Water Arabia 2011 Conference

Innovative Water & Wastewater Technologies for
A Sustainable Environment Conference

Bapco Innovative

Waste Water Treatment Plant

2nd February 2011
Gulf Hotel
Kingdom of Bahrain

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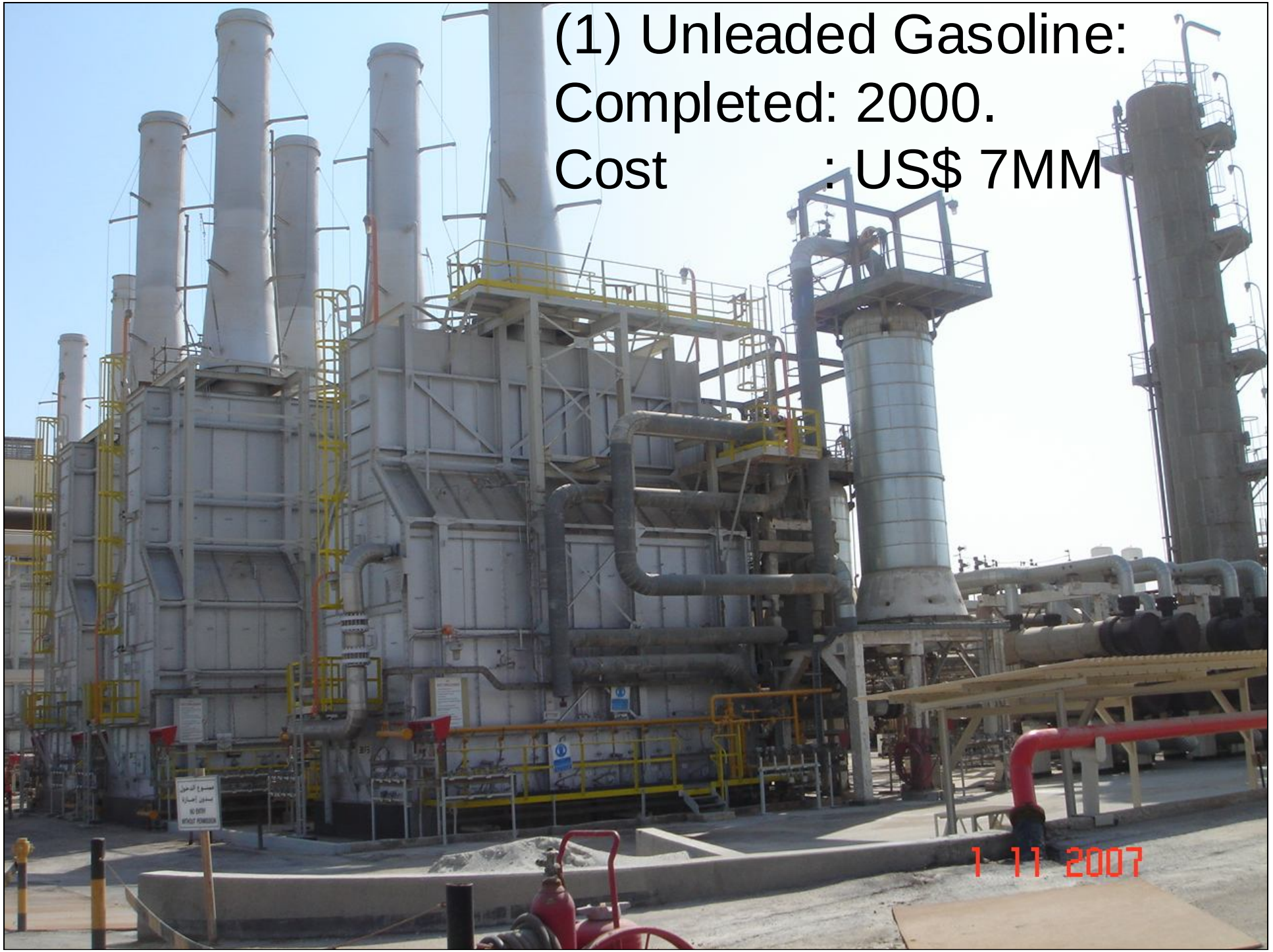
Background to the Presentation

- 1936 Bahrain Refinery with a capacity of 10,000 BBLD was commissioned. The first unit is still running.
- Environmental concerns only started to develop in the late 60's and early 70's within the industrialized world.
- Legislative Decree No. 21, 1996 with respect to the Environment.
- Ministerial Order No. 10, 1999 Environmental Standards (Air & Water).
- Air & Water Standards revised in 2001.
- Ministerial Order No. 3, 2006, Management of Hazardous Wastes.

