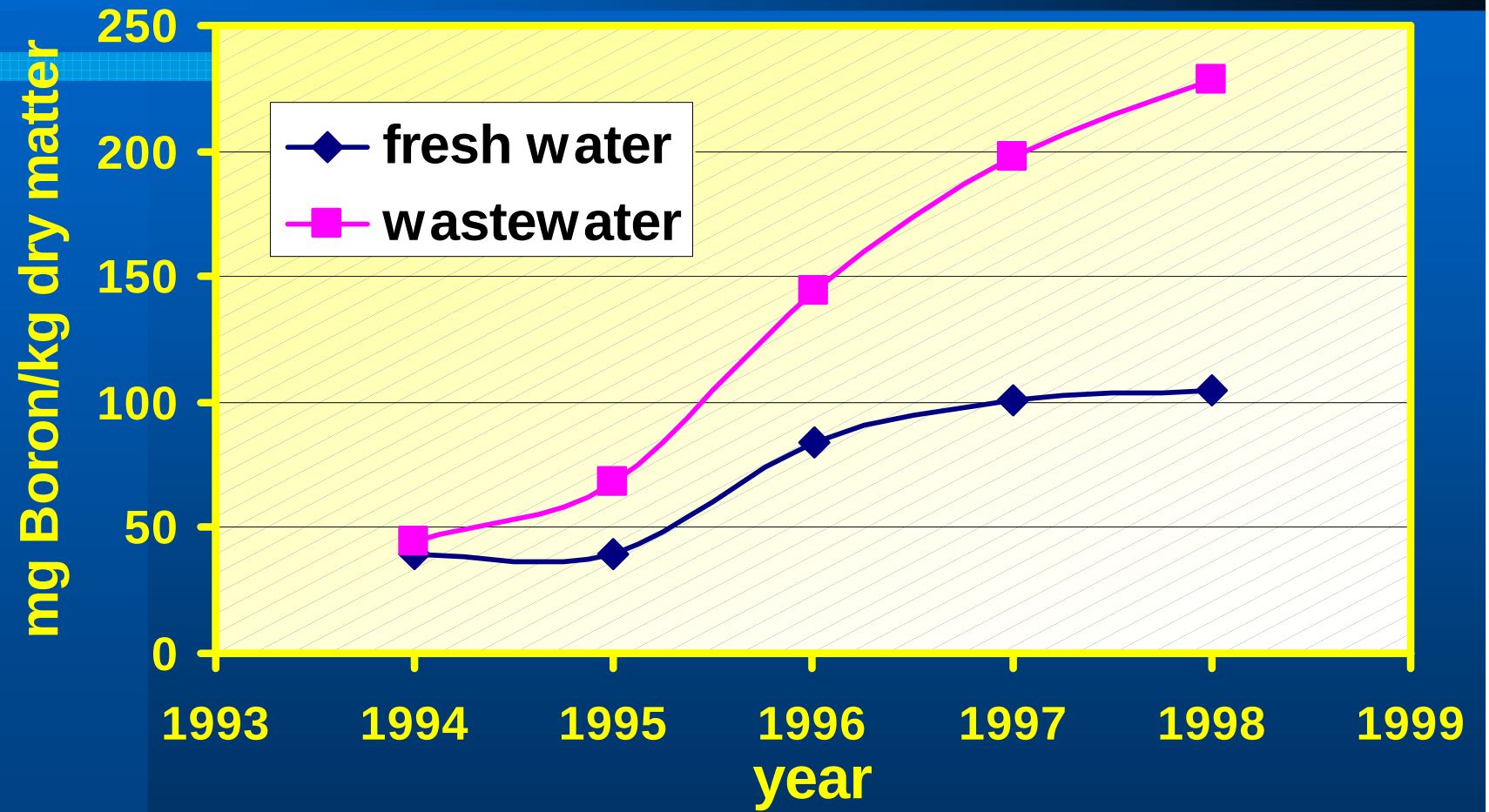

Fresh water
Treated Wastewater

Boron in citrus leaves



Aizenkot et al. – Mizra Experiment

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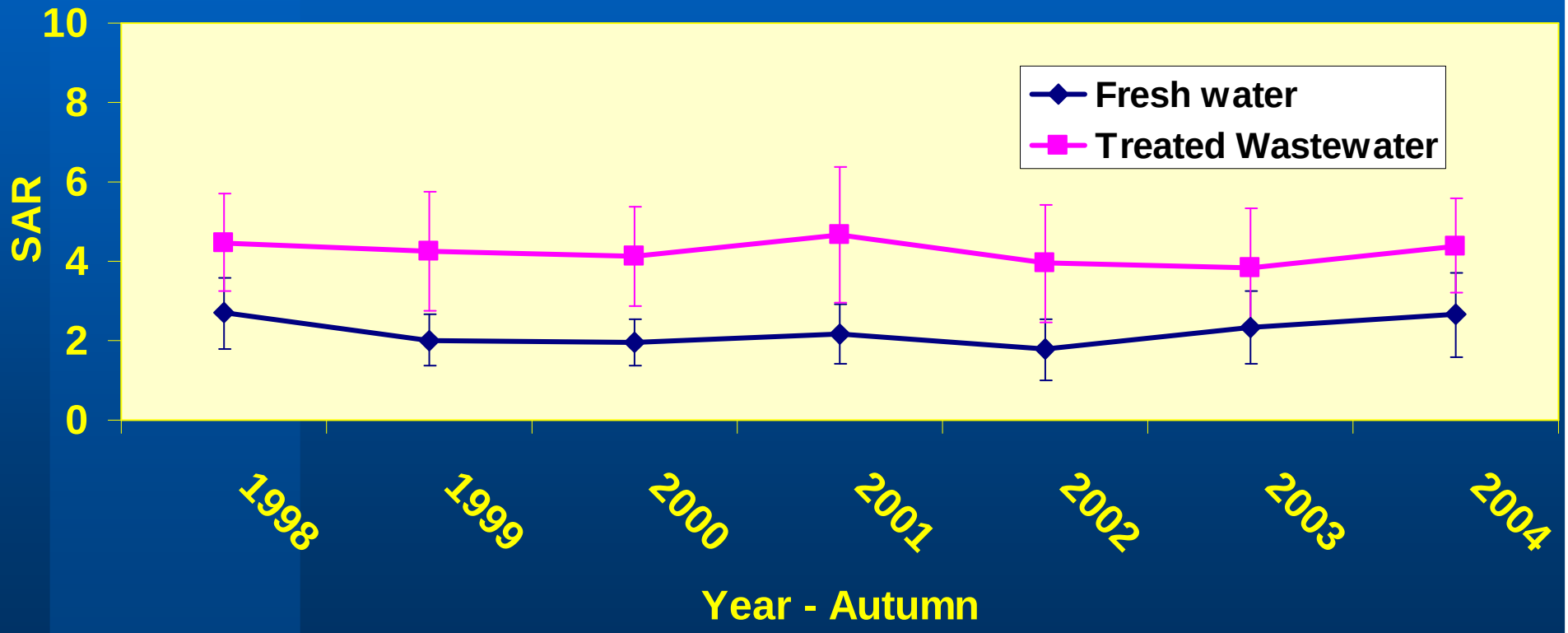
Potential damage to soil

