Reinhold Environmental Ltd.

2007 NOx Round Table & Expo Presentation

February 5-6, 2007 in Cincinnati, OH

HALDOR TOPSOE, INC.

Washing Your Own Catalyst

NOx Round Table
2007
Cincinnati, Ohio

Presented by:

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INTRODUCTION

- Quick Overview
  - History
  - Current
- Discussion of the Process
  - Procedure development
  - Basic cleaning elements
  - General cleaning recommendations
  - Plant experience and results

History

- Avedore Station
  - Unit 1, 250 MWe, coal fired boiler
    - 1999 development of catalyst washing technology
    - First in-situ washing 2000
    - First external washing 2002
  - Unit 2, 570 MWe biomass fired boiler
    - Further in situ washing development
    - Catalyst is washed several times a year

Current Washing Experience

- (7) coal fired units
  - (4) PRB – Washed (5) times over 20,000 operating hours
  - (3) Bituminous
    - One washed (3) times over 120,000 operating hours
    - (2) units washed once
- (1) Biomass unit
  - Washed (9) times over 30,000 plus operating hours
- (1) Industrial unit
  - Washed twice

Procedure Development

- Understanding customers NOx strategy and cleaning goals
- In-situ / external cleaning
- Evaluate present catalyst

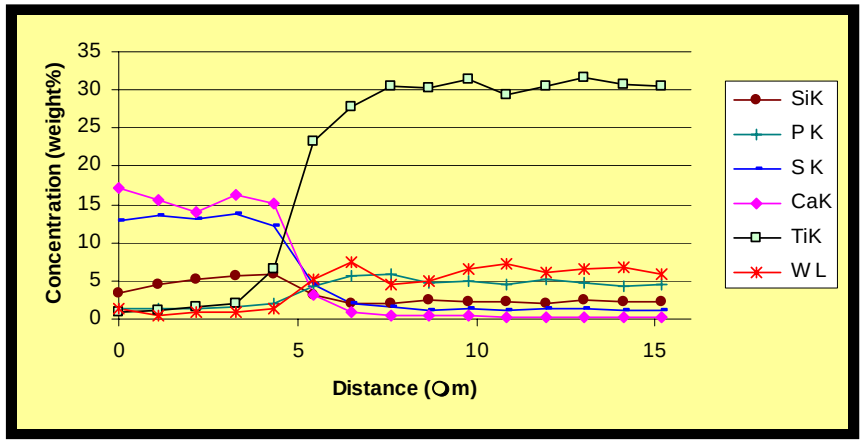
Catalyst Cleaning Evaluation

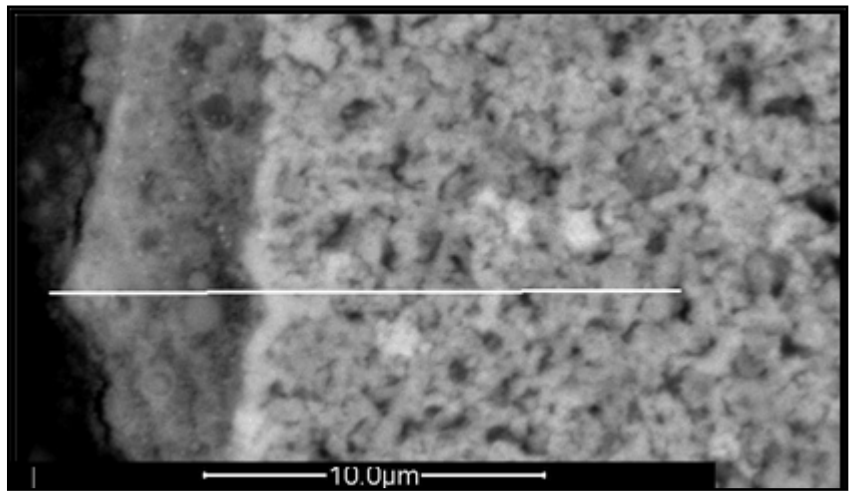
- Activity at (3) temperatures
  - determines loss of activity due to diffuse (pore pluggage) or poisons
- Perform a chemical analysis
  - Indicates poisons and catalyst masking compounds present
- Look at surface area
  - Indication of pore pluggage

Sample	Reference	Layer 2
K (soluble), ppmw	150	3,647
Na (soluble), ppmw	500	3,408
Ca (soluble), w%	500	1,363
K (total), ppmw	120	4,065
Na (total), ppmw	500	3,720
Ca (total), w%	2	2,088
As, ppmw	25	2,330
P, ppmw	1,000	1,440
Mg, w%	< 0.08	0.08
Fe, w%	< 0.08	1.64
Al, w%	0.97	1.78
Si, wt%	4.85	5
S, w%	0.01	1.65
HBET, m^2/g	46 - 50	39.5

