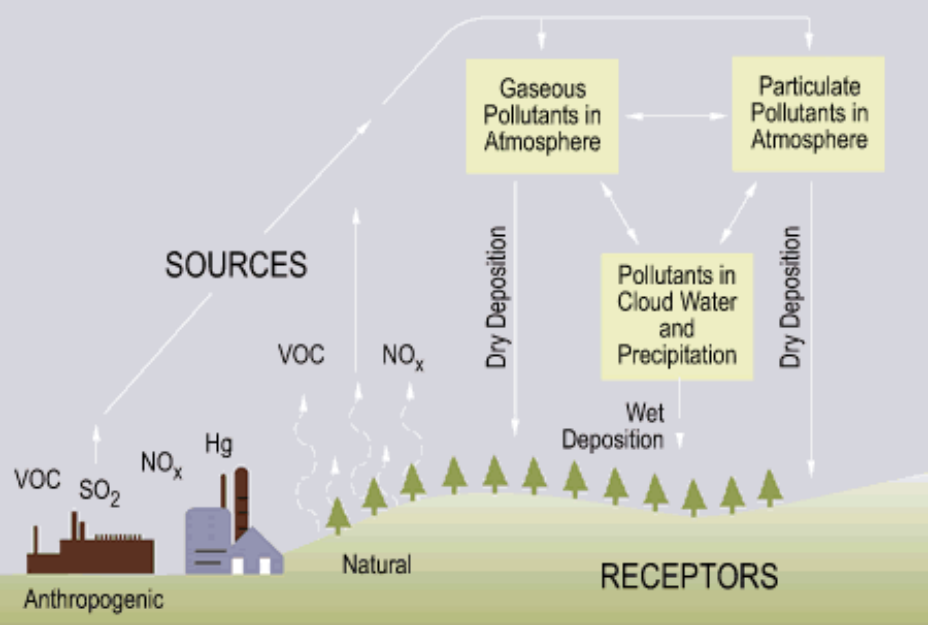
Identification and treatment of corrosion as a hazard in power plants in Sudan

تحديد ومعالجة التآكل كأحد المخاطر بمحطات توليد الطا قة الكهربائية فى السودان

Objectives الأهداف

- **To identify hazards and failures in thermal power plant in Sudan.**
- **To suggest solution and remedies to the identified problems after necessary diagnosis.**
- **To apply suggested solution and test their validly in the actual site.**
- **To suggest preventive measure, to prevent and avoids hazards and failure in existing plants and future projects.**



Nyala Power Station

Kassala Power Station Emission

Air pollution

الهواء تلوّث

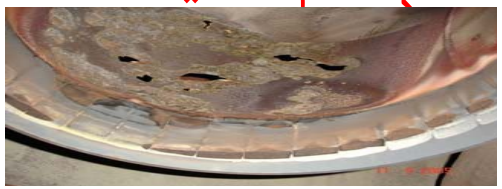
Water impurities شوائب المياه

- **Result in serious operating problems caused by:**
  - **Deposits formation**
  - **Corrosion of metals**
  - **Microbiological fouling and**

Gas turbine Garri Power Station

Hot corrosion in combustion system

التآكل الساخن في نظام الإحتراق بالتوربينة الغازية بمحطة توليد

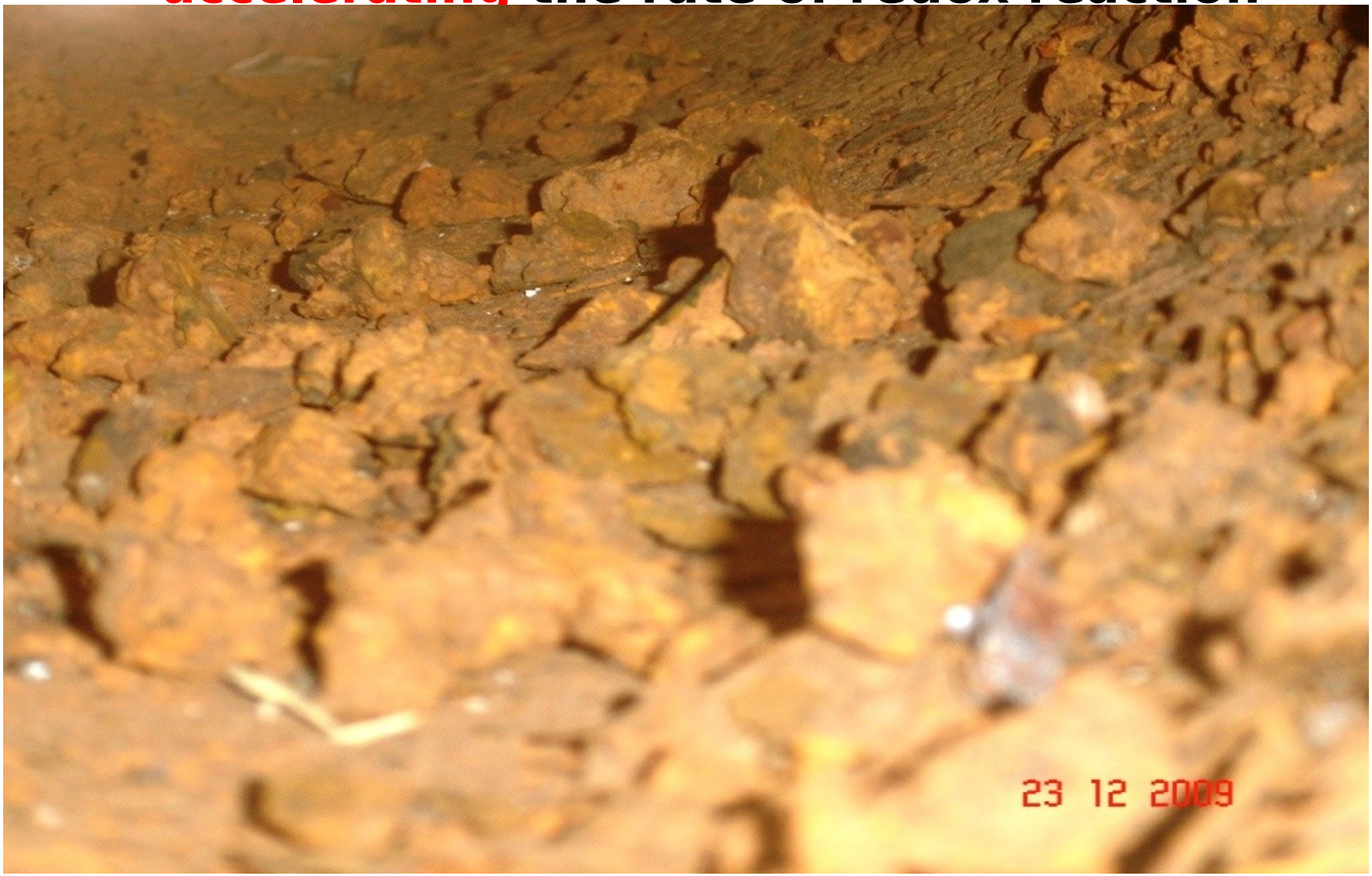






Microbiological corrosion

التآكل الميكروبيولوجي

Bacteria are able to facilitate corrosion kinetic by accelerating the rate of redox reaction



Dearator Remove oxygen before boiler

نظام نازع الأكسجين والهواء قبل الغلاية

- **passivation of iron-based metals, Formation of magnetite Fe_3O_4 and cuprous oxide (a more protective form of copper oxide)**

Kosti Power Station Projec
Cubes Tests Failure

إختبارات المكعبات لـ قواعد الغلاية
بمشروع محطة توليد كهرباء كوستي

- In this research you find problem of cube test Failure.