- **Soil structure**
  - SAR
  - Organic matter effect
- **Water movement in soil**
  - Hydraulic conductivity
  - Water infiltration
  - Hydrophobicity

Israel Ministry of Agriculture - National Wastewater Survey

SAR in soil

SAR in sandy soils (< 15% clay) - 0-30 cm depth



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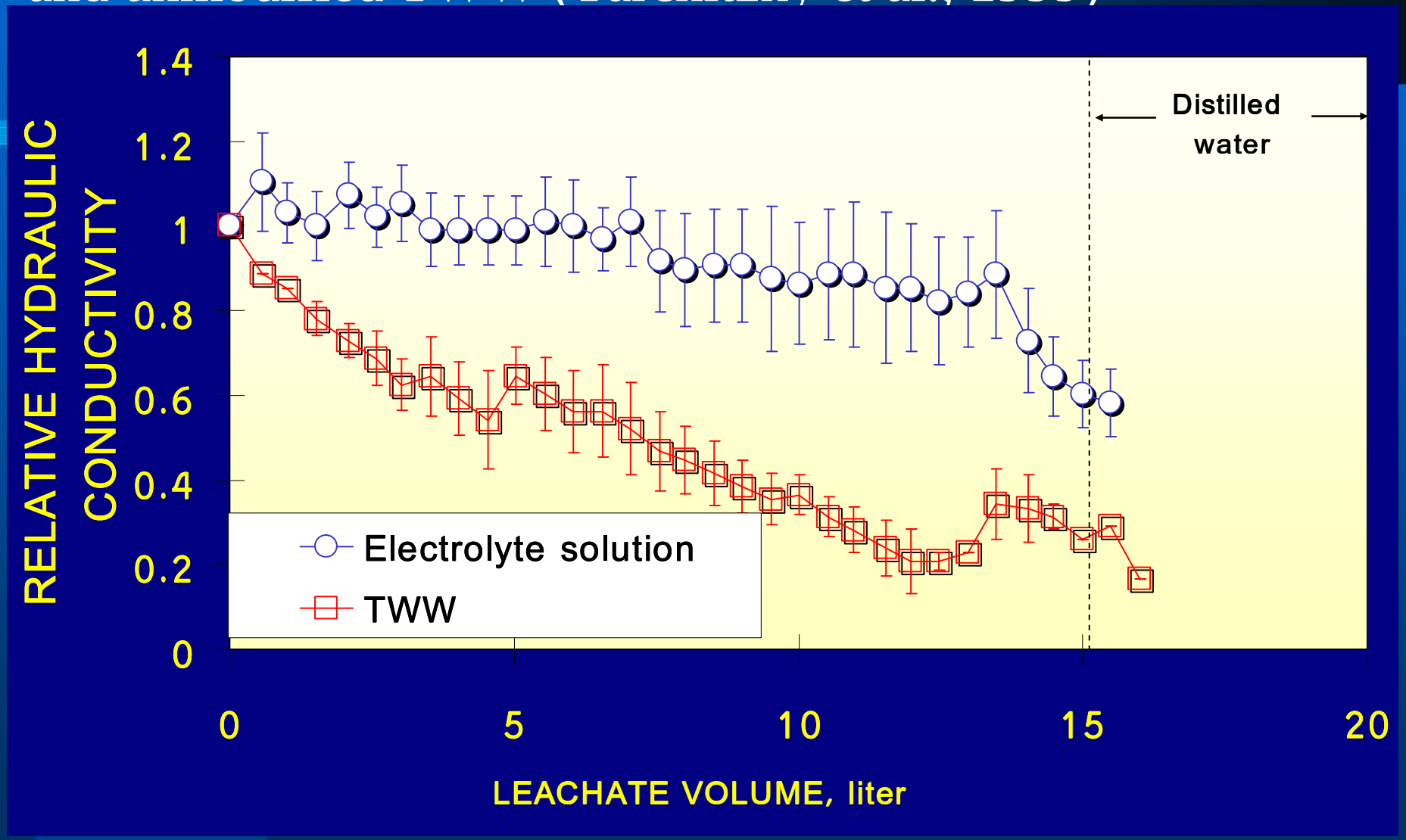
Relative hydraulic conductivity of a sandy soil as a function of leachate volume for two treatments: electrolyte solution and unmodified TWW (Tarchitzky et al., 1999)