Catalyst Cleaning Evaluation

- % loss of catalyst activity due to surface masking
- % loss of catalyst activity due to surface masking
- % loss of catalyst activity due to Chemical poisons, such as K, Na

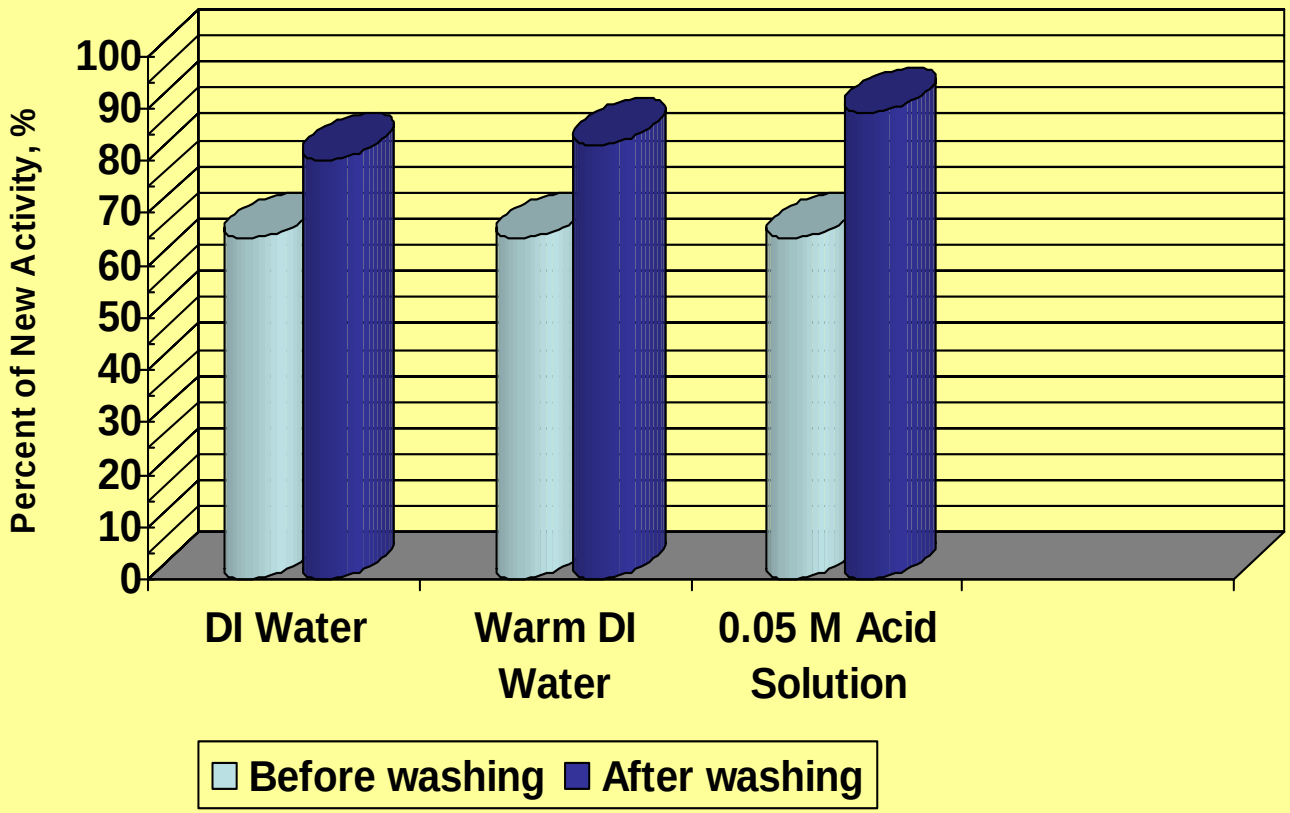




✓ Develop cleaning procedure to recover activity that meets customers requirements

Cleaning Procedure

- Bench testing of cleaning procedures



Basic Cleaning Elements

- Dry cleaning
  - Air blowing
  - Vibrating the module with a pneumatic vibrator
  - Vacuuming
  - Physical removal of pop-corns
- Water washing
  - Shower with or without chemical additives
  - Soaking with or without chemical additives
- Water rinse
- Air dry