Background to the Presentation .. Cont'd

- Ministerial Order No. 4, 2006, Management of Hazardous Chemicals.
- Ministerial Order No. 10, 2006, Monitoring of Air Pollutants.
- A detailed gap analysis was carried out to identify non-compliance.
- The following environmental projects with a total anticipated cost > US$ 400 Million were agreed with GDEWP in year 2000 to achieve compliance:


(1) Unleaded Gasoline:
Completed: 2000.
Cost : US$ 7MM
1 11 2007


(2) KERO-MEROX Unit:
Completed: 2001
Cost : US$ 30MM

(3) Sitra Effluent Treatment:

Completed: 2002

Cost : US$ 1.6

(4) RGDP :
Completed: 2008
Cost : US$ 150MM

(5) Hazardous Waste Landfill Project:

Completed : 2006

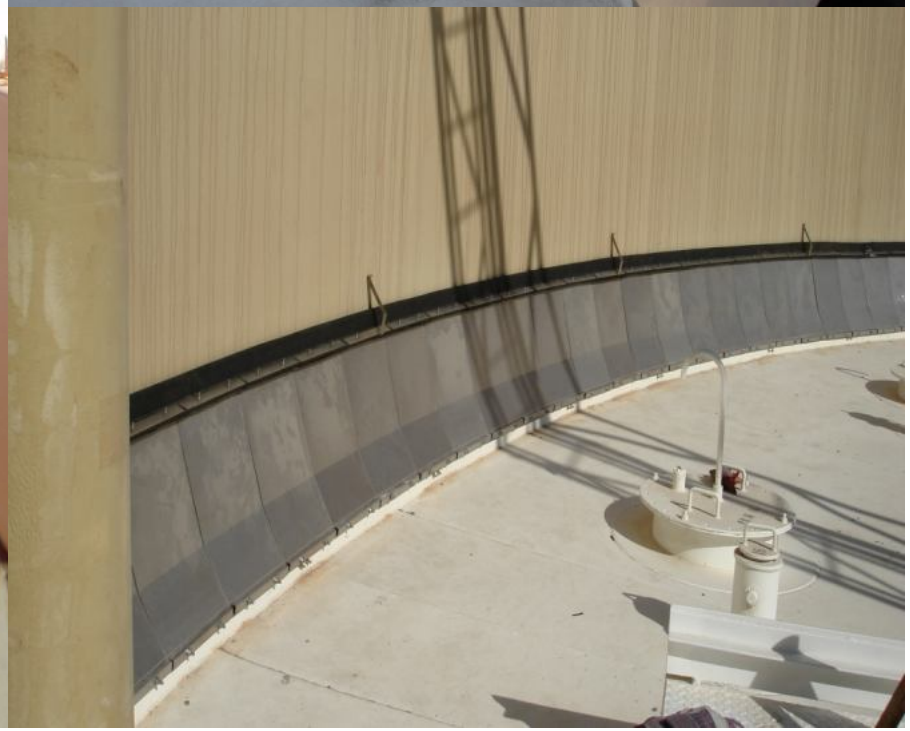
Cost : US$ 5.2 MM

(6) Tank double seals for VOC Control:

