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WATER STANDARD

شركة تنمية نفط عمان
Petroleum Development Oman

Water Management using constructed Surface Flow

Wetland system in ASP flooding projects

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Prigent Stephane - Bauer

PRODUCED WATER
MIDDLE EAST

WITH QWI

Agenda

شركة تنمية نفط عمان
Petroleum Development Oman

- Introduction
- Introduction to ASP
- Challenge Definition
- ASP Produced water Management
- Nimr Reed Bed
- Trial Objective
- Experimental set up
- Operation Sampling and Analysis
- Results

Introduction

شركة تنمية نفط عمان
Petroleum Development Oman

- Petroleum Development Oman (PDO) is the leading exploration and production company in the Sultanate of Oman
- PDO deliver the majority of the country's crude oil production and natural gas supply, but above all we focus on delivering excellence, growth and sustainable value creation within and well beyond our industry
- PDO produce 70% of the country's crude oil production and nearly all of its natural gas supply
- Production of produced water is increasing along with oil production
    - Current ratio is 9 bbl Produced Water (PW) / bbl Oil
    - Oil API varies from light to heavy

Concession Area ~100,000km2

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Introduction

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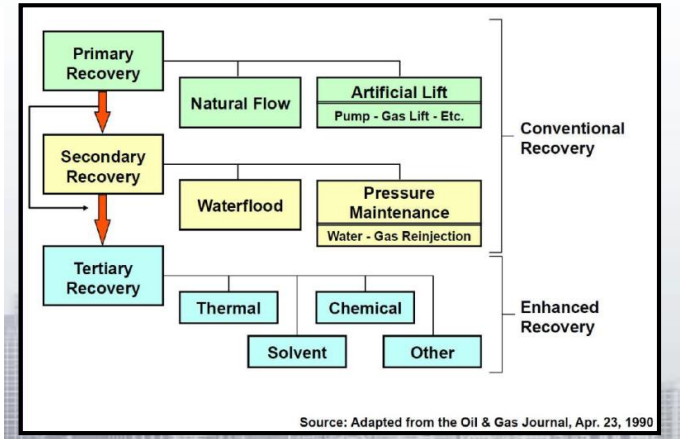
- EOR technique identified to maximize production in heavy oil fields in PDO
- Leads to deployment/trial of new enhanced oil recovery techniques such as Polymer flooding and ASP.
- These new techniques alters the produced water physical/ chemical properties which creates produced water treatment/disposal problems
- Petroleum Development Oman (PDO) has already carried out feasibility work to deploy ASP flood in several fields.
- There was a field trial on ASP injection in one of the field, with the objective to reduce key uncertainties on the performance and operation prior to start of full field development

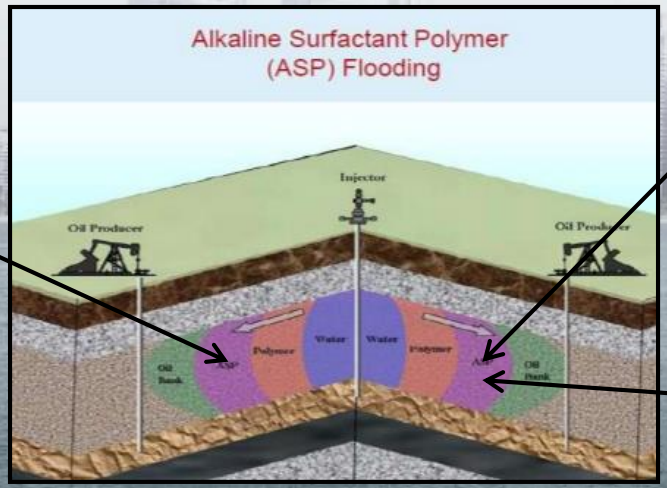


Source: Adapted from the Oil & Gas Journal, Apr. 23, 1990

Introduction to ASP

Petroleum Development Oman

- Alkaline Surfactant Polymer (ASP) flooding is a potential follow-up process of water flooding.
- Polymer flooding improves the macroscopic sweep but not the microscopic sweep URF= incremental of 6% to 10% wrt water flooding
- ASP flooding improves both macroscopic and microscopic sweep URF= incremental of 12% to 20% wrt water flooding)



Alkali: Forms in-situ soaps by reacting with petroleum acids (IFT reduction)and Reduces surfactant adsorption
Examples: NaOH, Na_2CO_3

Surfactant: Lowers the Oil-Water IFT to less than 10^{-3} dynes/cm and mobilizes the capillary trapped oil
Examples: Shell Chemicals, other vendors

