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Treatment Performance of The BAPCO Biological Waste Water Treatment Plant

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Abbreviations of Key Design Parameters

TKN – Total Kjeldhal Nitrogen

NH3-N – Ammonia-Nitrogen

NO3-N – Nitrate-Nitrogen

NO2-N – Nitrite-Nitrogen

RAS – Return Activated Sludge

WAS – Waste Activated Sludge

COD – Chemical Oxygen Demand

BOD – Biochemical Oxygen Demand

TDS – Total Dissolved Solids

TSS – Total Suspended Solids

Abbreviations of Key Design Parameters

SRT – Solids Retention Time

HRT – Hydraulic Retention Time

F/M – Food to Microorganism Ratio

MLSS – Mixed Liquor Suspended Solids

MLVSS – Mixed Liquor Volatile Suspended Solids

WWTP – Waste Water Treatment Plant

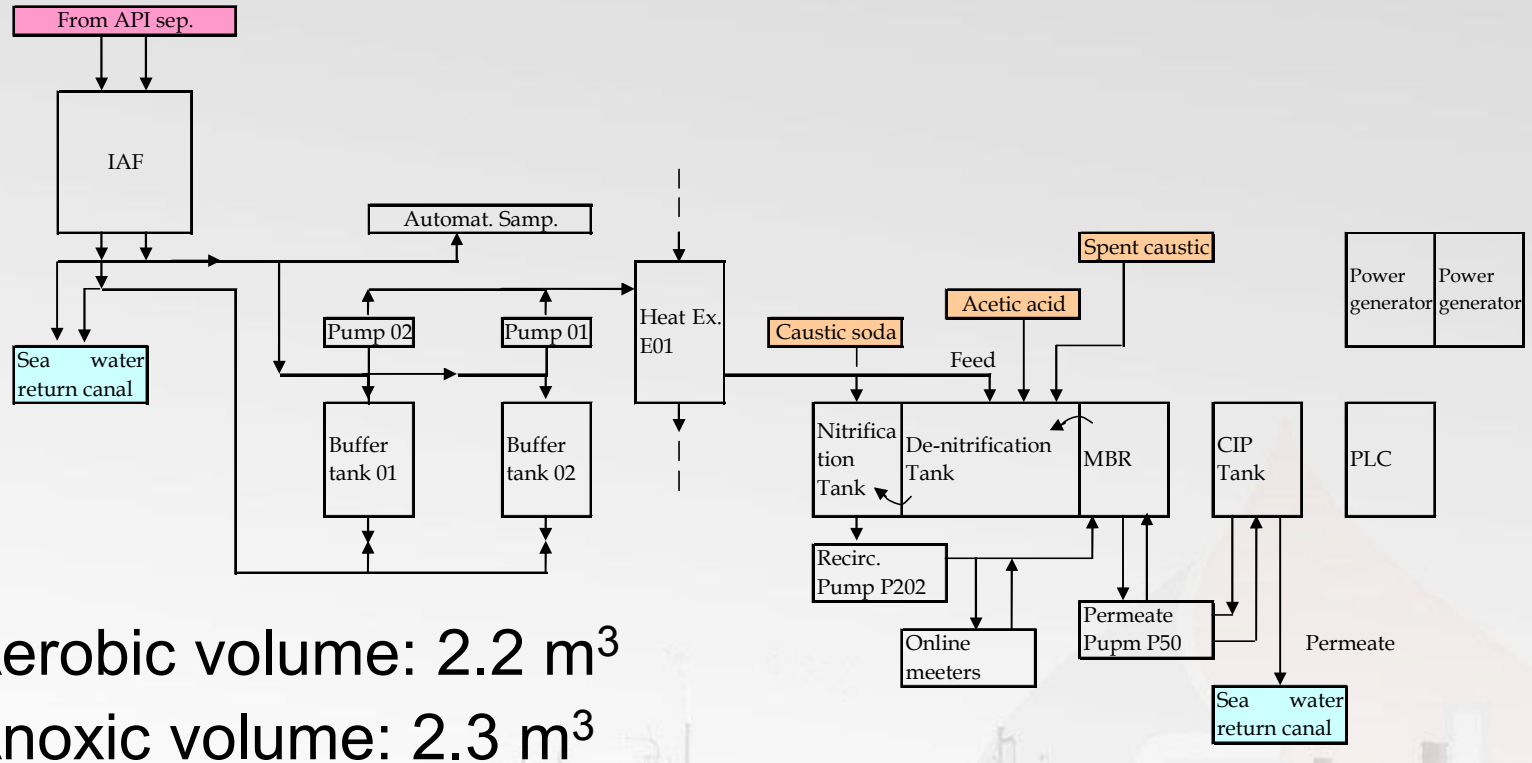
Background

- BAPCO (Bahrain Petroleum Company) owns a refinery, whose capacity is 267,000 BPSD (11.2 MGPD).
- Existing WW treatment:
