



Greatest Cases: Contaminant Series

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The Challenge

- Perhaps once in every 1,000,000 samples the end user desperately needs help to figure out the true source of contamination
- Logistics and/or cost dictate the case can only be solved with help from the armchair detective



The Method

- Listen to the evidence
- Request a sample
- Interpret the data
- Make the fewest assumptions to arrive at a simple answer
 - Principle is often referred to the principle of Occam's Razor; "other things being equal, a simpler explanation is better than a complex one"



Occam's Razor

- Experience certainly helps, but back-and-forth discussion will 'shave away' unnecessary assumptions
 - **“Eliminate all other factors, and the one which remains must be the truth.”** – Sherlock Holmes
- Thinking of all reasonable possibilities often requires thinking *outside of the box*



Occam's Toothpaste (Part 1)

- A toothpaste factory has an excessive number of empty boxes coming off production line, resulting in lost revenue
- CEO spends millions to solve the issue
 - Scales installed on production line immediately after packaging
 - 'Light' boxes trigger a bell and stop the line so worker can throw empty box into a reject bin and restart the line



Occam's Toothpaste (Part 2)

- Toothpaste company no longer ships empty boxes, so CEO thinks money was well spent
 - Statistics show the scales caught hundreds of boxes the first week
 - Recently, alarm is no longer being triggered and CEO is worried scales are no longer functioning
- Puzzled, the CEO visits shop floor for a firsthand look and finds **no boxes** in reject bin



Occam's Toothpaste (Part 3)

- Just ahead of the scales there is a cheap desk fan on one side of the line
 - Empty boxes are being blown off the production line **before** they can trigger the alarm
- CEO requests explanation from nearby worker, who said they put it there because they were tired of walking over every time the alarm sounded
- While we often believe some of the best solutions come from thinking outside of the box, sometimes...
there is no box



Case Files

- The Case of the Pestilent Potassium
- The Case of the Gunnite Plight
- The Case of the Adiabatic Panic
- The Case of the Fine Filter
- The Case of the Fizzy Fuel



The Case of the Pestilent Potassium

- The Client
 - Millar Western Pulp, located in Whitecourt

- The Crime
 - In May 1998, all gearboxes fail on-site screening using particle count



The Case of the Pestilent Potassium

- The Evidence
 - Gearboxes were not topped up recently
 - Gearboxes not equipped with filtration, and are all located indoors
 - Other screened systems within the plant seem unaffected, though they are all closed-loop hydraulic systems



The Case of the Pestilent Potassium

- The Sample Results
 - Laboratory testing confirms elevated particle count and shows anomalous potassium
- The First Suspect
 - Client asks where potassium could come from and is quickly told: coolant
 - These gearboxes are not equipped with liquid cooling. Nothing else in the plant either, so coolant does not exist on-site

The Case of the Pestilent Potassium



- The Second Suspect



- Don't laugh, old mechanic trick to quieten down a noisy gearbox

The Case of the Pestilent Potassium



- The Third Suspect
 - Stuck, the conversation turns to a discussion about the weather
 - Client asks if the smoke from the forest fire up past Whitehorse has hit the lab yet, says he's been living in a haze for the past week



The Case of the Pestilent Potassium



- New evidence
 - Environment Canada was contacted for an air quality report
 - Recent analysis was not available, but data from a previous fire confirmed high levels of potassium in the particulate matter
 - Intense forest fires release potassium into the air, but worth noting that coal fires produce potassium too
- Case Closed



The Case of the Gunnite Plight

- The Client
 - Dairyland Power, Wisconsin

- The Crime
 - In 2004, a known water leak from a hydraulic system cooler seemed to coincide with rapid plugging of duplex filtration system



The Case of the Gunnite Plight

- The Evidence
 - Coarse pre-filter rated $\beta_5=1000$
 - Fine polishing filter rated $\beta_1=1000$
 - Both filters made from synthetic media and covered in visible granular material
 - Normally changed yearly, currently would not last one week before tripping a high differential pressure alarm