Polymer: Increase the injected water viscosity resulting in a better sweep efficiency and more accelerated oil production
Examples: HPAM

Challenge Definition

Petroleum Development Oman

- **Stokes Law:**

$$V_t = \frac{g(\rho_p - \rho_l)\, d^2}{18\mu}$$

- **Stoke's law depicts the effects of ASP chemicals on conventional produced-water treatment systems.**
- **Alakali: Increases produced water pH and creates severe scaling and corrosion issues.**
- **Surfactant: Reduces the IFT resulting in smaller droplet size leading to longer residence time**
- **Polymer: Increases the viscosity of the aqueous phase leading to slow down of oil water separation (O/W emulsion) and decreases water quality.**

Typical Back Produced ASP Water Quality

pH	**8-12**
Viscosity	8-12cP
Oil in Water	<200 ppm

ASP Produced water Management

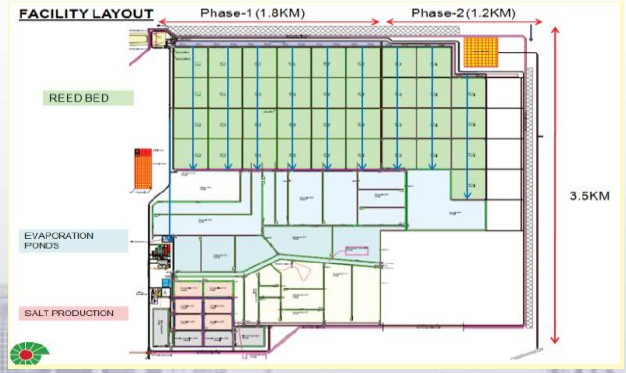
Primary water Treatment	Secondary Water treatment	Polishing	Treatment for Re-use opportunities)
1. Deep Well Disposal (DWD)	1. Produced Water Re Injection	1. Produced Water Re Injection	Like salt production, Agriculture
More energy consumption due to high Viscosity	No Nearby water flood developments available	No Nearby water flood development available	Requires removal of ASP chemicals from produced water but till today no proven technologies are available.
Seek alternative disposal option for ASP			

Under Evaluation

Nimr Reed Bed

Petroleum Development Oman

- Treats 115,000 m3/day of production water that is produced from Nimr Production Station.
- Uses a series of surface flow constructed wetlands – 360ha.
- Disposes of the water through evaporation ponds – 510ha.
- Gravity fed system.
- Reed bed water treatment system is energy efficient for Produced water disposal



Trial Objective

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Aim of the research project

To investigate the effect of the back produced ASP chemicals on the Reed bed.