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Water drop on a soil surface exhibiting hydrophobic properties

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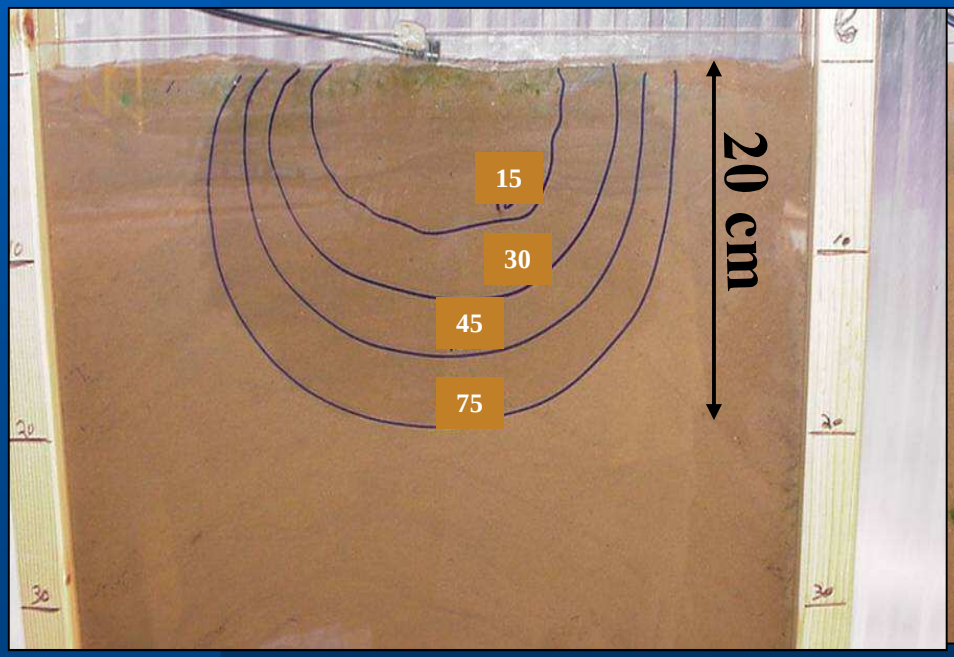
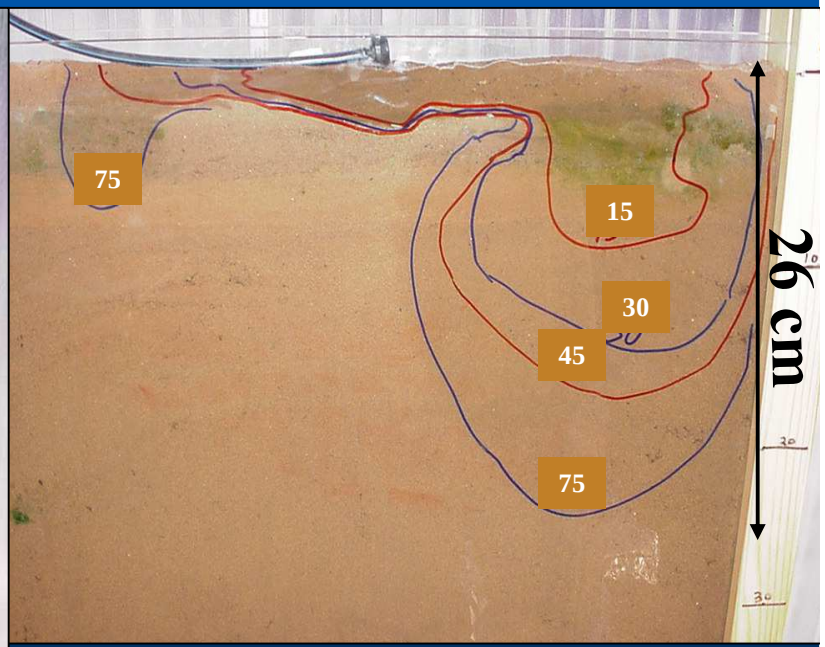
Hydrophobicity Effect

(Tarchitzky et al., 2007)