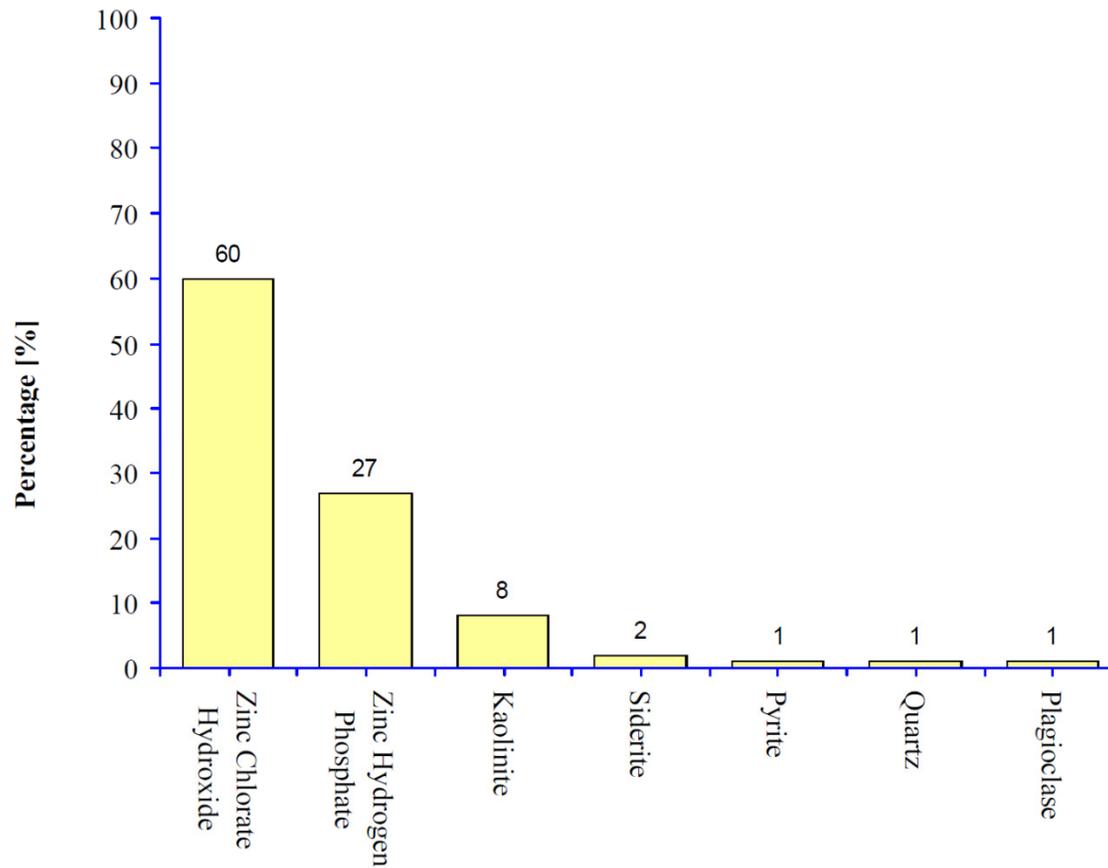
The Case of the Gunnite Plight

- The Sample Results
 - Filters were backwashed and debris was analyzed using X-ray diffraction to identify compounds
 - Results between the two filters indicate a single common denominator