Objectives

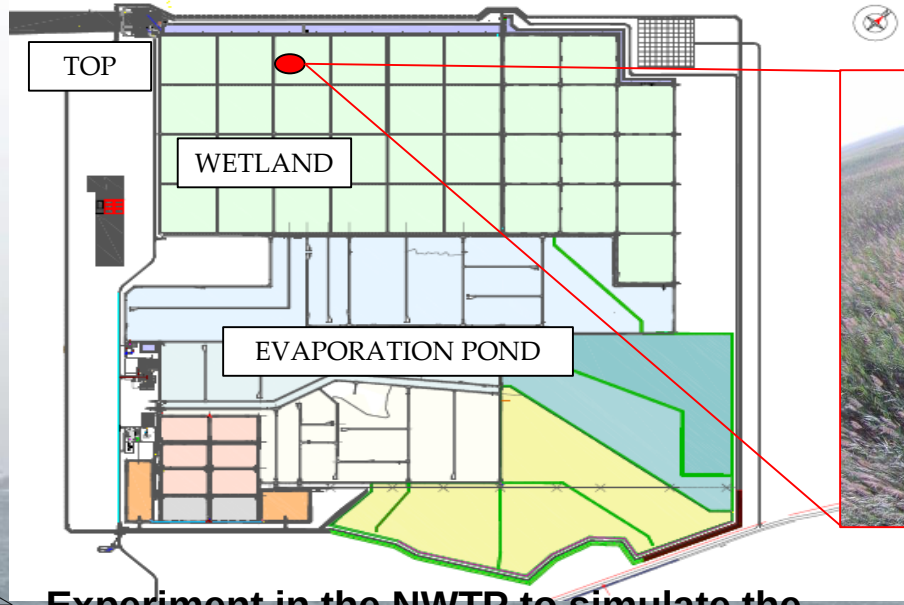
1. **Effect of ASP concentration on**

   a. **Water quality in the Reed bed terraces,**

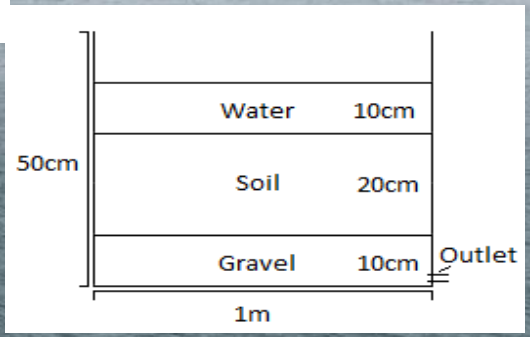
   b. **Plant growth and health,**

   c. **Water loss.**

Experimental set-up, Location



- **Experiment in the NWTP to simulate the wetland environmental condition**
- **18 wetland mesocosms of 1.2 m² filled with substrate**



Experimental set-up, Plant species

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Five wetland plant species

Phragmites
P

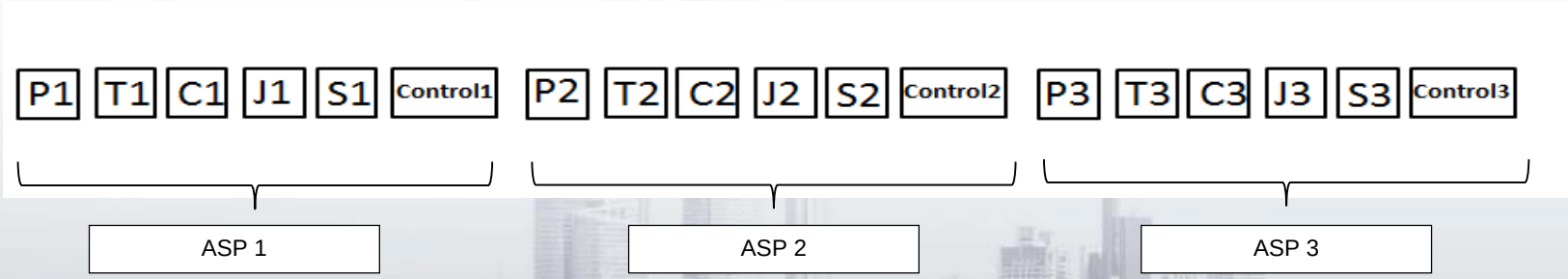
Typha
T

Schoenoplectus
S

Cyperus
C

Juncus
J

Experimental set-up, ASP solution preparation



	Phase 1			Phase 2		
	A (ppm)	S (ppm)	P (ppm)	A (ppm)	S (ppm)	P (ppm)
ASP1	8-10 pH	100	10 cP	8-10 pH	325	10 cP
ASP2						
ASP3						

Experimental set-up, ASP solution preparation

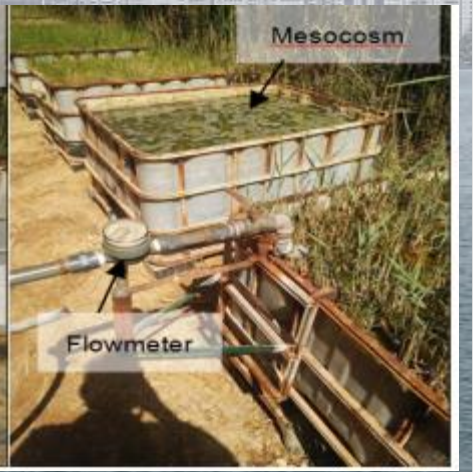
Each ASP treatment solution was prepared in a separate IBC.

A diesel pump enabled to send PW from RB 3.1 of the NWTP in each IBC dedicated for the preparation of ASP solutions.

An exact weight of 0.9kg of polymer was slowly added to the IBC while sending approximately 500 L of PW. Mechanical agitation was then conducted for 30min.

Alkali and Surfactant were added in the IBC while filling the IBC with PW up to 1000 L.

Continuous mechanical agitation was conducted for an additional three hours.



Operation, Sampling and Analysis

Day	Daily Operation		Weekly Operation		
	Topup Water loss	Water Analysis	Bulk Mixing	Flushing	Refilling
Saturday			X		X
Sunday	X	X			X
Monday	X				
Tuesday	X	X			
Wednesday	X				
Thursday	X	X			
Friday	X		X	X	

- Water quality: measured in-situ in each mesocosm with portable meter. pH – DO – EC (BNO) & Polymer (PDO)
- Above Ground Dry Biomass: measured after completion of the phase; i.e. 12 weeks. Separation alive/dead biomass
- Water loss: measured with a flowmeter. Volume of water added to datum level.