Fresh water



Wastewater



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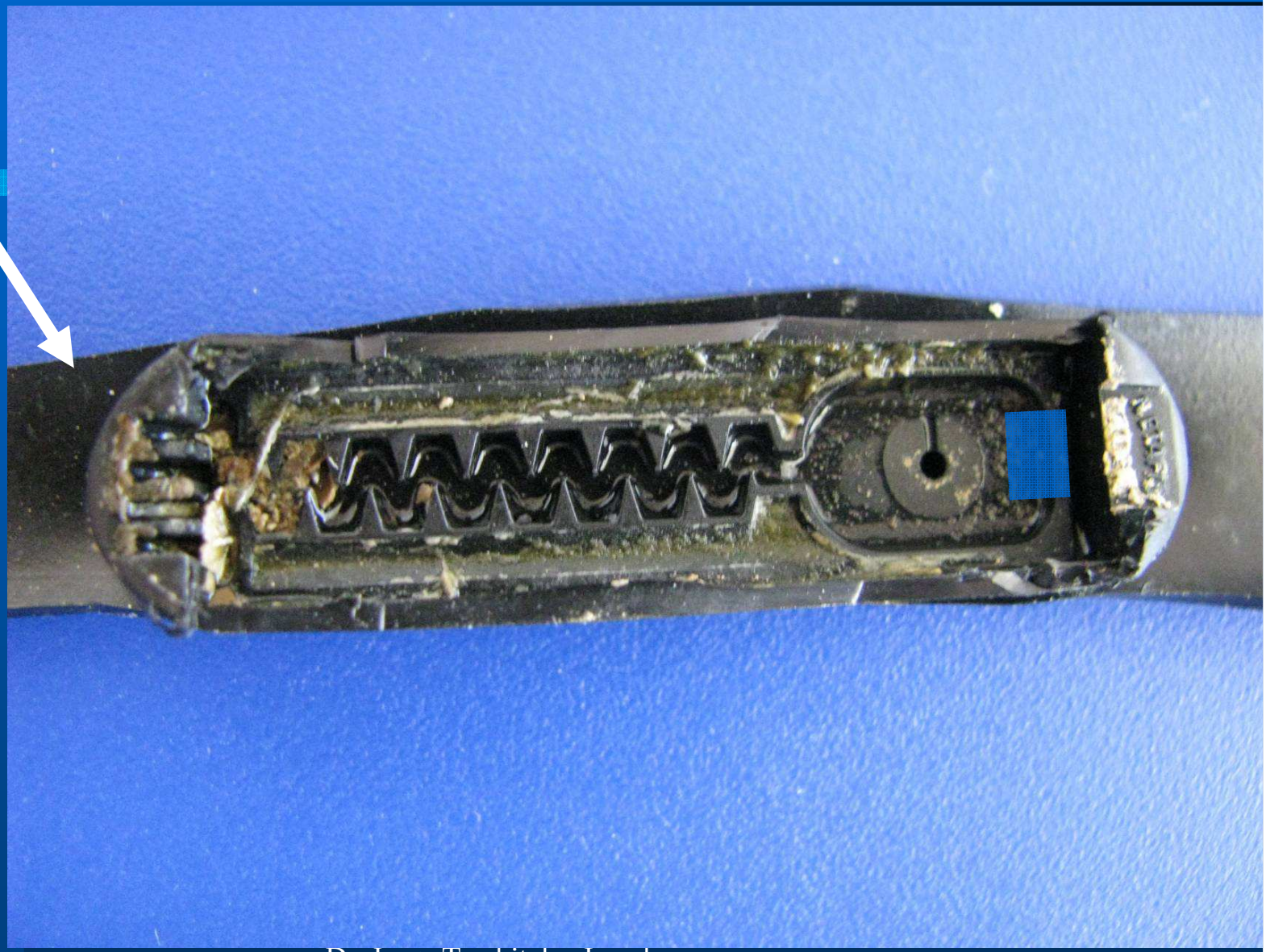
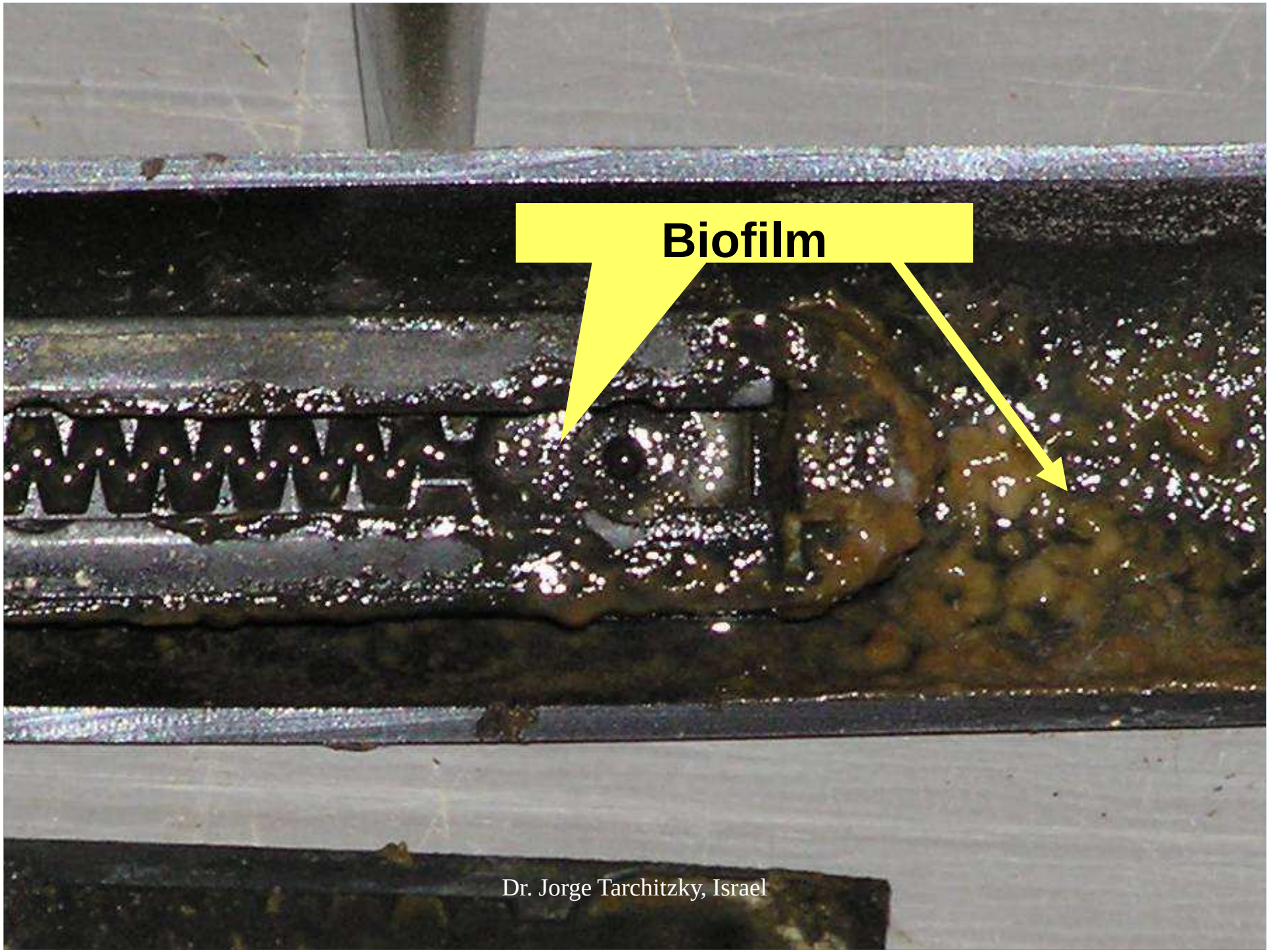
Effects on Irrigation Equipment