The Case of the Gunnite Plight



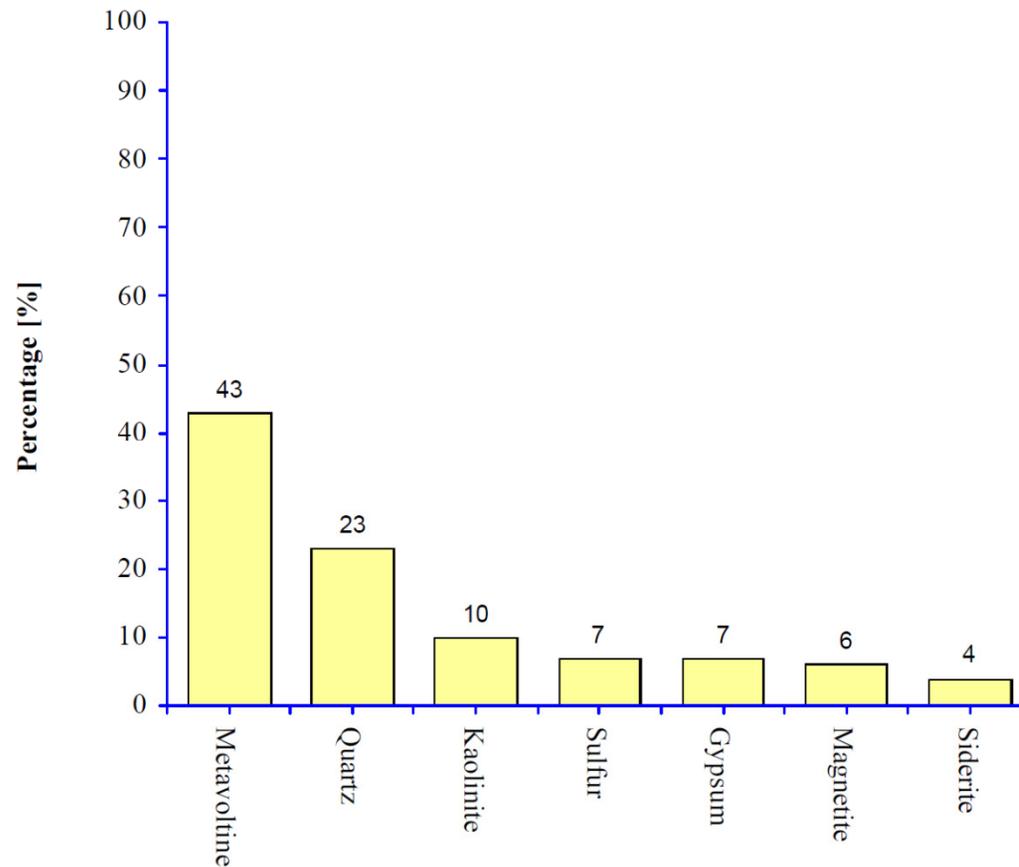
- Pre-filter XRD Results



The Case of the Gunnite Plight



- Polishing filter XRD Results





The Case of the Gunnite Plight

- In English?
 - Plagioclase is also used in the production of **ceramics**
 - Quartz is one of the most abundant minerals on earth, but one of its many uses is also in **ceramics**
 - Kaolinite is important to the production of **ceramics** and porcelain
 - Gypsum is not only found in wall boards, it is used in some **cements**



The Case of the Gunnite Plight

- The First Suspect
 - Client asks if those compounds are the ingredients in Gunnite
 - *Gunnite* is “dry mortar conveyed through a hose and pneumatically projected at high velocity onto a surface” then wetted to set
 - *Stucco* is mortar that is applied wet, by contrast



The Case of the Gunnite Plight

- New evidence
 - Client reveals boilers were relined in 2002 (two years before event) using Gunnite
 - Boiler is 50 feet away from hydraulic system, which was open to atmosphere during boiler refit
 - Gunnite dust sat dormant in reservoir until activated by water leak creating concrete-like particles
 - Cooler replaced, filters stop plugging
- Case Closed



The Case of the Adiabatic Panic

- The Client
 - Texas Genco – Limestone Generating Station

- The Crime
 - Darkening of hydraulic fluid, without a change in routine oil analysis



The Case of the Adiabatic Panic

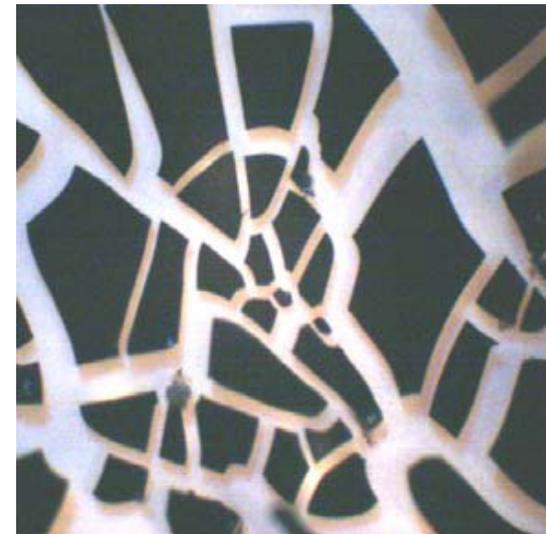
- The Evidence
 - Particulate filters appeared to be working properly and were not changed recently
 - Fuller's Earth acid scavenging filters also appeared to be working properly and were not changed recently
 - Hydraulic pump is axial piston pump