External – Water Shower

External – Water Shower

External – Water Shower

Internal – Water Shower

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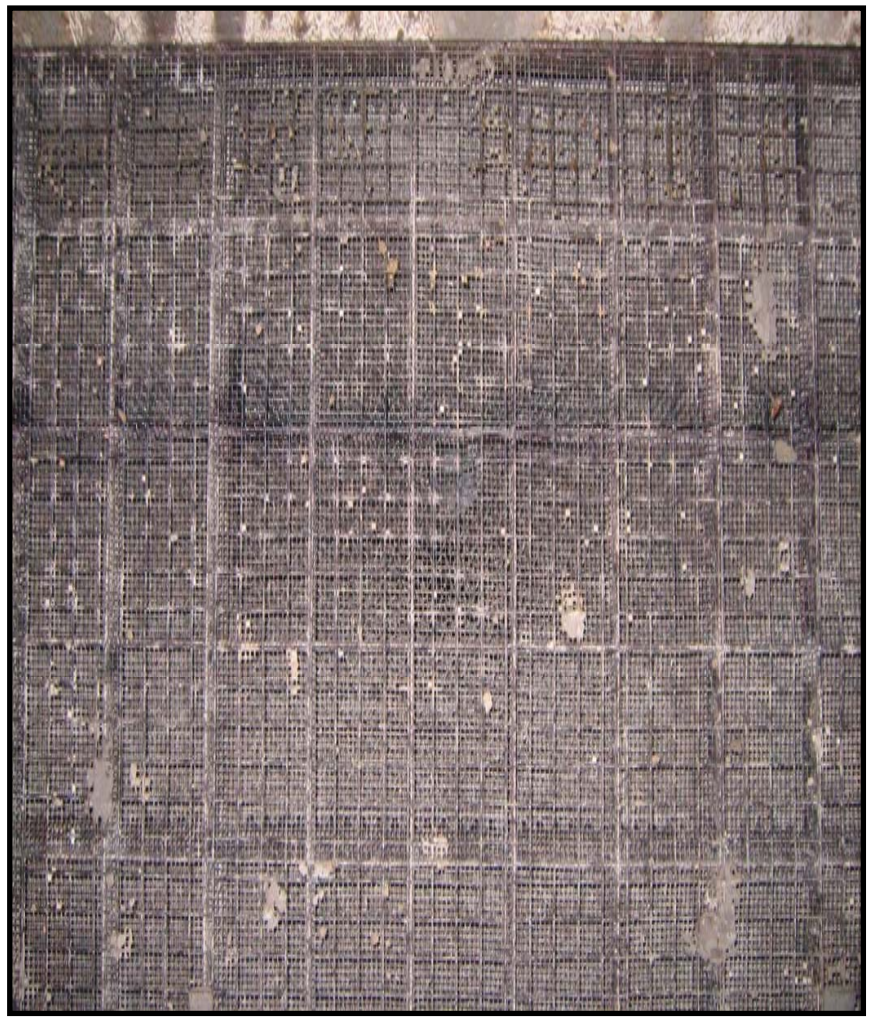
Internal – Water Shower