Description of Thermal power generating plant critical systems وصف الأنظمة الحرجة بمحطات التوليد الحراري

Within the water pre-treatment plant suspended solids shall be removed from the water

المعالجة الأوليّة للمياه يتم بتن قية وترسيب الشوائب والمواد الصلبة

Inorganic Coagulants

The most common are:

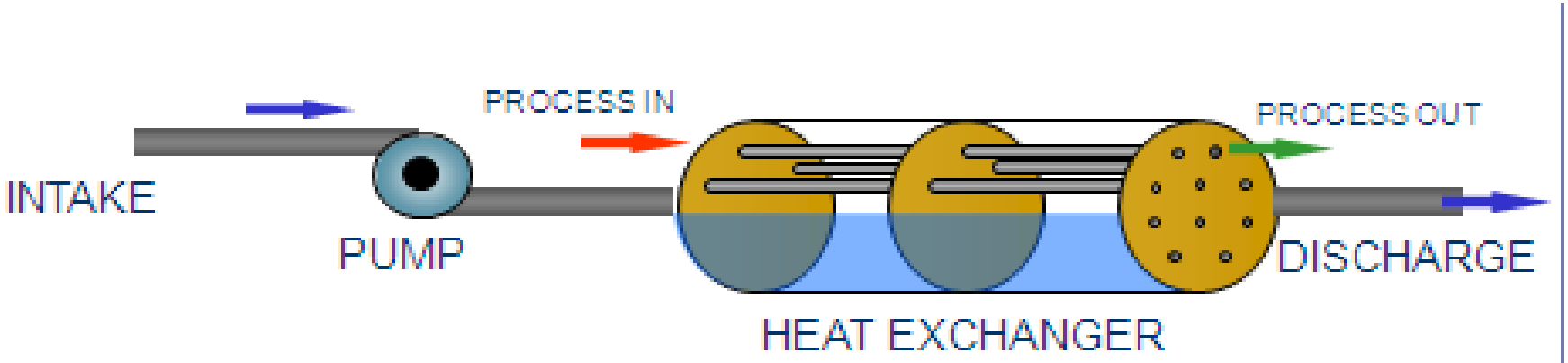
- **Alum-aluminum sulphate-$Al_2(SO_4)_3$**
- **Ferric sulphate-$Fe_2(SO_4)_3$**
- **Ferric chloride-$FeCl_3$**
- **Sodium aluminate-$Na_2Al_2O_4$**
- **Poly aluminum chloride PAC**

Internal and external corrosion deposits
Garri Power Station –Sudan

ترسبات نتيجة التآكل الداخلي والخارجي بأنابيب المياه المغذية لمحطة توليد قري

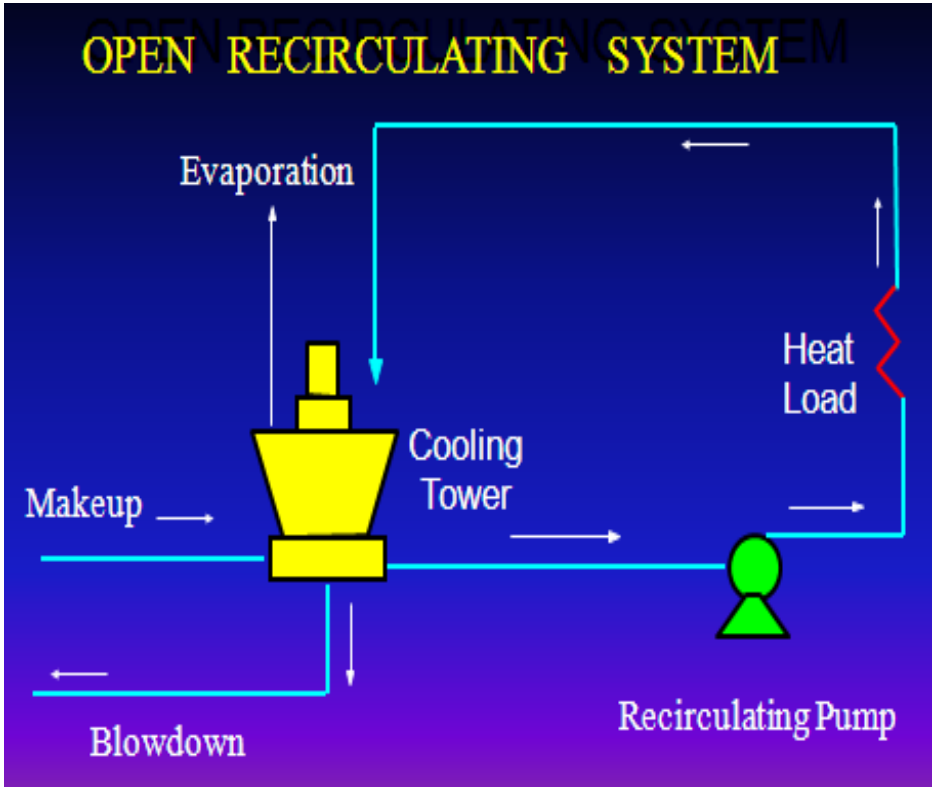
Cooling water systems أنظمة تبريد الماء

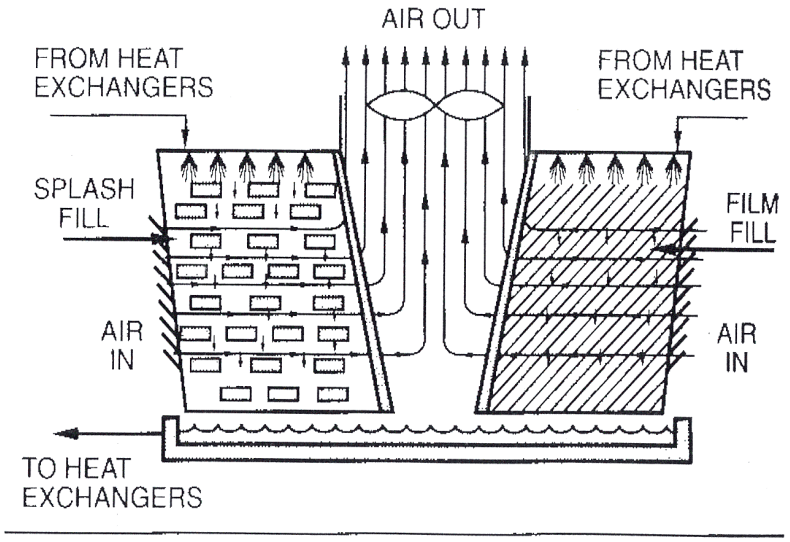
- **Three types:**
  - **Once-through**
  - **Open-recirculating**
  - **Closed**