Completed : 50

Outstanding : 5

Cost : US$ 6MM

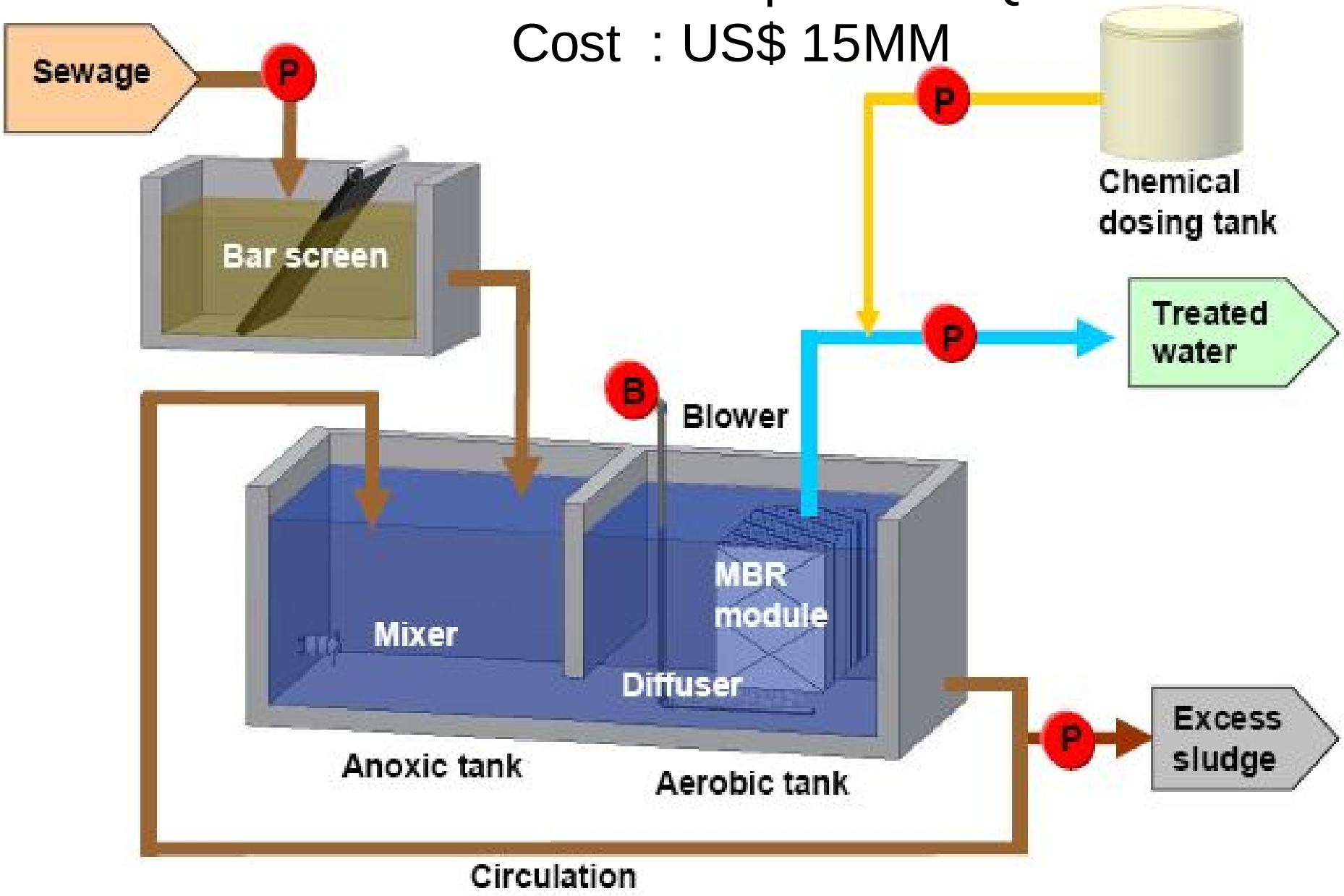


General Process Flow Diagram

(7) Sewage Treating Plant

Estd. Completion: 4Q2011

Cost : US$ 15MM




(8) FCCU Particulates Study:
Being studied under
Refinery Master Plan Project
1 11 2007

(9) Waste Water Treatment (WWTP)