  - American Petroleum Insitute (API) oil water separator
  - Induced Air Flotation (IAF)
- In 2006 BAPCO started testing its waste water for treatment and the tests revealed:
  - Possibility to remove COD with aerobic biological treatment.
  - Difficulties in settling of sludge.
  - Not stable nitrification.

Goals of Study Phase

- Primary objectives of the study phase:
  - Characterize the wastewater influent streams.
  - Perform pilot testing to confirm the performance of the MBR process.
  - Develop kinetic and design parameters to be used in process modeling.
  - Evaluate spent caustic treatment.
  - Calibrate the process design model to BAPCO's wastewater treatability characteristics.
  - Develop a biological process design.

Pilot Plant Description



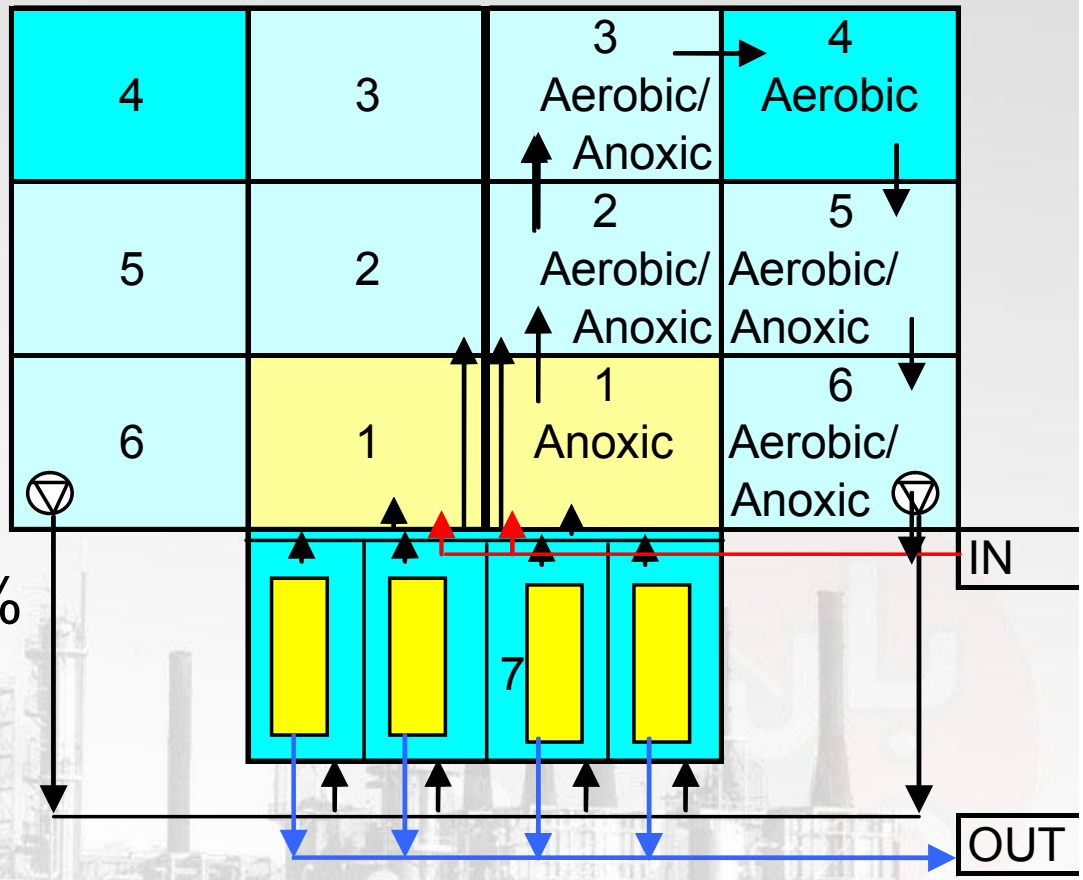
- Aerobic volume: 2.2 m^3
- Anoxic volume: 2.3 m^3
- Membrane surface: 30 m^2 (Puron module)
- Buffer tank volume: 13.2 m^3 each