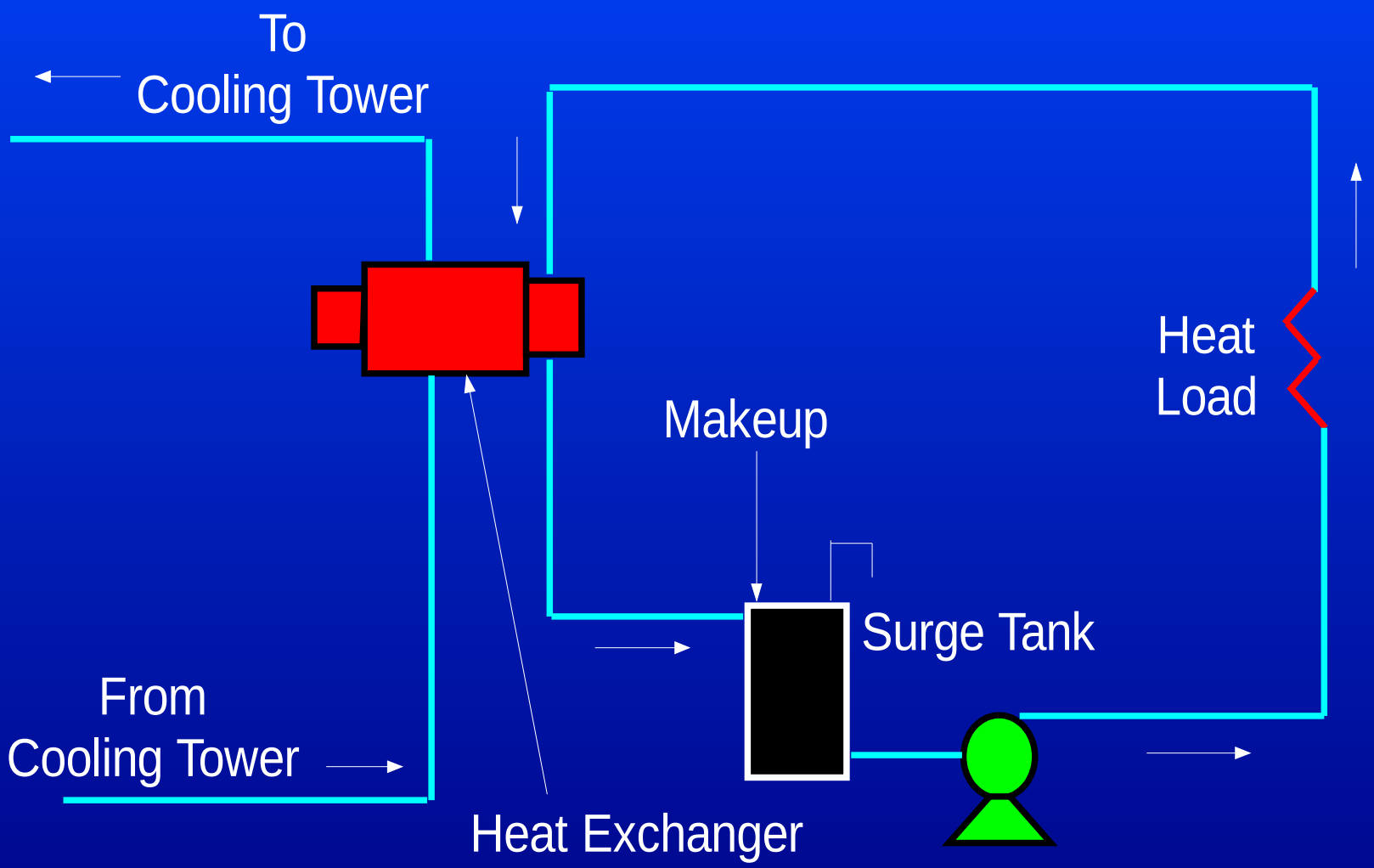
ONCE - THROUGH COOLING SYSTEMS

Open recirculating cooling w





CLOSED RECIRCULATING SYSTEM



Heat exchange mechanism

الحراري ميكانيكيذ

- **The water from heat exchanger (condenser, cooler) is considered to be a heat source while the cooled sink is taken to be the atmospheric air (the hottest body gives heat to the cold body)**

Treatment option Base Exchange softening

المعالجة باختيار طريقة المبادلات الأيونية كأساس لتنقية المياه

- Replace calcium and magnesium in water with non-hardness forming sodium by ion exchange columns regenerated by NaCl brine

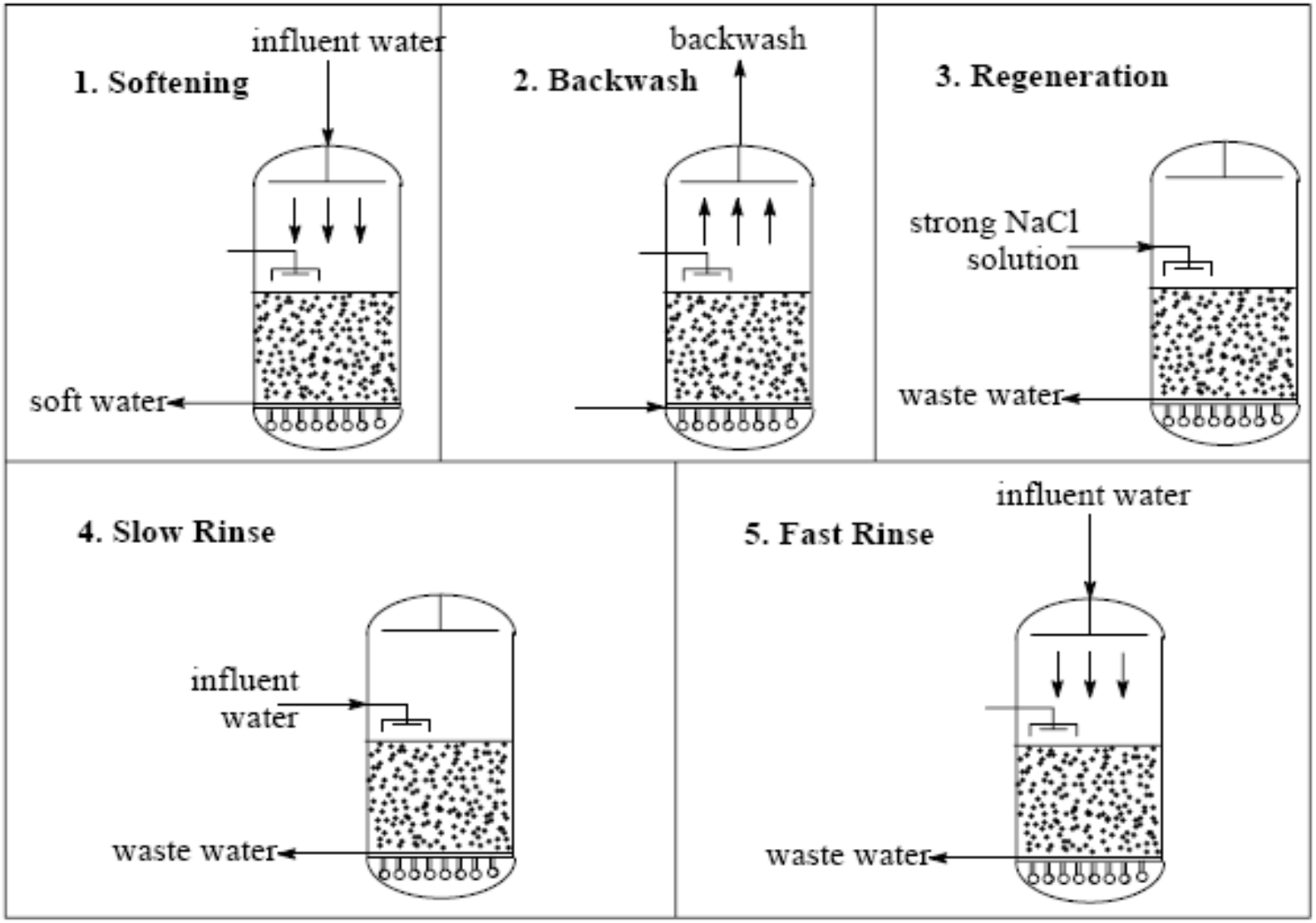
$(RSO_3)_xM^{x+} + xNa^+ \rightarrow xRSO_3Na^+ + M^{x+}$

Solid water solid water

- The M^{x+} cations (calcium, magnesium or iron) released are sent to waste during this cycle.
- When the hard water passes through the resin, the M^{x+} cations are exchange for Na^+ ions, and the water is softened.