Before

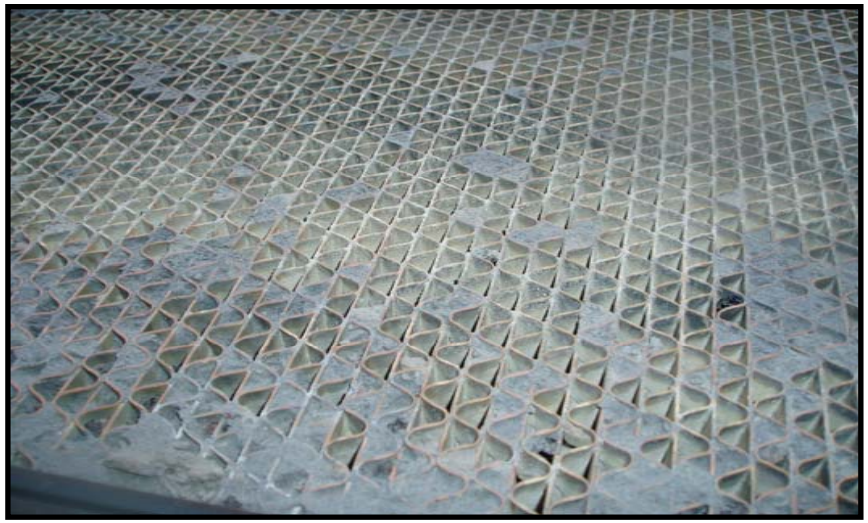


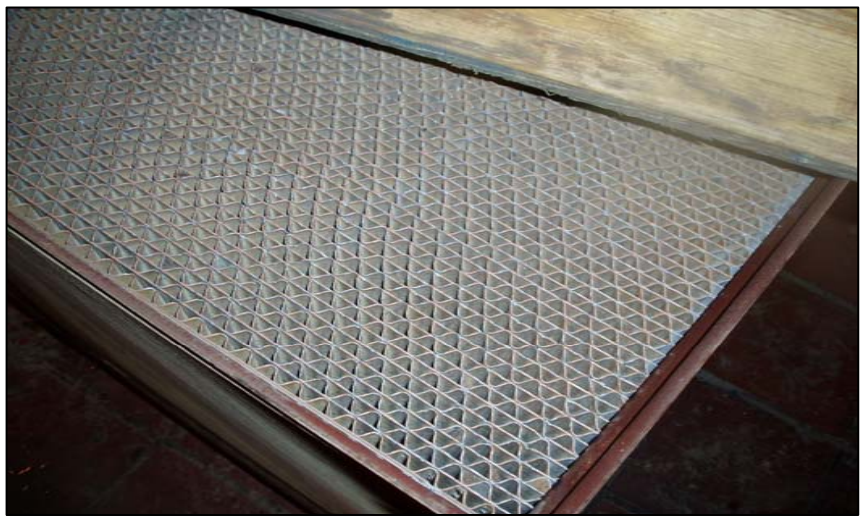
After

General Shower Recommendations

- Separate top elements from bottom
- Dry clean using air, pneumatic vibrator, air and vacuum
- Water shower
  - Clean, Tap or better
    - Pressure < 40 psi
  - Nozzle distance > 12 inches
  - Nozzle size, a large water volume
  - Duration depends on testing, usually less than 15 minutes
- Air dry catalyst