Bapco Innovative

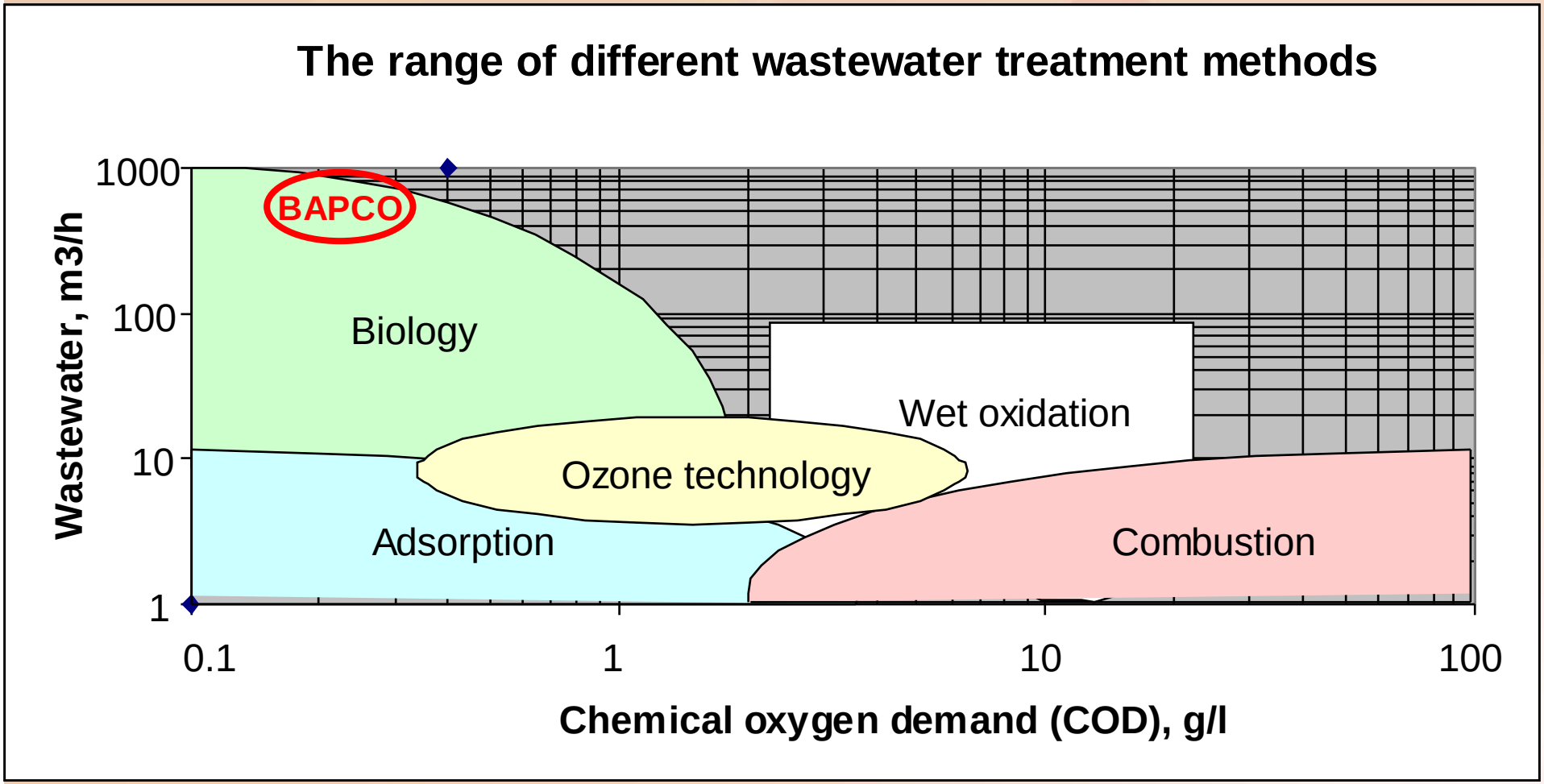
Waste Water Treatment Plant

Introduction

- Bapco identified a need to install secondary treatment to improve the quality of the waste water being discharged from the Refinery to the Gulf.
- At present the waste water undergoes primary treatment in a system which consists of American Petroleum Institute (API) oil separators followed by Induced Air Flotation (IAF) units.
- Biological secondary treatment has been common practice for a long time in Oil Refineries because of the high flow rates and the nature and concentration of the contaminants.
- Biological secondary treatment was favoured because of its lower cost.

Application of Waste Water Treatment Technologies Based on Flow and COD Concentration

LARGE REFINERY WW FLOWS WITH RELATIVELY "LOW" CONCENTRATION ORGANIC POLLUTION: "BIOLOGY" IS "WITHOUT COMPETITION" IN THIS RANGE OF FLOW AND CONCENTRATION, IF IT WORKS FOR THE SPECIFIC CASE