$xRSO_3^-Na^+ + M^{x+} \rightarrow (RSO_3^-)_xM^{x+} + xNa^+$

Cation exchanger resin Sodium form

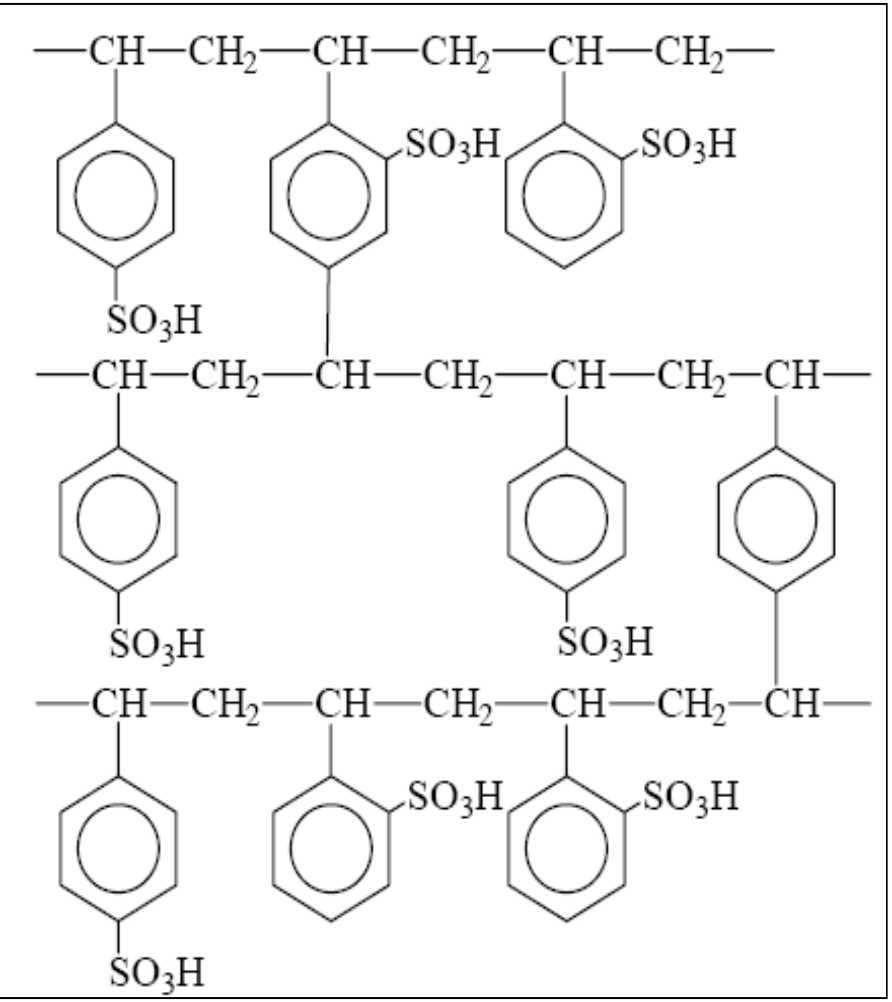


Water quality control (demineralized water process)

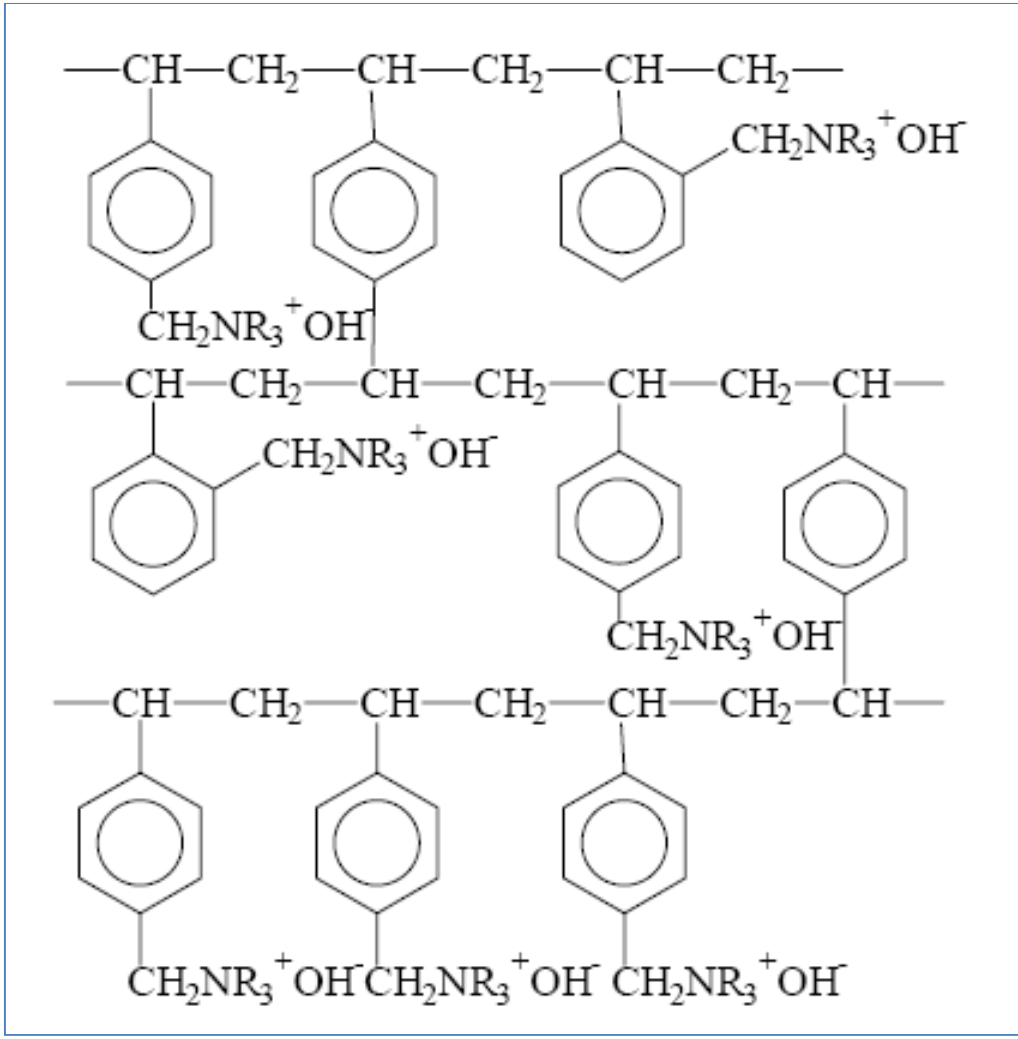
مراقبة جودة الماء (عملية نزع الأيونات والأملاح)

- Remove all hardness-forming ions together with other ions in solution by mixed bed ion exchange

Cationic and anionic Resins



A strongly acidic sulphonated polystyrene cation



A strongly basic quaternary ammonium anion exchanger

Demineralization process

Water Quality Control

Cat ion reaction

Service

$$\begin{matrix}Ca\\Mg\\2Na\end{matrix}\begin{matrix}CO_3\\SO_4\\2Cl\\SiO_3\end{matrix} + 2\,RSO_3H \longrightarrow 2\,RSO_3\begin{matrix}Ca\\Mg\\2Na\end{matrix} + \begin{matrix}H_2CO_3\\H_2SO_4\\2HCl\\H_2SiO_3\end{matrix}$$