- Effect on water filtration
- Effect on emitters (drippers, microsprinklers)
  - Scaling by precipitation of low solubility salts
  - Biofilm formation
  - Emitters malfunctions (discharge changes
  - Lower water distribution uniformity (reduced irrigation efficiency)

Scaling and solid particles accumulation





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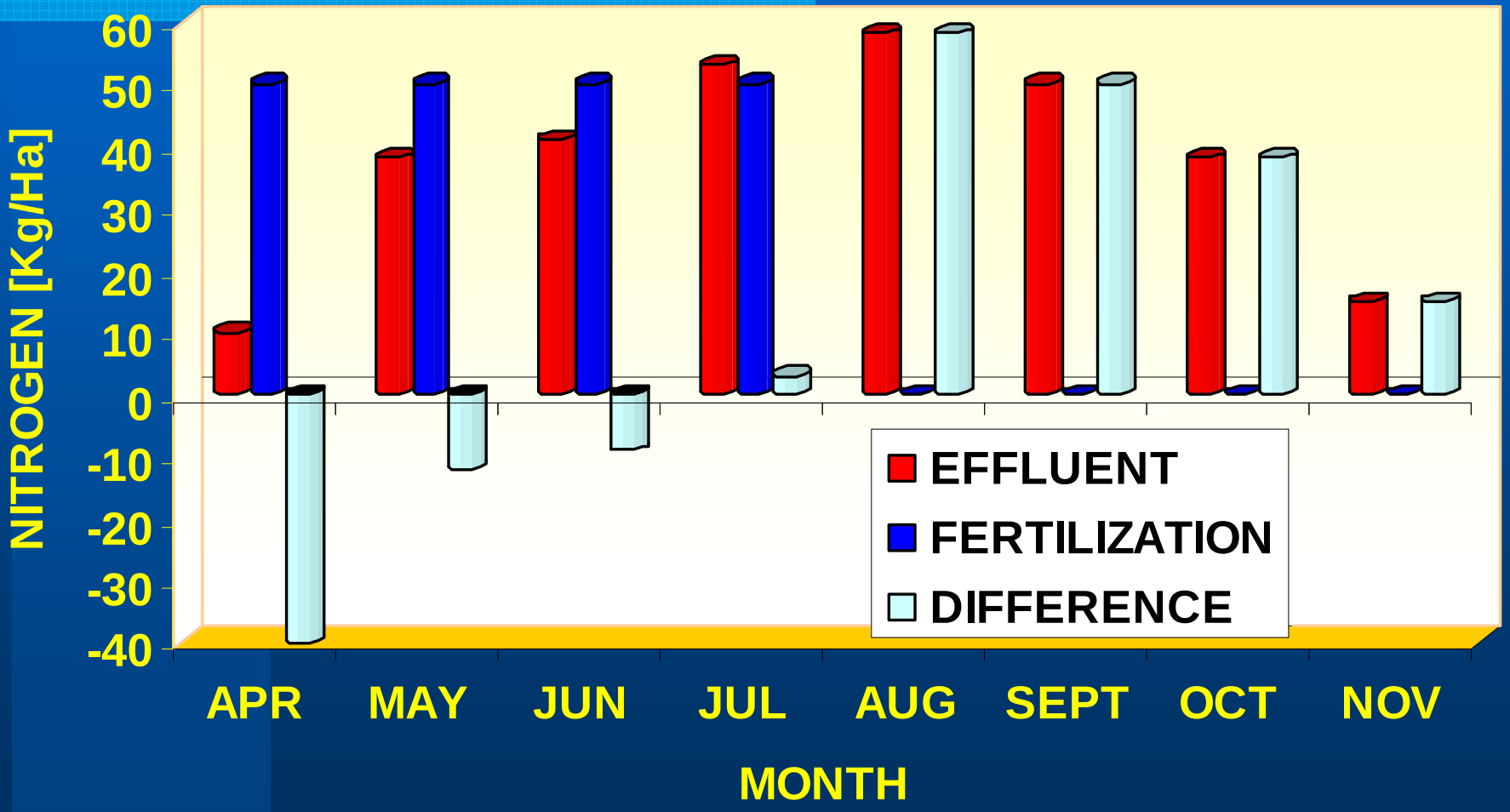
Plant nutrient value in TWW

- **Total quantity applied**
- **Timing (relative to regular fertilization)**
- **Availability (relative to inorganic fertilizers)**