Introduction ... Cont'd

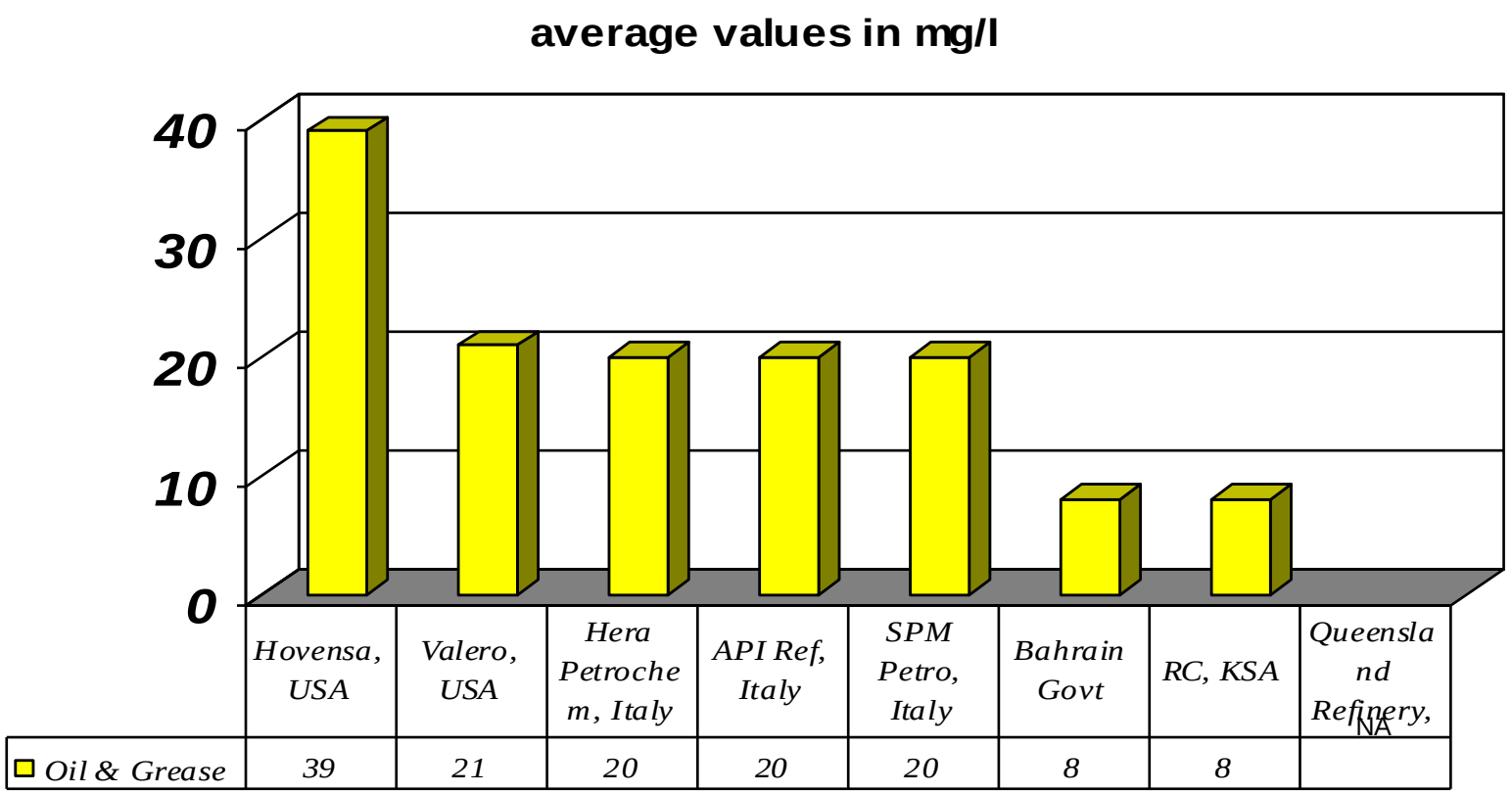
- Bapco's waste water was considered a challenge to treat because of:
  - stringent water quality regulations.
  - high temperature
  - high and variable salinity

- This presentation describes how and why the biological process technology used in the new plant design was selected.

Discharge Specifications

- severe specifications on 4 different nitrogen forms ($N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$, TKN);
- combined with specifications on organic carbon (COD, BOD , TOC);

Comparison of Standards specified by Authorities Worldwide for oil & grease



NS -Not specified
NA -Not available

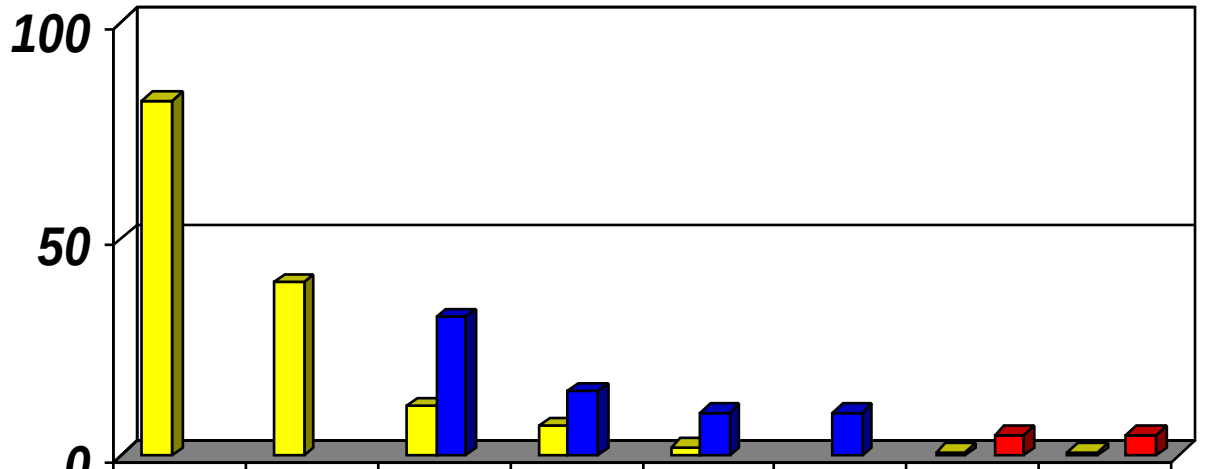
Notes

(1) For the US, the standards specified are load-based (monthly average and daily maximum).
(2) For Italian refineries the standards specified are on 3 hours average basis.
(3) Bahrain Govt and KSA have specified standards on monthly average and maximum value basis.
(4) World Bank have specified standards on maximum value basis.
(5) For queensland refinery the values specified are on 75th percentile and maximum basis.