Pilot Plant Operation

- Average flow rate: 420 l/h.
- Solids Retention Time (SRT): 35-45 d
  - high SRT targeted to achieve high organic carbon and organic nitrogen removal.
- Food to Microorganism (F/M) Ratio:
  - 0.046 d^{-1} May-June (start-up and acclimation).
  - 0.1-0.12 d^{-1} July-August (acetic acid addition to achieve full denitrification).
  - 0.21-0.24 d^{-1} September-November (COD of wastewater increased).
- Final equilibrium mixed liquor suspended solids (MLSS):
  - Net yield was much lower than we anticipated with MLSS 4g/l.

Full-Scale Wastewater Treatment Plant Design

- Design parameters:
  - SRT = 35 d
  - HRT = 8.3 h
  - MLSS = 5.4 g/l
  - RAS = 400%
  - F/M = 0.1 d^{-1}
  - Cell Volume = 550 m^3
  - Anoxic % Volume 45%
  - Aerobic % Volume 55%
  - Nitrate recirculation = 200%



Chemicals used at the WWTP

Chemical	Purpose
Acetic acid	Additional source of organic carbon for completion of the denitrification reactions
Phosphoric acid	Nutrient required for bacteria synthesis, when the P in the wastewater is not enough for biological growth
Ferric chloride	Is injected (in the EQ tanks and/or Bio cells) in order to remove the excess phosphorous
Sodium hydroxide	Is added to the biological system to control pH
Sulphuric acid	If the spent caustic is added to the system, sulphuric acid may be required to maintain the pH in the optimum operating range in the biological system
Anti-foam	In order to control the foaming in the biological cells
Polymer	A cationic polymer is used to improve the dewaterability of the sludge upstream the centrifuges

Chemicals used at the WWTP (Continued)