Regeneration

$$2RSO_3\begin{matrix}Ca\\Mg\\2Na\end{matrix} + 2H^+\begin{matrix}Cl\\SO_4\end{matrix} \longrightarrow 2\,RSO_3H + \begin{matrix}Ca\\Mg\\2Na\end{matrix}\begin{matrix}2Cl^-\\SO_4\end{matrix}$$

Demineralization process

Water Quality Control

Anion reaction

Service

$$\begin{matrix} 2H_2CO_3 \\ H_2SO_4 \\ 2HCl \\ H_2SiO3 \end{matrix} + 2\,R_3NOH \longrightarrow 2\,R_3N \begin{matrix} CO_3 \\ SO_4 \\ 2Cl \\ SiO_3 \end{matrix} + H_2O$$

Regeneration

$$2R_3N \begin{matrix} CO_3 \\ SO_4 \\ 2Cl \\ SiO_3 \end{matrix} + NaOH \longrightarrow 2\,R_3NOH + 2Na \begin{matrix} CO3 \\ SO4 \\ 2Cl \\ SiO3 \end{matrix}$$

Hazards Involved both thermal and hydro power generation plants المخاطر المتو قعة في محطات التوليد الحراري والمائي

- **Hazard defined as the source or situation with a potential for harm in terms of human injury or ill health, damage to property, damage to the workplace environment, or a combination of these.**

A condition or practice with the potential for accidental loss.

Hazard Unsafe Condition

Safety السلامة

Safety is the measure of the relative freedom from risk or danger.

- Safety is the degree of freedom risks and hazards in any environment – home, office factory, power station, school, or anywhere else.

Safety is control of incidental loss. Or, control of accidental losses to an acceptable level

Water Steam cycle control program mainly used two types

برنامج مرا قبة دورة الماء والبخارباستخدام نوعين من المعالجة

1. All volatile treatment (AVT) used ammonia for adjust pH and hydrazine for oxygen scavenger.
2. Phosphate treatment used Tri - sodium phosphate for adjust pH and hydrazine for oxygen scavenger

1- Pre-Boiler : Control by volatile treatment program

Control Point	Parameter	Standard
1.Condensate Pump Discharge 2.Dearator	pH	8.50 – 9.00
	Conductivity (µS/cm)	<5
	Dissolved Oxygen (ppb)	<7
	Silica (ppb as SiO_2)	<20
	Total Hardness (ppm as $CaCO_3$)	0

2- Boiler : Control by Non-Volatile Treatment program

Control Point	Parameter	Standard
1.Steam Drum	pH	9.60 – 10.30
2.Water Drum	Conductivity (µS/cm)	<100
	Phosphate (ppm)	3 - 10
	Silica(ppb as SiO_2)	<2,000
	Total Hardness (ppm as $CaCO_3$)	0

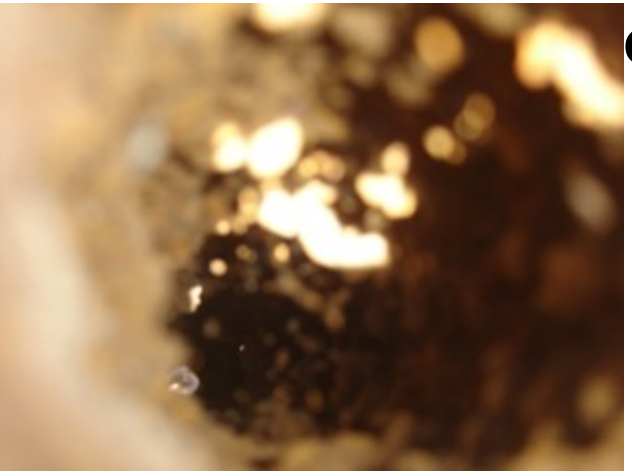
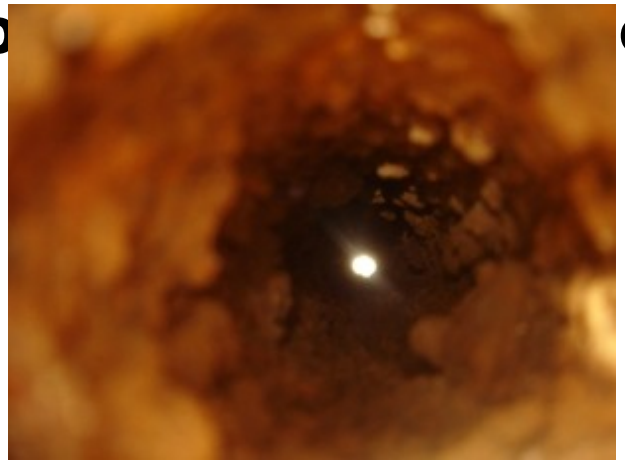
Corrosion التآكل

- **Corrosion is the destruction of a metal by chemical or electrochemical reaction with its environment.**
- **Corrosion means the breaking down of essential properties in a material due to chemical reactions with its surroundings.**
- **A loss of electrons of metals reacting with water and oxygen.**
- **Corrosion removes metal that cannot be replaced**
- **Most failures in oil and gas well systems are due**



Microbial corrosion التآكل الميكروبي

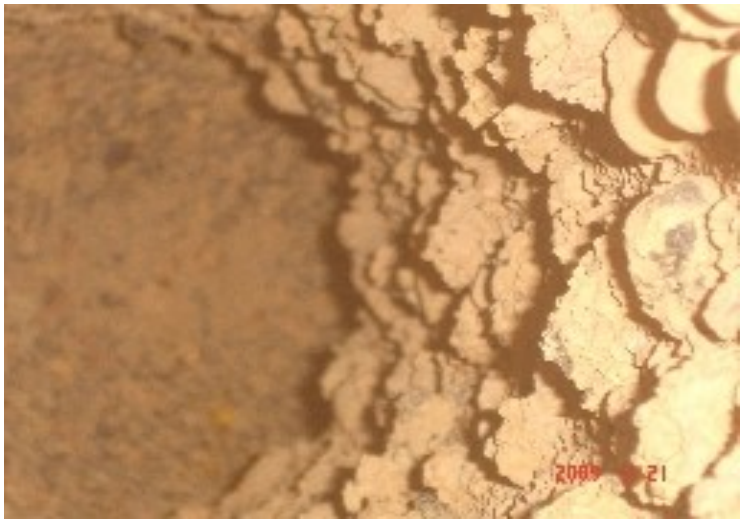
- **Microbial corrosion**
  - **Sulphate-reducing bacteria are common in lack of oxygen**
  - **Microbiologically influenced corrosion (MIC)**
- **Bacteria classification**
  - **Aerobic bacteria: it require Oxygen to grow**
  - **Anaerobic bacteria: grow in absent of Oxygen**
  - **Facultative Bacteria: grow either the o er**

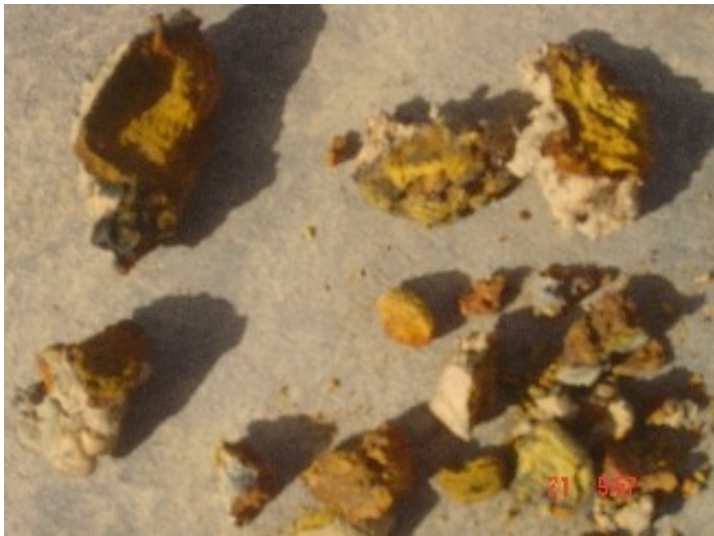




Effects of iron reducing bacteria (IRB)