NUTRITIONAL VALUE OF EFFLUENTS
AVAILABILITY



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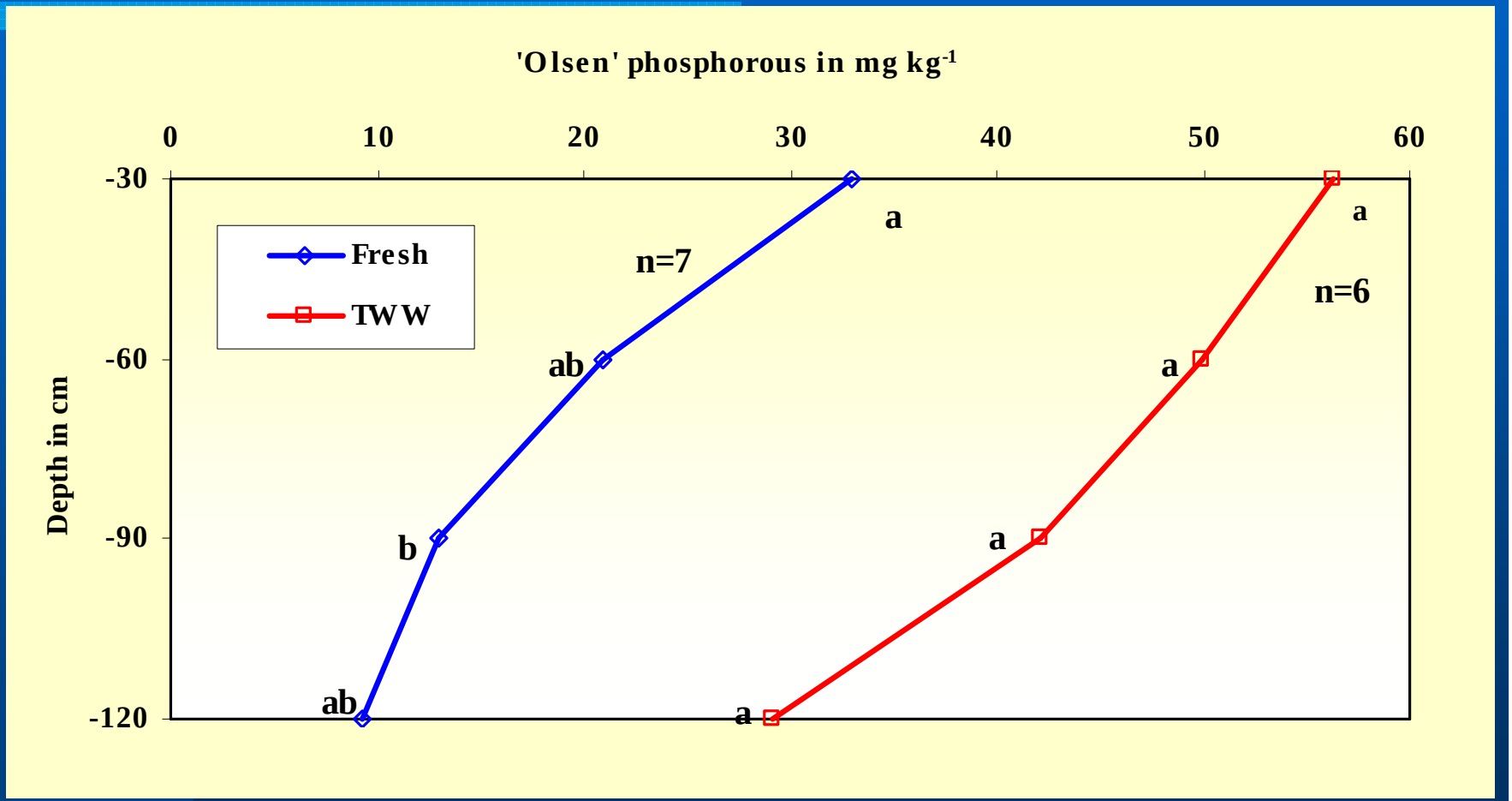
Israel Ministry of Agriculture – National Wastewater Survey

Phosphorus (Olsen Extract) (Clay = 20%-30%) Spring 2003 – Comparison between water types



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Are the negative effects unavoidable ?

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How TWW negative effects could be minimized?

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Improving TWW quality

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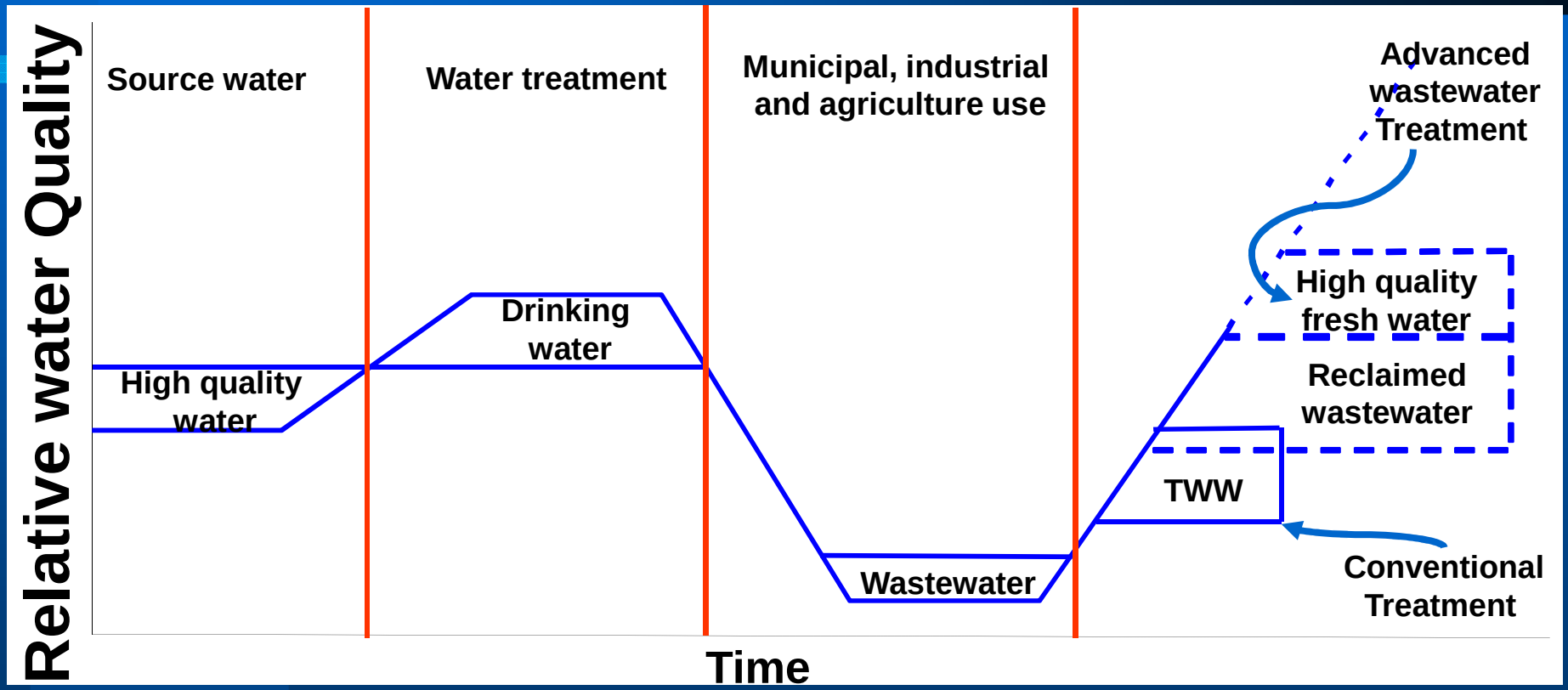
Water quality path