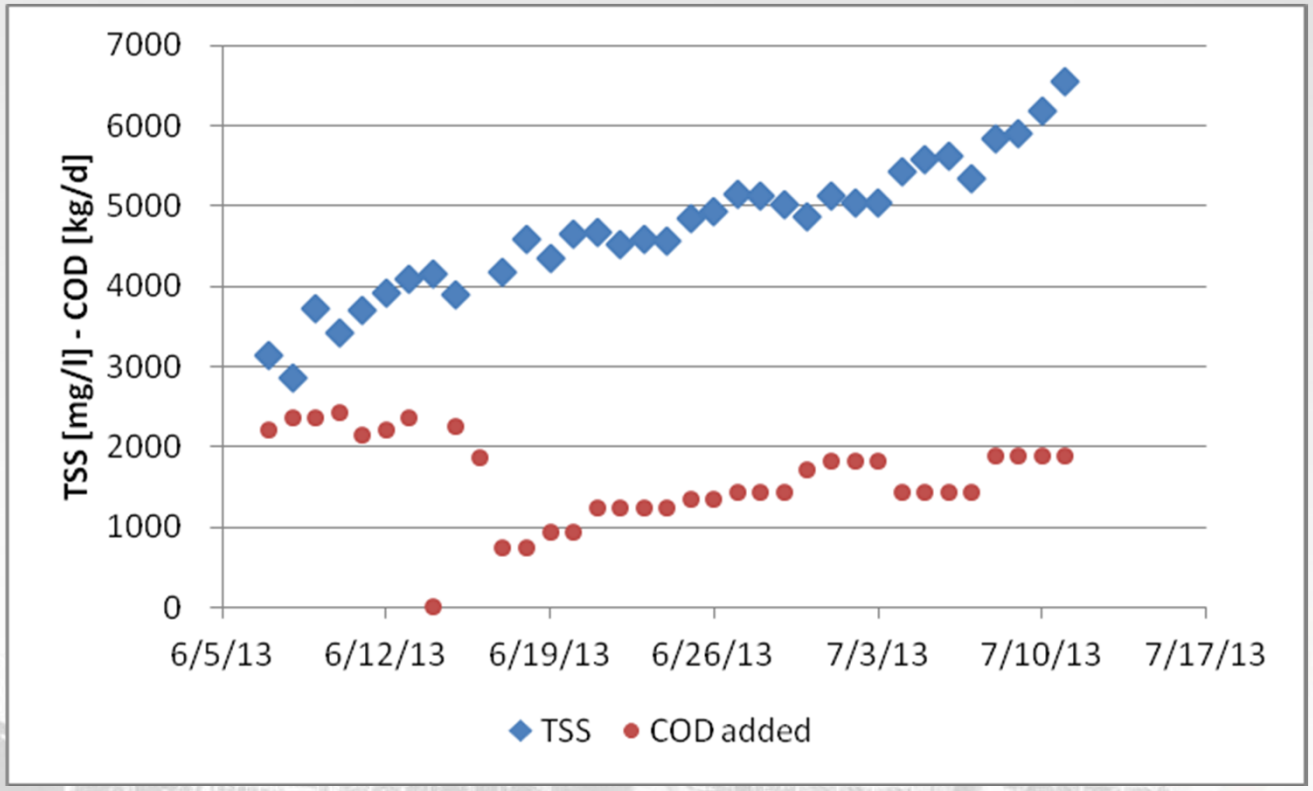
Chemical	Purpose
Sodium Hypochlorite	Disinfectant for the membrane cleaning to oxidize and degrade the microorganisms from the membrane surface
Citric acid	Used for membrane cleaning. Removes the metallic hydroxides that may have formed on the membrane surface during the sodium hypochlorite wash
Formic acid	Used to clean the fin air bubble diffusers installed into the biological cells
Antibiofoulant	Ensure a proper performance of the cooling tower and minimize fouling to the towers due to biological growths
Antiscalant	Ensure a proper performance of the cooling tower and minimize fouling to the towers due to scaling phenomena

Start up and Commissioning of the Full-Scale Wastewater Treatment Plant

- Seed from Sitra plant (90% municipal – 10% industrial)
- 900 m3 of sludge @ 8-9 gTSS/l transferred to one biological train full with Sitra effluent
- Start up phases:
  - TSS increase
  - TDS increase
  - Biomass acclimation
  - Performance test

MLSS Increase Phase

- Scope: promote biomass growth
- Plant operated in recycle mode with addition of acetic acid, phosphoric acid and urea.
- Duration: 3 – 4 weeks