تأثيرات البكتيريا مختزلة الحديد

- Clogged and corroded piping .
- Increased chances of sulphate reducing bacteria infestation – MIC .
- Unpleasant odors and taste.
- Increased organic .
- Severe damage to pumping equipment.
- Seriously impacts water treatment.
- Reduces distribution





Contaminants of Fuel specification ملوّثات مواصفات الو قود

- **The contaminants cause damage or fouling in the fuel system and result in poor combustion.**
- **The hot corrosion mechanism is not fully understood. It is believed that the deposition of alkali sulphates (Na_2SO_4) on the blade reduces the protective oxide**

Examples of chemical reactions in combustion process

أمثلة لتفاعلات كيميائية في عملية الإحتراق

$CH_4 + O_2 \rightarrow CO + 2\ H_2O$

$C_2H_6 + 1.5\ O_2 \rightarrow 2\ CO + 3\ H_2O$

$C_3H_8 + 3.5\ O_2 \rightarrow 3\ CO + 4\ H_2O$

$i\text{-}C_4H_{10} + 4.5\ O_2 \rightarrow 4\ CO + 5\ H_2O$

$n\text{-}C_4H_{10} + 4.5\ O_2 \rightarrow 4\ CO + 5\ H_2O$

$i\text{-}C_5H_{12} + 5.5\ O_2 \rightarrow 5\ CO + 6\ H_2O$

$n\text{-}C_5H_{12} + 5.5\ O_2 \rightarrow 5\ CO +$

Example using butane مثال بإستخدام و قود البيوتان

- **Ideal Chemical Equation**:

  $C_4H_{10} + 6.5\ O_2 \rightarrow 4CO_2 + 5H_2O$

- **Practical Chemical Equation:**
- **Air used as oxidizer, not pure oxygen**

$C_4H_{10} + 6.5(O_2+3.76N_2) \rightarrow 4CO_2 + 5H_2O+24.44N_2$

$C_4H_{10} + 31.03D.A. \rightarrow 4CO_2 + 5H_2O+ 31.03D.A - 6.5O_2$

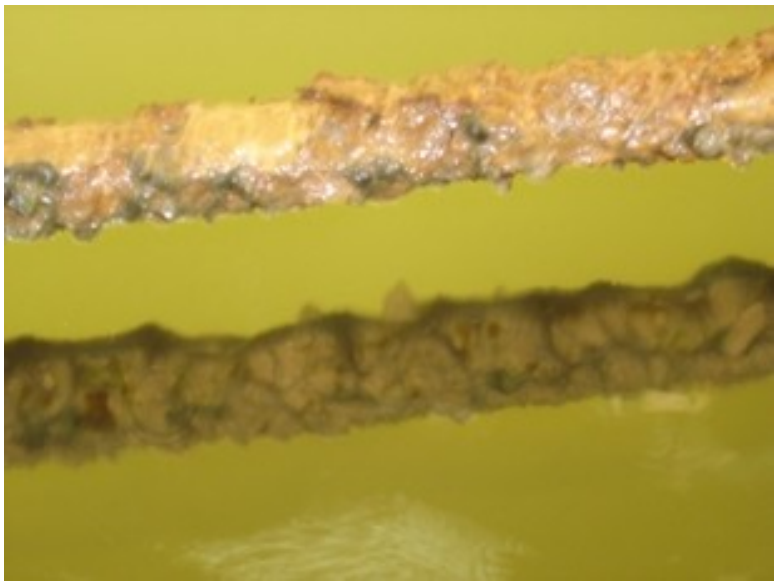
Balancing Made Easy

$C_4H_8 + a(O_2+3.76N_2) \rightarrow bCO_2 + CH_2O + dN_2$

Circulating cooling system and condenser problems

مشاكل دورة مياه التبريد والمكثّف بمحطة قري

- **Deposition depends upon**
  - **Quality of makeup water**
  - **Treating chemicals used**
  - **Amount of concentration allowed**
  - **The degree of overheating**



Deposit Classification

الشهيد تصنيف الترس

- **Scales**
  - Formed when solubility of material is exceeded
  - Inorganic, crystalline deposit on metal surface
  - Occur in boilers as a result of inadequate water treatment

Sludge الترسبات الغيرمتحجرة

- **Sludge**
  - **Desired form of hardness precipitates**
  - **Removed by blow down**
  - **Metal Oxides**
  - **The result of corrosion**
  - **Can be transported and deposited elsewhere**
  - **Undesirable in boilers;**

Metal oxides بمختلف الأنظمة

Organics and CO_2

- Frequently a portion of deposits
- From process

Dissolving of emitted ammonia into water

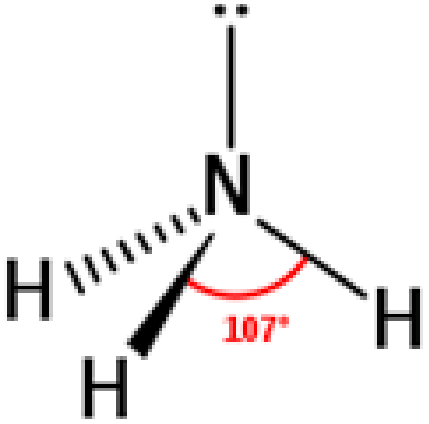
- Emissions into water from the production plant during normal operation can thus be fully avoided

$NH_4^+ + H_2O \rightleftharpoons NH_3 +$

$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$K_a = [NH_4^+][OH^-]$



Ammonia lone electron pair.

Water and Soil Pollution

الماء وتلوّث التربة

Methyl Mercury dumping +
Agriculture e.g. Fertilizers (oxygen using wastes, radioactive material, sediments and inorganic chemicals) Acid rain