(Modified from Asano, 2006)

Sites along the water path to improve TWW quality

- Improving fresh water quality supplied for municipal and industrial uses
- Decreasing pollutants pickup during fresh water use
- Pollutants removal during the treatment in the STP
- Complementary treatment, before and after storage in the reservoir or treatment in the irrigation head

Desalinated water quality

- Less than 25 mg L^{-1} Cl^{-}
- Less than 30 mg L^{-1} Na^{+}
- Less than 0.3-0.4 mg L^{-1} B
- The B concentration is a special issue in sea water desalination due to high B concentration in sea water (6-9 mg L^{-1}) and low rejection capacity of RO membranes
- Most of the desalinated water will be supplied for municipal use in order to produce higher TWW quality

Reduction of diffuse pollutants

Salt Treatment at the source

Detergents

Contribution of Detergents to salt pickup into the Sewage (% of total salt pickup)

Sodium	41%
Chloride	7%
Boron	80-90%

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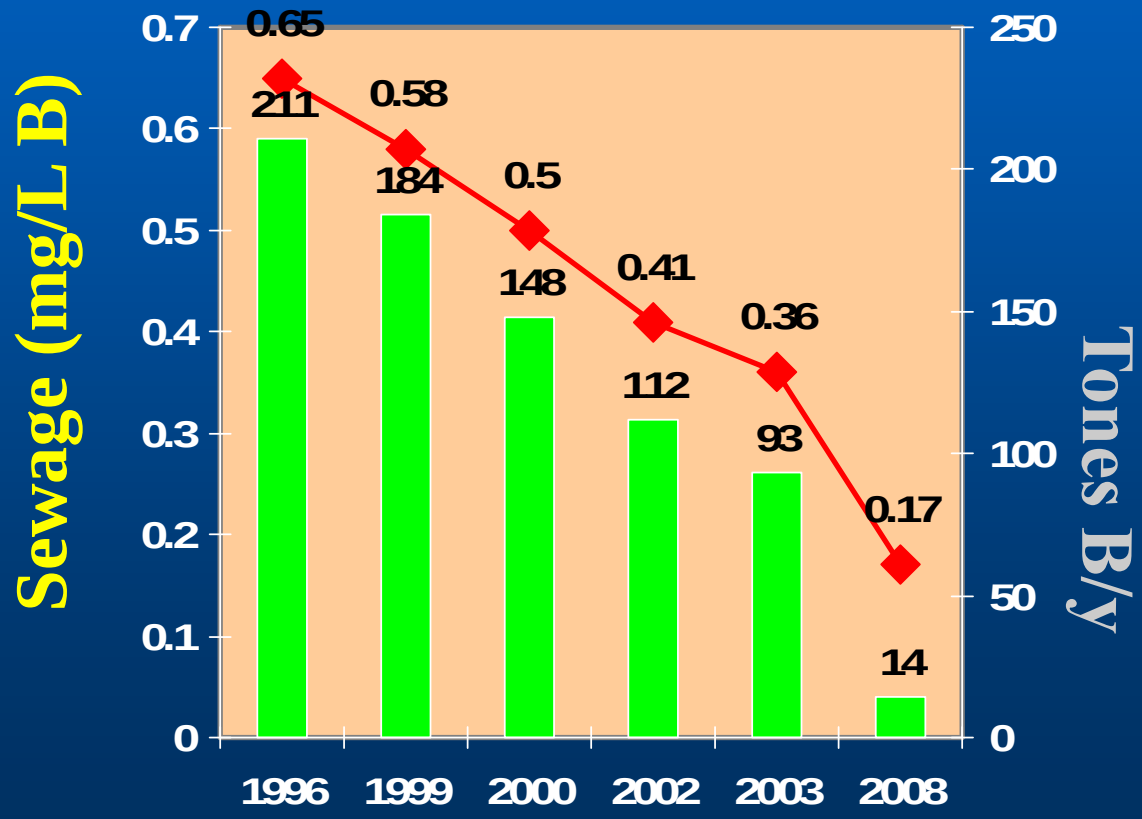
Reduction of Boron concentration

Treatment at the source -Detergents

Israeli Standard for Detergents (October 1999)