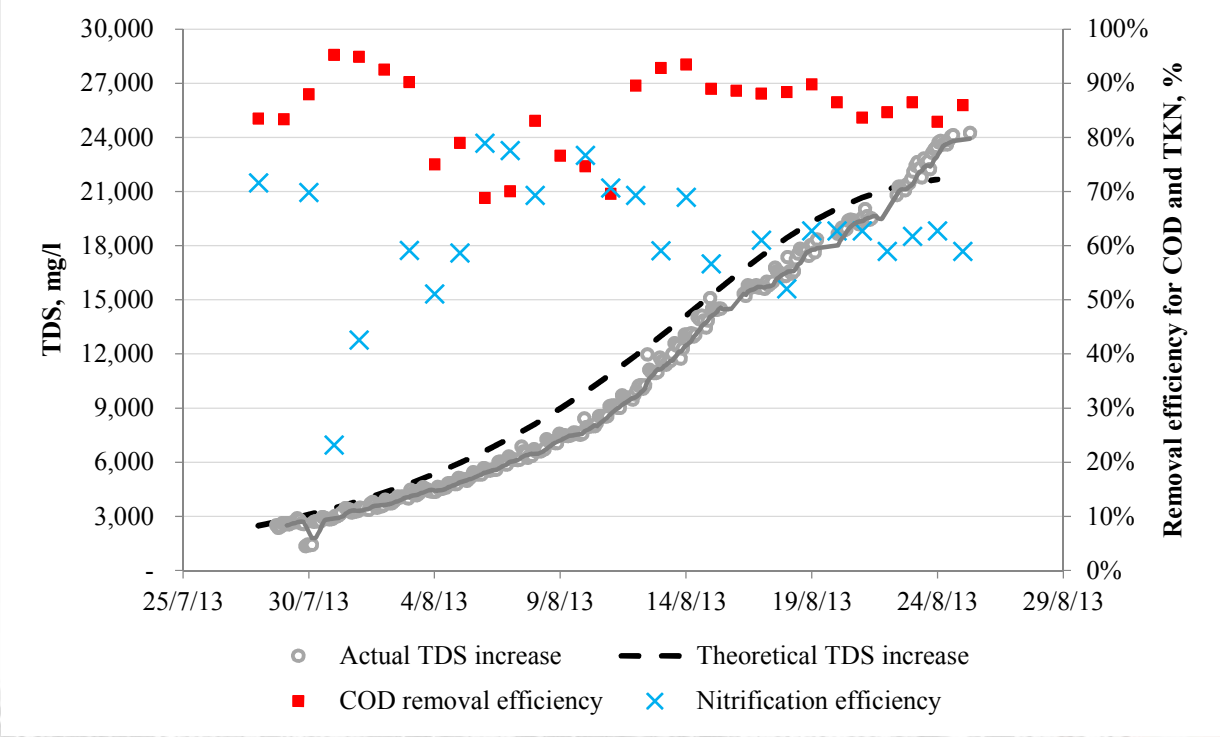


TDS Increase Phase

- TDS of Sitra sludge was 2500 mg/l
- TDS of BAPCO wastewater is approx 25000 mg/l
- To avoid problems to biomass, a 10% TDS increase on a daily basis was implemented
- TDS increase was accomplished by introduction of calculated quantity of BAPCO wastewater on a daily basis
- Duration: 1 month
- Acetic acid and nutrients were added to promote sludge growth