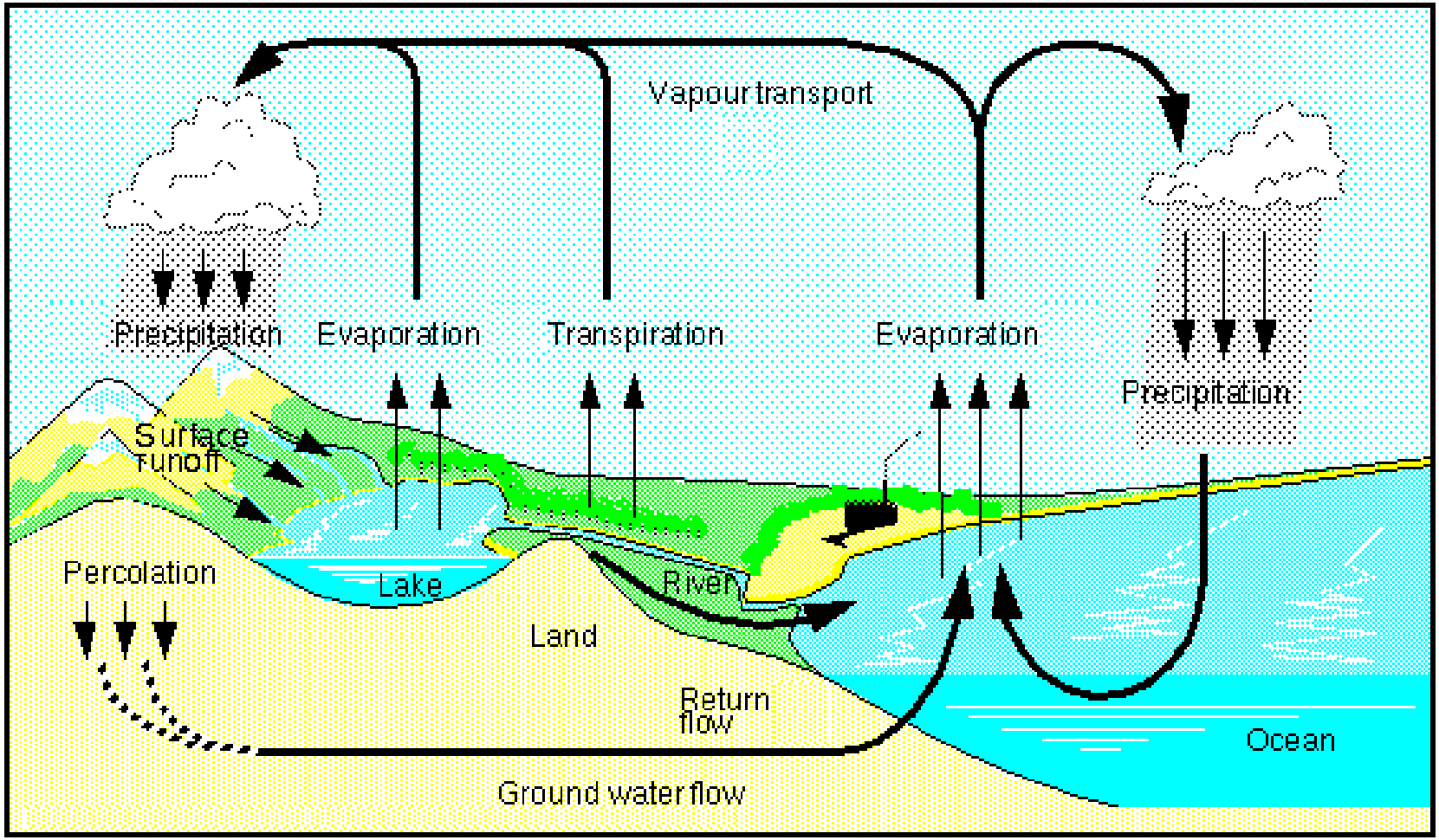
Soil affects to Corrosion

تأثيرات التربة والتآكل

- Soil moisture content;
- Soil pH;
- Soil sulphides level;
- Soil resistively
- Structure to soil potential;
- Influence of nearby underground metal structures (e.g., piping);
- Existence of stray electric current;
- Existing corrosion-protection measures (e.g., coating, cathodic protection).

(Soil resistivity is a function of soil moisture and the concentrations of ionic soluble salts and is considered to be most comprehensive indicator of a soil's corrosively)

GROUND WATER featuring



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

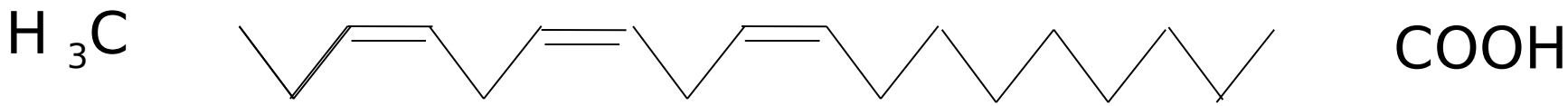
Khanom Electricity Generating Company Thailand

- **Khanom VISION** To be a good citizen company with commitment to safety as well as society and environment- friendly operations

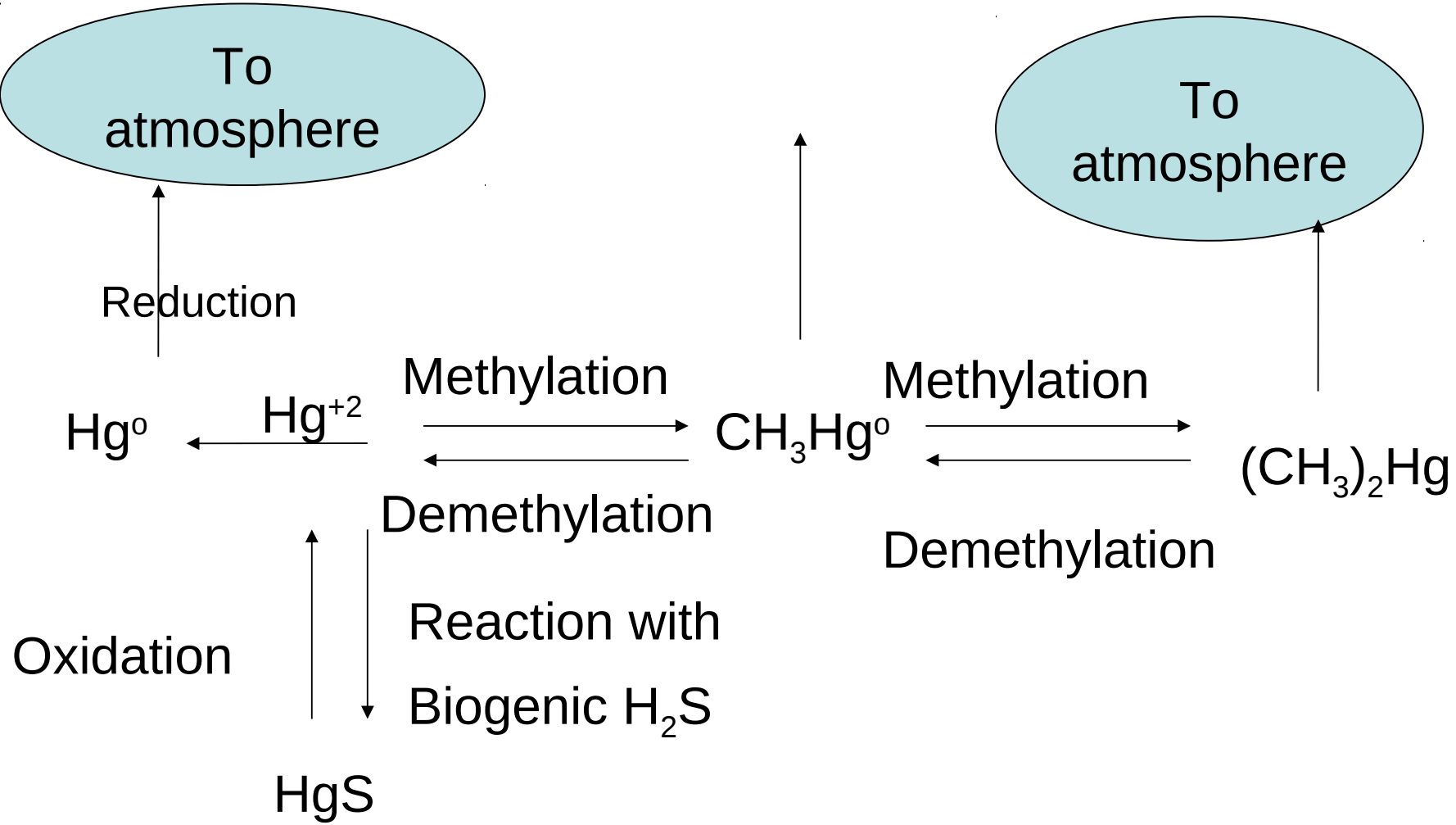
Chemical hazards مخاطر الكيماويات

- **Eating fish is an important part of our diet, unfortunately as a society we are polluting this important resource via mercury laden emissions.**
- **Omega-3 Polyunsaturated Fatty Acids**