• Hera Petrochem, Ravenna, Italy - Special limit due to discharge into sensitive / naturalistic area (defined by the specific study) with risk of eutrophication.

** SPM Petrochem, Venice - Special limit due to discharge into sensitive / naturalistic area (venice lagoon) issued after detailed study.

Comparison of Standards Specified by Authorities Worldwide for Ammoniacal-N, Total-N and TKN



	Hovensa, USA	Valero, USA	API Ref, Italy	Queensland	SPM Petro,	Hera Petroche	Bahrain Govt	RC, KSA
Amm-N	82	40	11.6	7	2	NS	1	1
Total-N	NA	NA	32	15	10	10	NS	NS
TKN	NA	NA	NS	NS	NS	NS	5	5

NS -Not specified
NA -Not available

Notes

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First Steps

- It was necessary to use a fundamental approach since there were no plants working under similar conditions. Bapco decided to start with the basics.

- Samples of waste water were shipped from Bapco to two independent consultants in the UK. These consultants performed bench scale treatability tests on the waste water using live activated sludge.

- The bench scale tests gave a good positive indication that the waste water from the existing primary treatment is biologically treatable.

First Steps

- The bench scale tests did not provide any firm indication regarding which biological process would be best suited.

- The bench scale tests did not provide enough information to develop a plant design and what information there was, was unlikely to remain valid through scale-up.

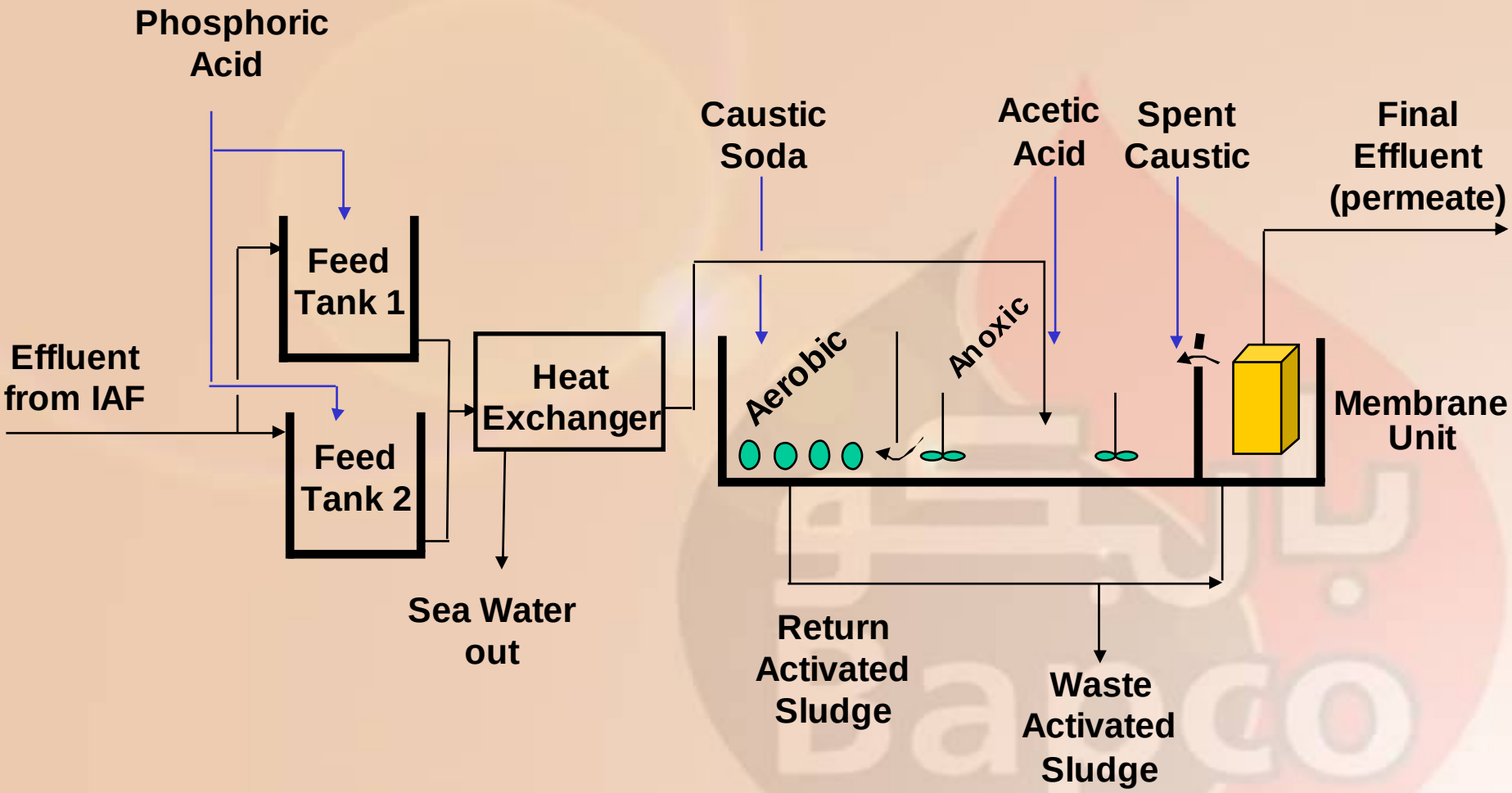
- Following the bench scale tests Bapco concluded that the next step would be to conduct pilot scale tests on site in order to increase the level of confidence and provide further insight to the solution.