Reduction of B quantities



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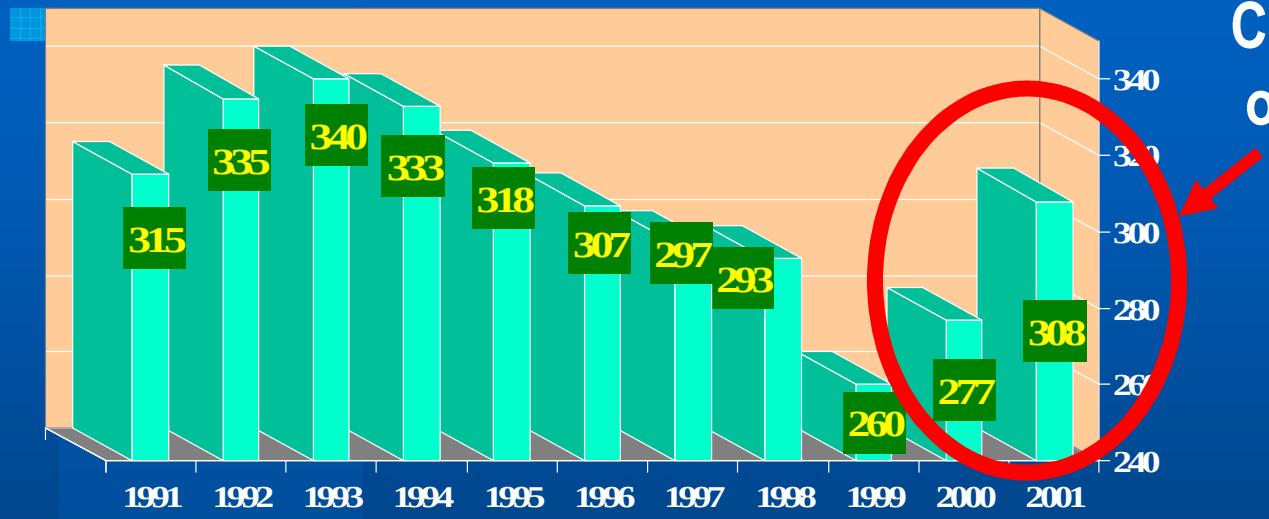
Reduction of salts at the source

Sea Disposal of Brine (2001)

- Total annual salts consumption – 90,000 t (55% textile, 15% slaughter houses, 14% ion exchange, 14% food industry, 2% misc.)
- 2001 – 746,000 m^3 Brine (31,000 t dry material) were sent for sea disposal by 135 factories through 10 sea outlets

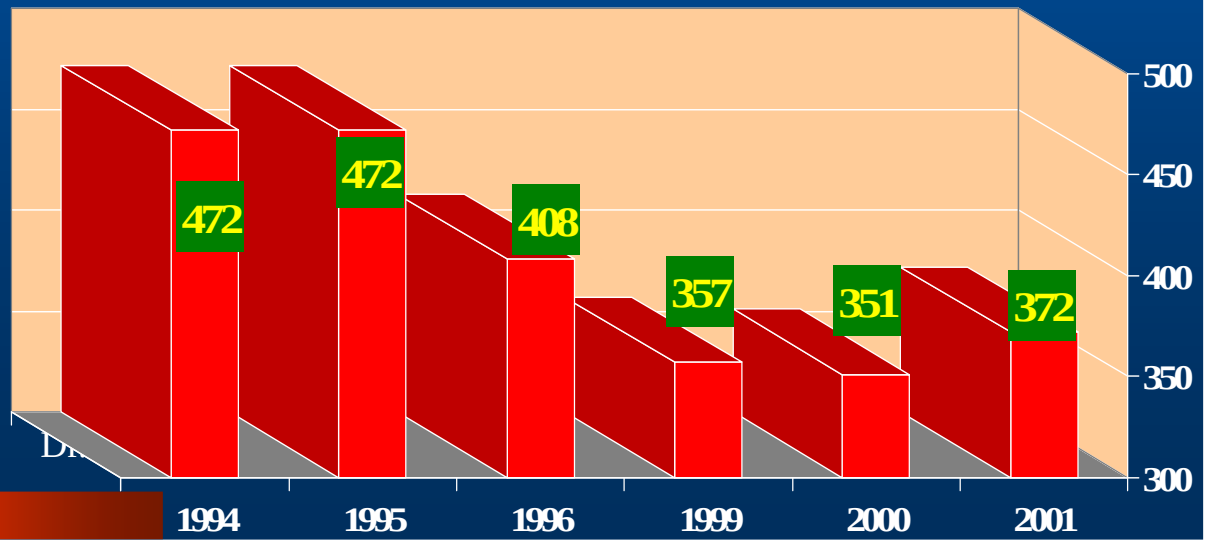
Reduction of Salts measured at the Waste Water Treatment Plants (mg Cl^- L^{-1})

Tel-Aviv (120 McM/y)



Change in quality of water supply

Haifa (30 McM/y)



Research and Development

- A National Wastewater Survey, a long-term observation study was established in order to:
  - Identify and Quantify hazards to wastewater irrigated land and crops
  - Submit the identified problems to research;
  - Set policy in treating wastewater for agricultural use;
  - Adjust agro-techniques to water quality;
- In the survey were monitored: Soil, Crop (leaves and yield) and Water in 160 orchard plots
- Enhancement of Research and Development on wastewater treatment and reuse – High priority

Take Home messages (1)

- **The key for a sustainable TWW reuse avoiding soil, crop and irrigation equipment damage is based on an improved TWW quality**

- **TWW can be improved at different steps in the water path: fresh water source, pickup during FW use and wastewater production, Wastewater Treatment Plant and in the reuse system**

Take Home messages (2)

- **TWW quality can also affect surface and groundwater sources and thus their future quality of fresh water supply**
- **In national perspective – the water system has to be planned integrally, taking into account recycling and reuse of water as well as the potential impact of steps in the water cycle/path**


Thank you !!!