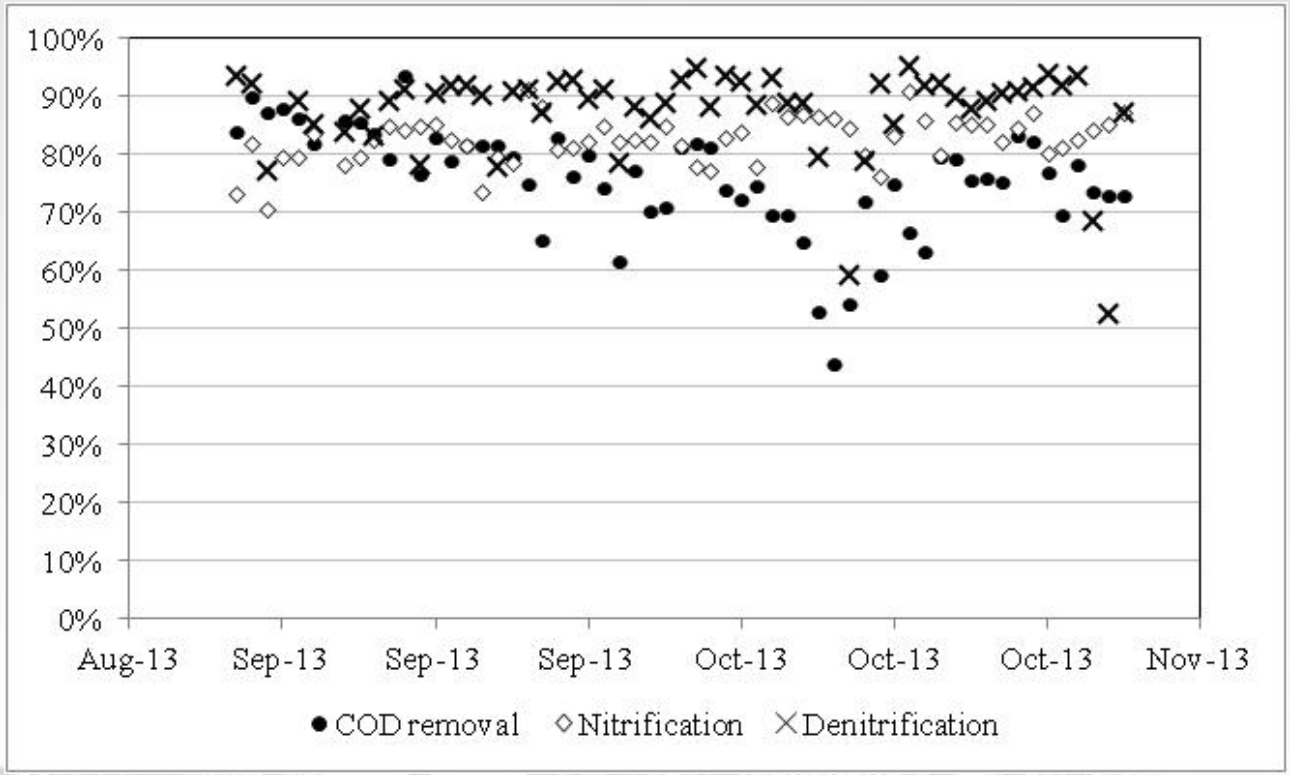
TDS Increase Phase (Continued)

- Real TDS increase in line with observed
- System stabilized when TDS > 10 – 12 g/l
- h_{COD} 85 – 90%
- h_{TKN} 60%
- NH3 < 1 mg/l



Biomass Acclimation Phase

- SRT = 35 – 40 d
- Urea addition to meet the design load
- Acetic acid addition to complete denitrification.
- Duration: 1.5 months



Biomass Acclimation Phase (Continued)

- COD
  - the residual concentration 63 mg/l
  - total load removed 3,000 kg/d
  - removal efficiency 77%;
- TKN
  - residual TKN concentration 1.4 mg/l (N-NH3 0.6 mg/l);
  - the load of nitrified nitrogen 440 kg/d
  - efficiency equal to 83%;
- NO_x (NO_3 + NO_2)
  - residual concentration 4.8 mg/l;
  - load of denitrified nitrogen 419 kg/d
  - denitrification efficiency 87%.