Results, Water Quality

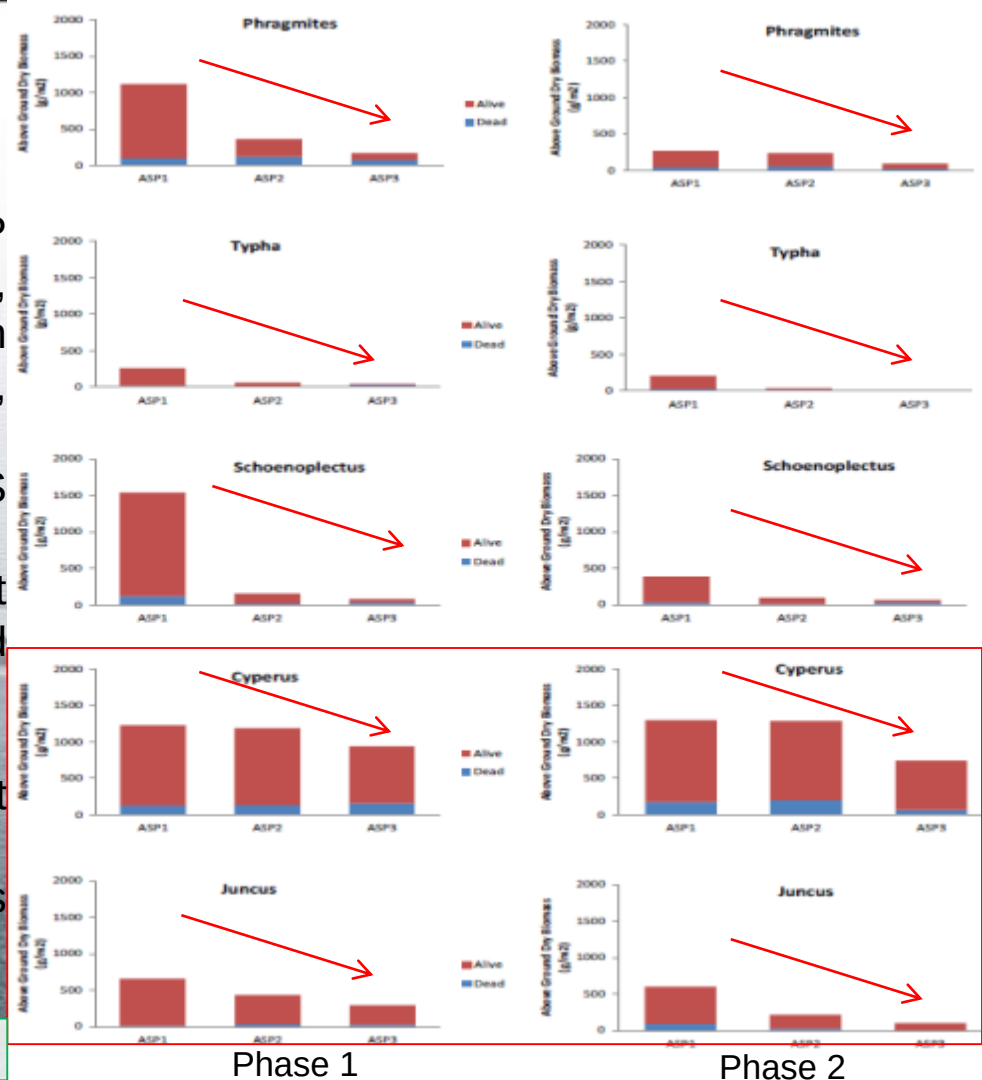
		pH (-)	EC (mS/cm)	DO (ppm)	Polymer (ppm)
ASP1	**Phase 1**	7.6 – 9.0	16.1 – 16.8	3.6 – 15.7	875
	Phase 2	7.8 – 9.0	16.6 – 18.7	12.7 – 17.5	
ASP2	**Phase 1**	8.9 – 9.7	16.7 – 18.5	3.0 – 23.9	875
	Phase 2	8.8 – 9.7	16.5 – 19.9	7.3 – 18.2	
ASP3	**Phase 1**	9.9 – 10.1	21.9 – 23.9	4.0 – 9.4	875
	Phase 2	9.9 – 10.1	23.6 – 28.2	9.5 – 15.7	
NWTP	**min - max**	**6.8 – 9.4**	**10.9 – 21.9**	**0.1 – 12.1**	