External – Water Soaking





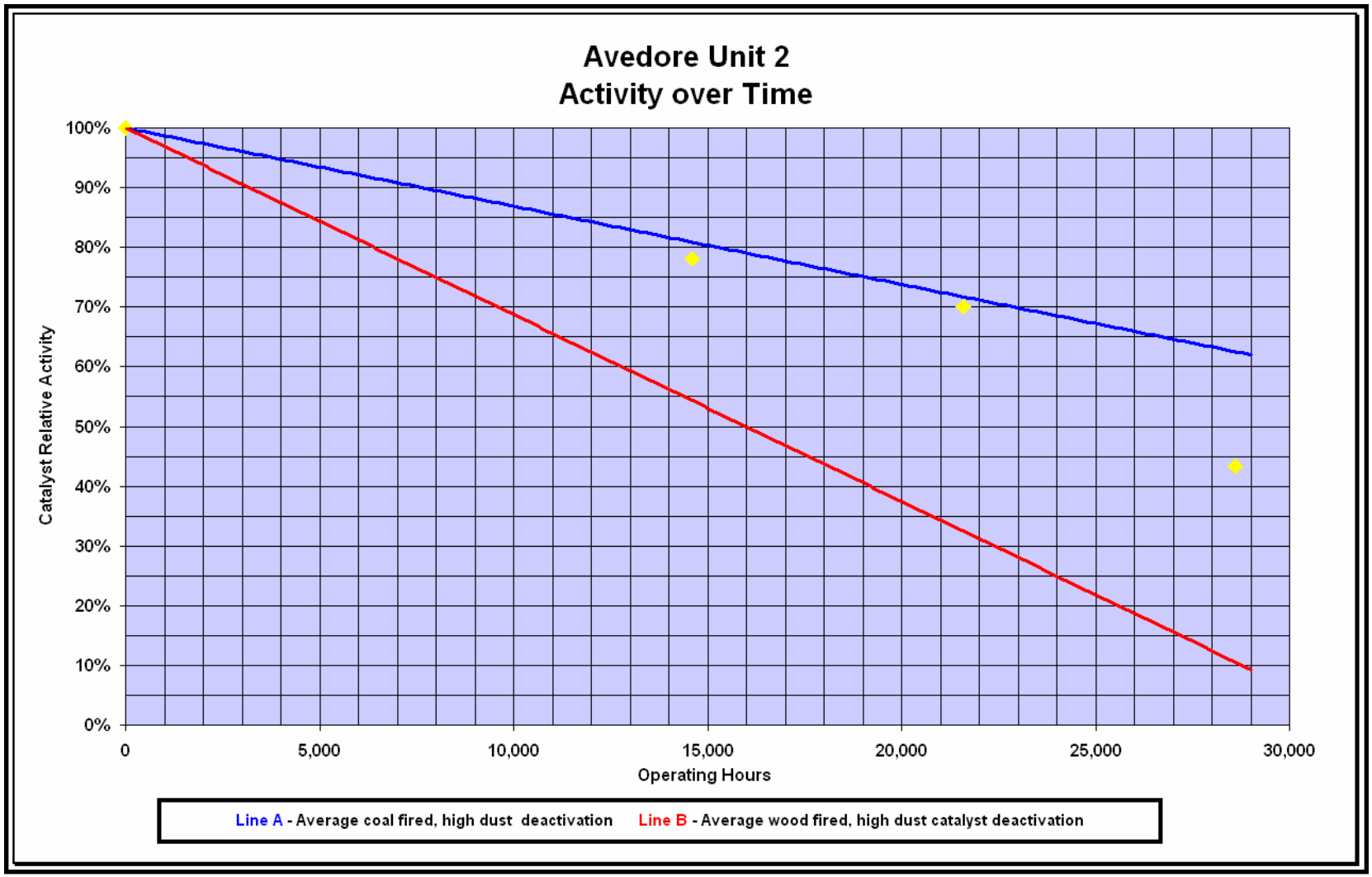
General Soaking Recommendations

- Separate top elements from bottom
- Dry clean using air, pneumatic vibrator, air and vacuum
- Water soak
  - Clean, Tap or better
  - 30 minutes in warm water solution
  - Agitate water with air
  - Monitor water, exchange frequently
- Rinse after removal from bath
- Air dry catalyst

Plant Cleaning Experience

- Avedore Unit 2, 570 MWe biomass (wood) fired
- High dust SCR placed in service in summer of 2002
- First catalyst wash summer 2003
- In-situ cleaning with a water shower
  - Started washing 8 minutes with tap water followed by a 0.05 M sulfuric acid solution
  - Presently, wash with tap water 18 minutes without following with sulfuric acid
- Catalyst has been washed (9) times during its 30,000 hours of operation
- Catalyst replaced summer 2006

Plant Cleaning Experience



Plant Cleaning Experience

- Avedore Unit 2 Catalyst Chemical Analysis

Sample	K, ppm total	K, ppm soluble	Na, ppm total	Na, ppm soluble	Ni, ppm
Reference	400	150	400	150	-
January 2004 (14,600 hours), pre-washing	2,790	2,495	735	710	380
January 2004, after washing	1,930	1,795	810	520	275
December 2004 (21,600 hours), pre-washing	2,140	1,901	1,587	1,242	135
December 2004, after washing	1,440	1,287	1,032	667	132

- Regular catalyst washing keeps the Na and K at acceptable levels thus avoiding severe catalyst deactivation due to alkali poisoning.