Pilot Plant

- A pilot plant with anoxic and aerobic biological treatment zones followed by a membrane separation stage was established on site. It was fed with water from the primary treatment.
- The pilot plant was operated on a continuous basis by Bapco for eleven months and then for seven months together with CH2M Hill.
- Pilot plant operation provided a range of fundamental process information. These parameters were used as inputs into process simulation programmes in order to:
  - Fine tune the configuration of the biological process.
  - select the most appropriate treatment technology.
  - prove that the selected technology is effective, applicable and viable.

Waste Water Treatment Pilot Plant

Pilot Plant Flowsheet



Pilot Plant Results

- The Pilot Plant demonstrated that an MBR can be used to treat Bapco's waste water and provide as complete a biological treatment as possible, leaving only hard/ non-biodegradable/ recalcitrant COD and TKN un-oxidised.
- Fundamental process information was used as input to process simulations to optimise the design.
- Reference sites were visited. These sites were using similar technology in a tightly controlled discharge environment.
- All of this was translated into a practical design.

Reasons for Selecting MBR Technology

- An MBR process, as the Best Available Technology (BAT), was considered because:
  - Low TSS limit
  - Low TKN limit
  - Low sludge growth rate
  - Low contaminant loading
  - Poor floc settling properties resulting from the high salinity.
  - Will retain all the bugs in the system
  - Lower Cost

- It was considered unlikely to meet the specs with anything other than an MBR.

- Despite rapid growth in MBR installations they have not been used in Refinery because of the perceived risk of membrane fouling by oil. The pilot plant demonstrated the manageability of this risk.

Process Configuration

- Currently the Best Available Technology (BAT) for the secondary biological treatment of refinery waste water would be an MBR; a biological plant (anoxic and aerobic zones) followed by a membrane separation stage.
- This process offers the most complete biological treatment possible including nitrogen removal. The specification from the GDEWP is stringent on all forms of nitrogen.
- 4 biological stages (anoxic/ aerobic/ anoxic/ aerobic) are necessary to meet the stringent specifications.
- Further biological treatment is not possible and as a result of this the polluting nature of the treated water is at an absolute minimum. This was also supported by toxicity testing.
- No problems with oil on the membrane or other issues concerning the membrane material were encountered.

Final Process Configuration

- The final process configuration is:
  - Max capacity 5000 USgpm
  - Unit feed pit
  - Equalization system
  - Cooling system
  - Integrated 4-stage flexible biological system (organics removal, nitrification and denitrification)
  - Membrane tanks for liquid/solid separation system
  - Sludge treatment (storage and dewatering system)
  - Chemical storage and dosing systems.