- Increase of pH and EC when increasing the alkalinity – EC increases in Phase 2 (ET)
- Comparable pH and EC between ASP 1-2 for Phase 1-2 and NWTP
- Inconsistency of DO (Air Temperature, salinity, plant density, mesocosm location)
- Polymer concentration matching with design concentration

Results, AGDB

- All wetland plant species can tolerate ASP concentration during the growth stage, variability and decrease in AGDB between ASP concentrations for both phase (pH, salinity effects)
- Lower AGDB in Phase 2 for P, T, S (Surfactant, salinity in water, salinity in soil)
- **Cyperus** and **Juncus** are the most tolerant plant species to the chemicals. Growth and health limitation for Juncus in Phase 2.
  - Investigation on hydrocarbon removal
  - Chemical accumulation to the plant tissues
- Level of necrosis is very low after 3 months experiment
  - Evaluation of the plant health over 1-year

NWTP biomass after 5 yrs operation = 800-2,000 g/m^2



Results, AGDB

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End Phase 1

Cyperus

Juncus

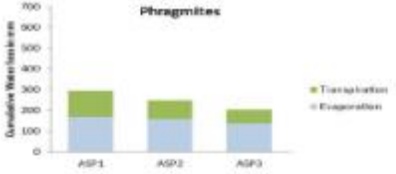
End Phase 2

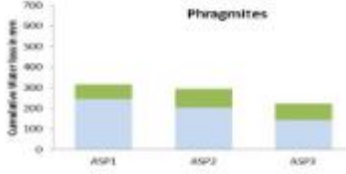
Cyperus

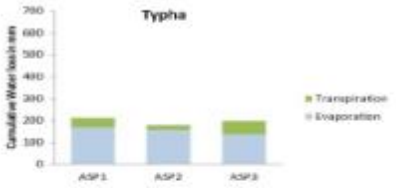
Juncus

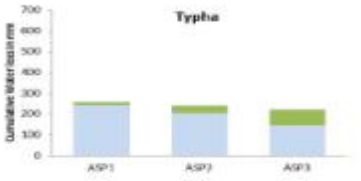
Results, Water Loss

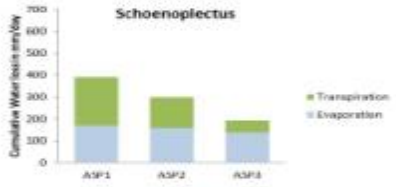
- Transpiration of all wetland plant species shown in green,
- Variability and decrease in water loss when increasing ASP concentrations
- Transpiration highly dependent on Above Ground Dry Biomass
- Cumulative water loss slightly higher with PW only – no statistical analysis conducted

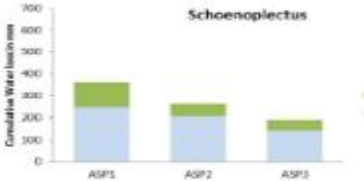


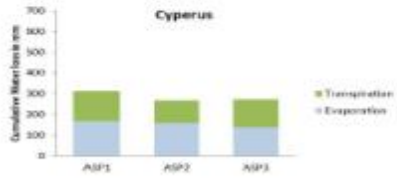


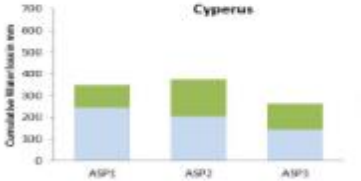


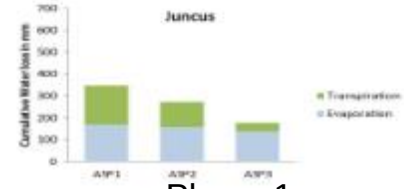


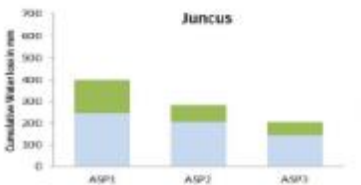












Phase 1

Phase 2

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Conclusion

Effect of ASP on water quality

- Alkalinity increases pH and EC,

Effect of ASP on plant growth

- Tolerance of all plant species to ASP solutions during the growth stage,
- Decreases in Above Ground Dry Biomass when Alkalinity increases,
- **Cyperus** and **Juncus** are the most tolerant plant species after short term experiment (3 months),

Effect of ASP on water loss

- Transpiration of all wetland plant species,
- Water loss highly dependent on AGDB

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