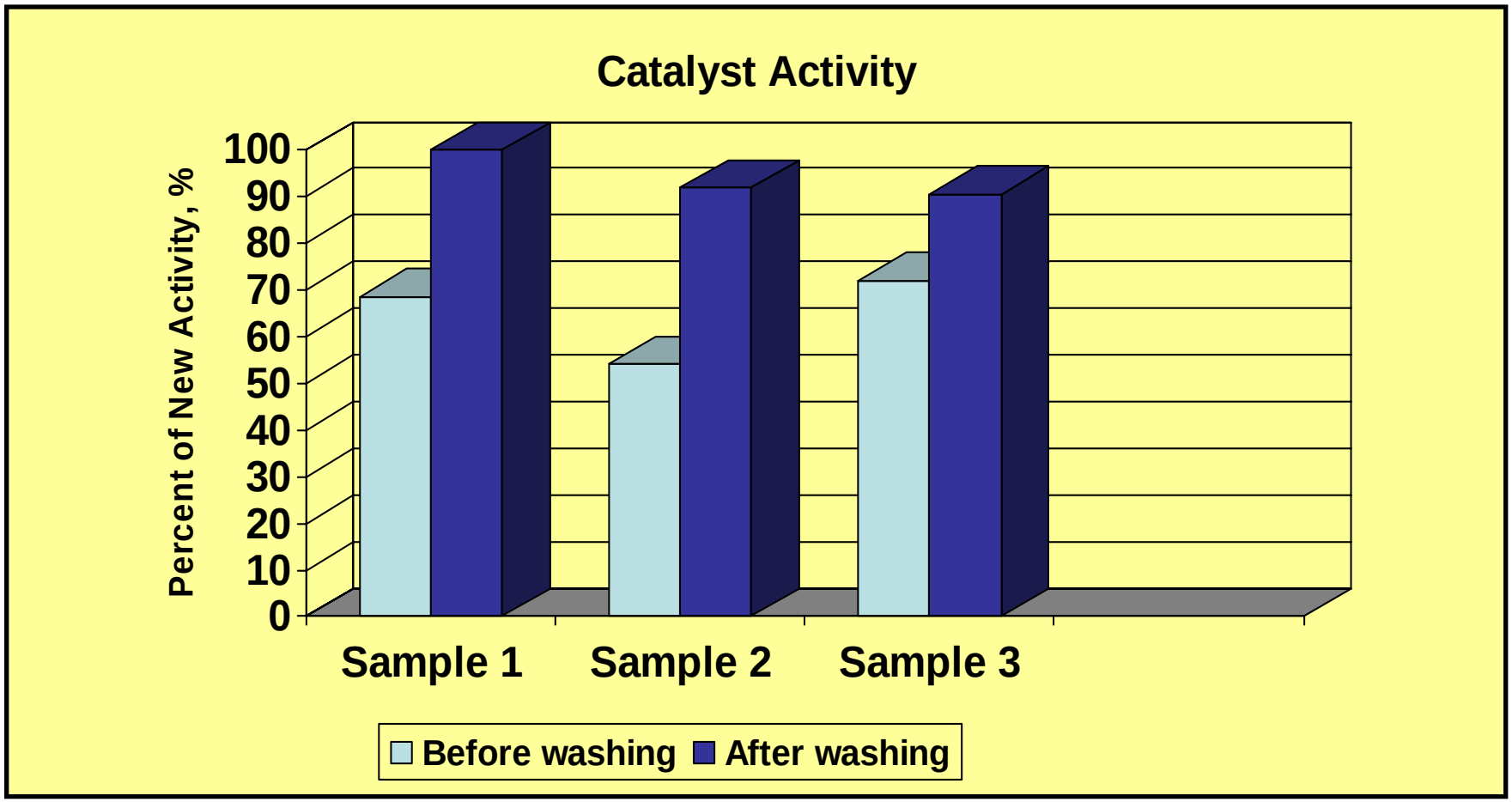
Plant Cleaning Experience

- 2 x 590 MWe, 2 x 690 MWe PRB fired boilers with high dust SCRs
- External cleaning procedure
  - Separate top elements from bottom
  - Dry cleaning of the catalyst
  - Water soak for a time period followed by a water shower rinse with warm water
  - Air dry
- Plant has washed catalyst (5) times