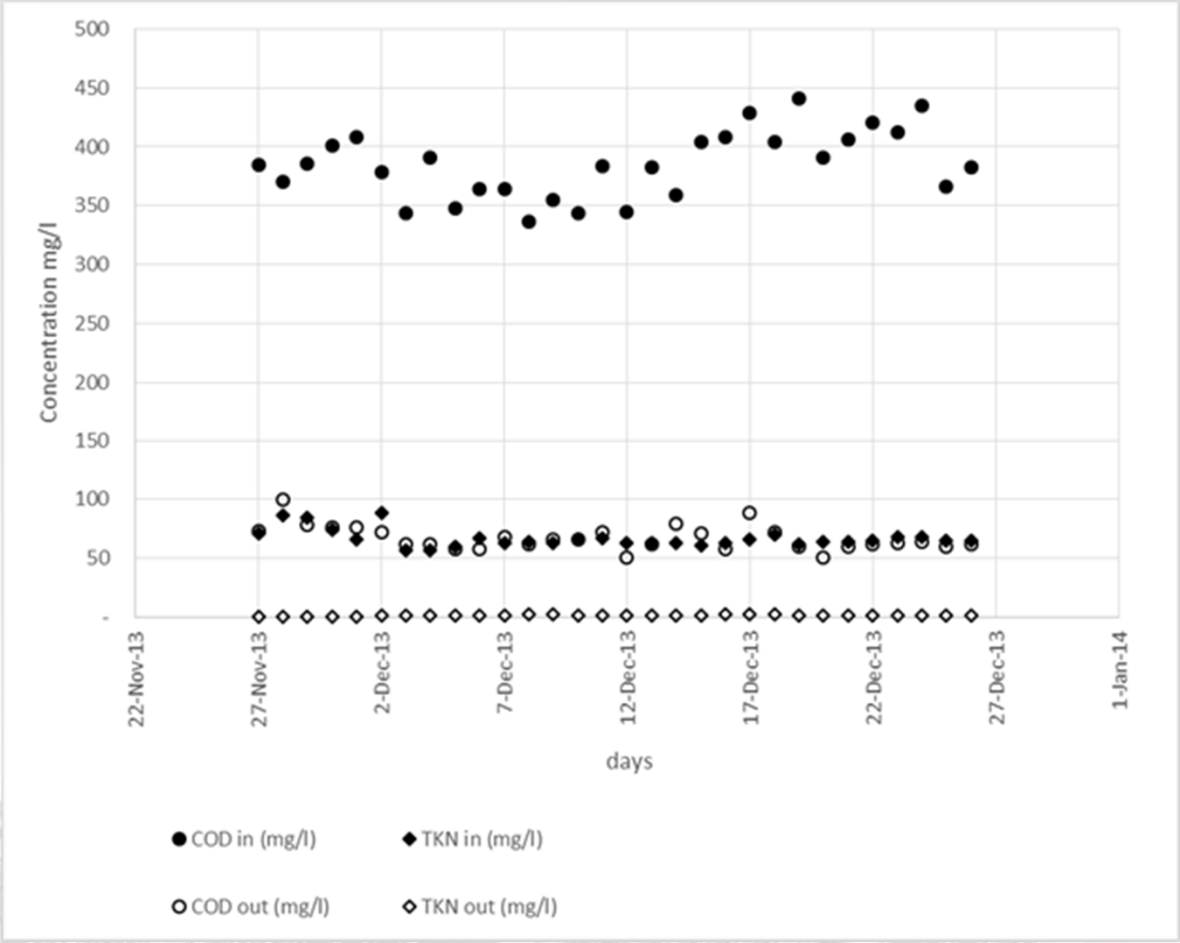
Maximum Month Load Performance Test

- COD load from refinery waste water: 4776 kg/d
- TKN load from refinery waste water: 1294 kg/d
- Target: treat the wastewater to meet the discharge limits
- Duration: 30 days
- Spent Caustic injection into the first anoxic cells
- Chemicals were added to the WWTP to controll the biological processes

Maximum Month Load Performance Test (Continued)

- Performance Test passed
- Discharge limits achieved
- Effluent Concetrations:

- Ammonia: <0.5ppm
- Ave.COD: 67ppm.



Conclusion

- Pilot plant's operation demonstrated good removal capability for organic compounds, ammonia, nitrite and nitrate.
- Pilot testing underlined the importance of pH control for nitrification and the need for high SRT and low F/M, both for nitrification and COD removal in a saline wastewater.
- The use of a calibrated model was critical to produce a successful process design.
- Presence of oils (influent average concentration 10.9 ± 5.0 mg/l; maximum value 37.6 mg/l) did not affect the performance of the membranes.
- Based on batch test and pilot test results, it was confirmed that spent caustic can be treated in the biological reactor.

Conclusion (Continued)

- Full –scale waste water treatment plant was realized and its startup was performed saccessfuly
- Procedure applied to increase the TDS of the sludge (+10% on daily basis) proved to be effective.
- Biomass acclimation confirmed good removal capabilities.
- Performance test successfully conducted in December 2013. At the maximum load the plant was able to meet the effluent discharge limits.
- WWTP is operating today and meeting the discharge limits.


THANK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