Spent Caustic

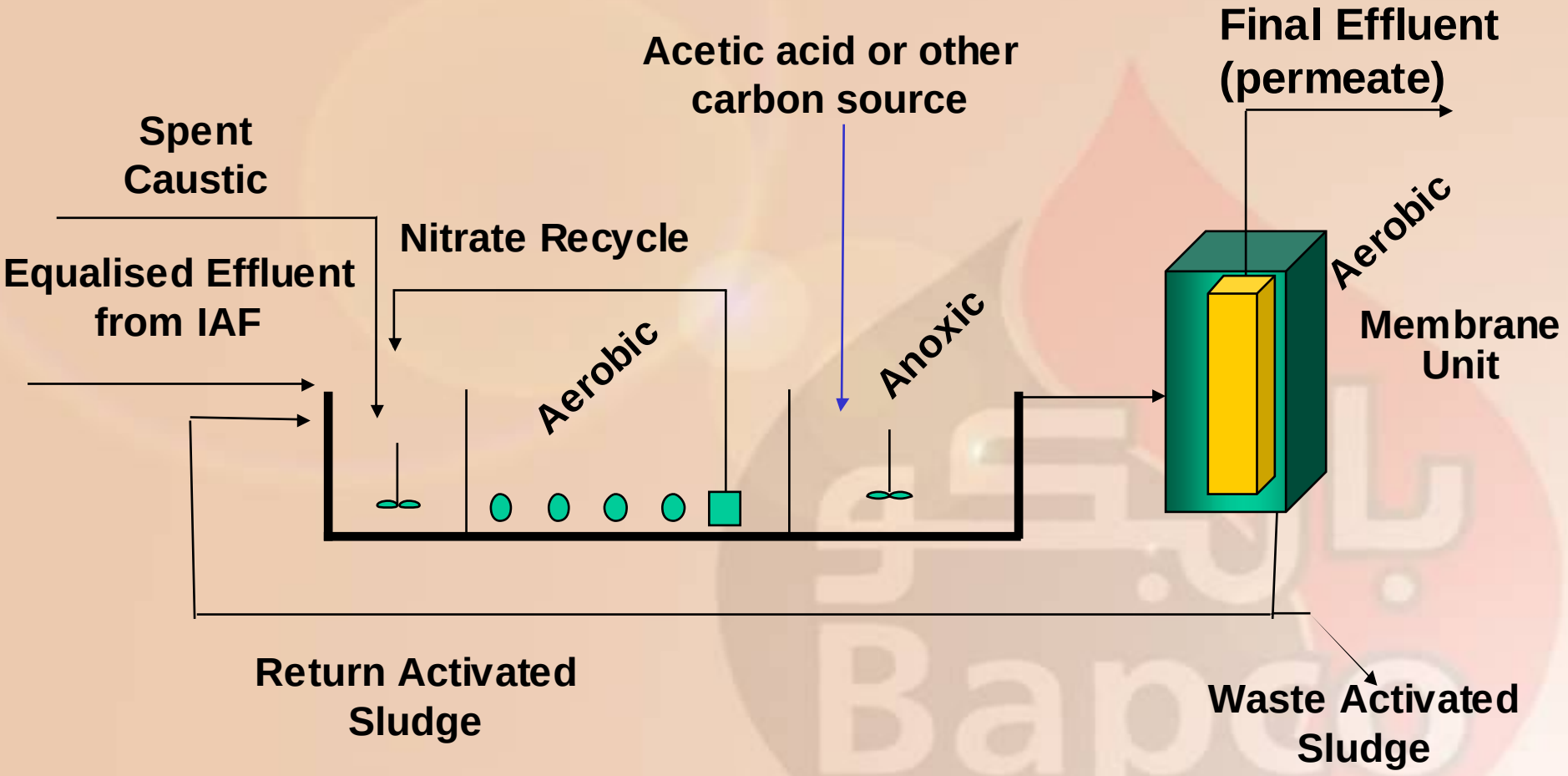
- Bapco has a waste stream of spent caustic, and ways of handling it in an environmentally acceptable way were being investigated.

- Following experiments on the pilot plant it was demonstrated that the spent caustic, when added in a controlled manner could be processed without a problem.

- The Pilot Plant mass balance showed a COD shortfall as required by the de-nitrification reaction. As an additional benefit, the spent caustic could help reduce the shortage by providing COD. This saves acetic acid addition as COD source.

- As another benefit, the alkalinity provided by the spent caustic reduces the alkalinity required for nitrification. This saves fresh caustic addition.

Process Flowsheet



Project Status

- The Engineering Design Package EDP was completed in December 2008.
- Front End Engineering Design (FEED) was completed in December 2009.
- EPC was awarded to GS E&C through Tender Board competitive bidding.
- Project was kicked off in November 2010.
- Project completion is scheduled for June 2012.

Waste Water Treatment Plant

Summary

- From a position of no one knowing anything about the best process, if any at all, to treat its problematic waste water and spent caustic, Bapco first established a knowledge base and then developed that further to a practical design based on an MBR, a state of the art technology.

Thank You

THE FINAL DESIGN DECISION PROCESS
WHAT IS THE APPROPRIATE WW TREATMENT PROCESS?