The Case of the Adiabatic Panic



- The Sample Results

- Oil analysis reveals particle count is ISO 16/14/12, AN=0.05 and only trace levels of Iron, Calcium and Magnesium (Fuller's Earth)
- Further patch analysis shows most particulate below 0.1 μm





The Case of the Adiabatic Panic

- The First Suspect
 - Particulate could be ultra-fine coal dust
- New evidence
 - X-ray Emission Spectrometry (form of elemental analysis) confirms Carbon as primary element in the composition, with lesser amounts of Silicon, Calcium and Chlorine (not necessarily from coal) and traces of Sulfur, Aluminum or Iron (typically found in coal)

The Case of the Adiabatic Panic



- New Evidence (continued)
 - However, to confirm carbon isn't from an alternate source, X-Ray Diffraction (XRD) is also performed
 - Only 'sees' compounds with definite, known crystalline substructures
 - Results shows 50/50 mix of kaolinite and chlorite (neither is carbon based)
 - The carbon, therefore, is amorphous



The Case of the Adiabatic Panic

- Again, I'm going to need that in English
 - Carbon is crystalline in three forms: diamonds, graphite or Buckminsterfullerene (Bucky Balls), and **can** be 'seen' by XRD
 - Carbon is non-crystalline in forms such as soot, from incomplete combustion, and **can not** 'seen' by XRD



The Case of the Adiabatic Panic

- The Second Suspect
 - The Carbon that is present must be due to a combustion process, which shouldn't exist in a hydraulic system
 - If it somehow did combust due to a hot spot, it should oxidize the fluid and affect the acid number
 - Unless it is not the oil being burned, and the heat of combustion is insufficient to oxidize the oil



The Case of the Adiabatic Panic

- Now you're just talking crazy!
 - Adiabatic (adjective), def. occurring without loss or gain of heat
 - Commonly used to describe the compression and power stroke in a diesel engine
 - Micro-bubbles in the hydraulic fluid can be compressed to the point of combustion as they pass through the pump
 - Process known as micro-dieseling
- Case Closed



The Case of the Fine Filter

- The Client
 - Shell Scotford Upgrader, Fort Saskatchewan
- The Crime
 - Darkening of compressor oil



The Case of the Fine Filter

- The Evidence
 - Fluid incapable of micro-dieseling as it is only lubricating bearings
 - Filters recently upgraded to smaller pore size
- The First Suspect
 - High-speed, high-temperature applications can produce varnish and other insoluble oxidation by-products



The Case of the Fine Filter

- The Sample Results
 - Laboratory testing shows normal spectrographic results, AN, Membrane Patch Colorimetry (Varnish Potential), but increase in particle count
- The Second Suspect
 - Pull a filter for filter debris analysis to determine if particulate related to colour

The Case of the Fine Filter

- New Evidence



- Outside of filter visually clean



The Case of the Fine Filter

- The Third Suspect
 - No laboratory analysis required, carbonaceous deposits on clean side of filter are the modus operandi of Electro-Spark Discharge (ESD)
 - Streaming potential created by flowing a liquid through an orifice, static will discharge to a grounded surface
 - Remedied by conversion to original filter
- Case Closed



The Case of the Fizzy Fuel

- The Client
 - Local engine re-build shop

- The Crime
 - Multiple engine replacements within 60 miles of driving



The Case of the Fizzy Fuel

- The Evidence
 - OEM engine failed inexplicably and vehicle towed to shop
 - First replacement engine ran less than 12 miles and was assumed to be defective and replaced under warranty
 - Second replacement engine was test run before turning over to customer, didn't last an hour



The Case of the Fizzy Fuel

- The First Suspect
 - The common denominator between all three engines was the fuel
- The Sample Results
 - The submitted sample separated into fuel on top and dark, brown liquid on the bottom
 - Crackle test was positive, but it left a residue on the hotplate
 - Karl Fisher analysis confirmed bottom layer as water

The Case of the Fizzy Fuel



- The Second Suspect



- An effective method of ‘sugaring’ an engine is to use sugar that will pass through the fuel filter

The Case of the Fizzy Fuel

- They might have gotten away with it



- Case Closed



**Thanks for your attention,
questions?**



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