Plant Cleaning Experience

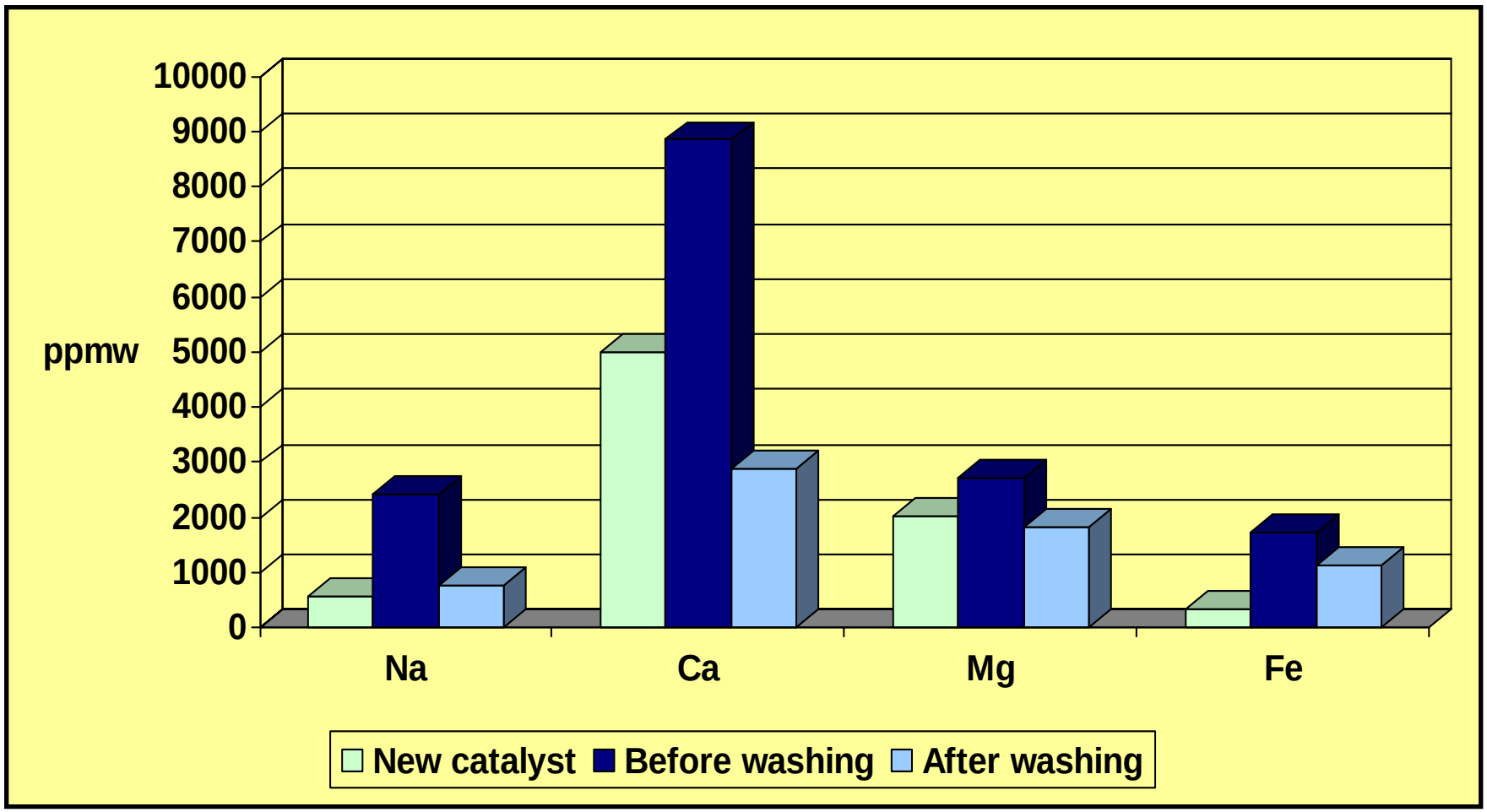
Plant Cleaning Experience

- Catalyst activity after 15,000 hours of operation



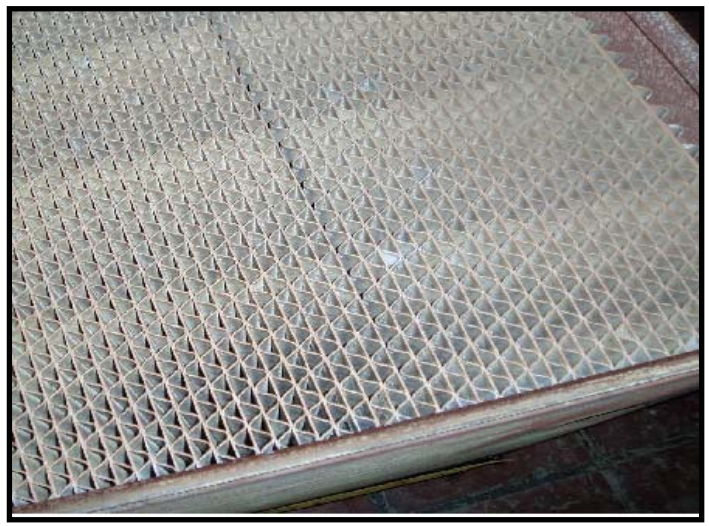
Plant Cleaning Experience

- Chemical analysis after 15,000 hours of operation



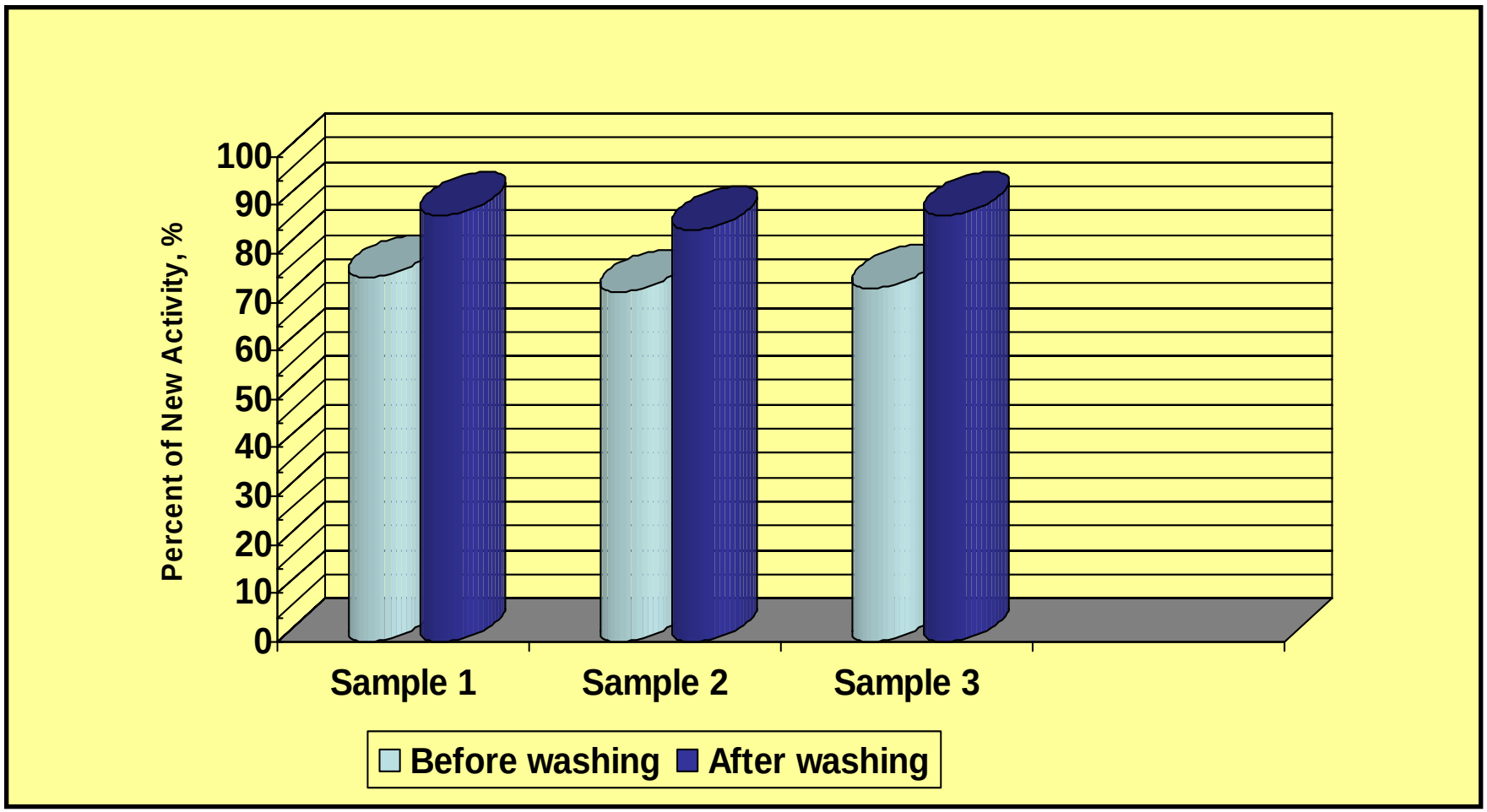
Plant Cleaning Experience

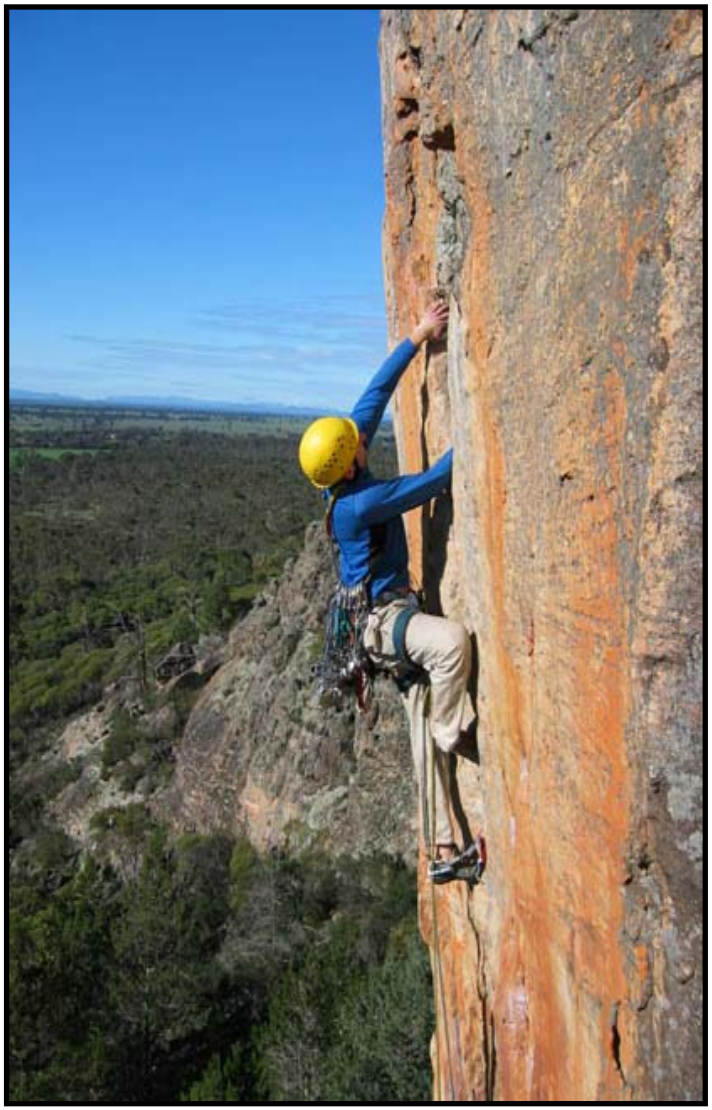
- Bituminous fired boiler with a high dust SCR
- Catalyst cleaned after 28,000 hours
- External cleaning performed;
  - Separate top elements from bottom
  - Dry cleaning the catalyst by vacuuming
  - Water soak for a time period of 15 to 30 minutes in a warm demineralized water tank with air agitation
  - Remove rinse and inspect catalyst
  - Air dry



Plant Cleaning Experience

- Catalyst activity after 28,000 hours of operation





Thank you

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Discussion