•Alpha-linolenic acid (ALA; 18:3n-3)

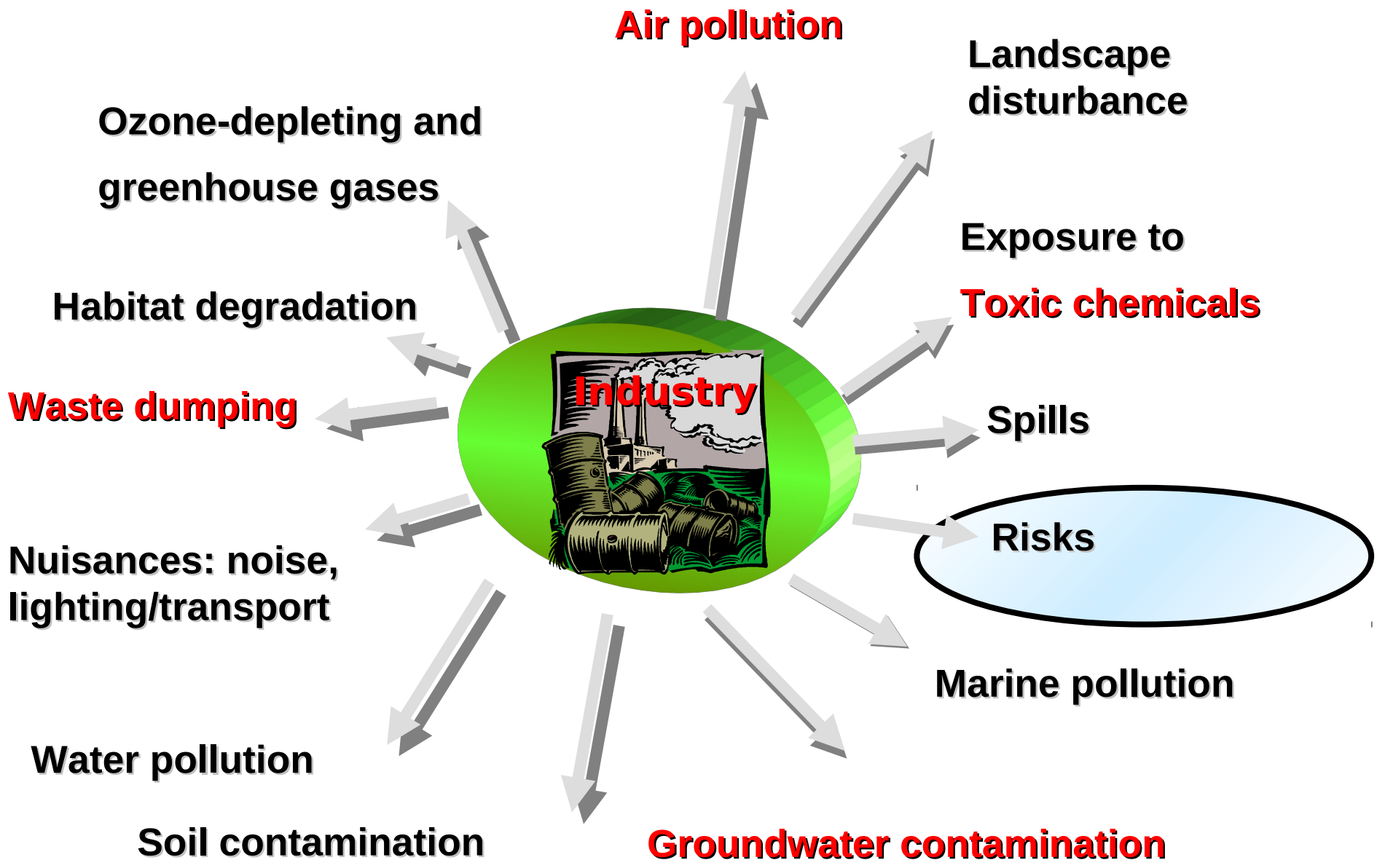


Bioaccumulation in food chain



Industries and Environment

الصناعات والبيئة



Equipment that problem occurred

Corrosion and scale formation

- **Corrosion occur when metal loss electron to environment**

  $Fe \rightarrow Fe^{2+} + 2e$

- **Water will dissociate**

  $H_2O \rightarrow 2H^{+} + 0H^{-}$

- **Ferrous ion reacts with hydroxyl ion**

  $Fe^{2+} + 2\ 0H^{-} \rightarrow Fe(OH)_2$

- **Hydrogen atom receive electron and change to hydrogen gas**

  $2H^{+} + 2e \rightarrow H_2$

- **Combine all reaction**

  $Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$

- **In high temp. Zone**

  $3\ Fe(OH)_2 \rightarrow Fe_3O_4 + H_2O + H_2$

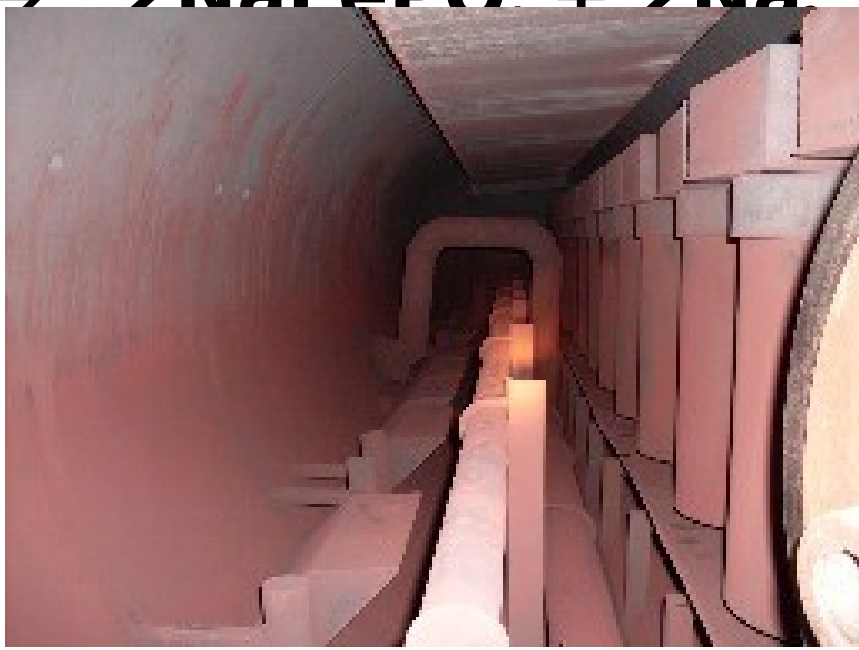
Boiler high pressure dosing

جرعات الضغط العالي بالغلاية

- **Alkali solution condition from phosphate solution that used for control boiler water**

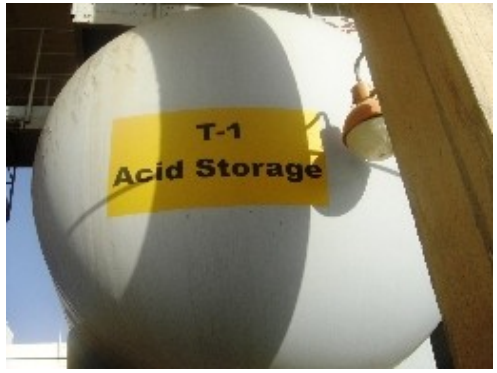
$$Na_3(PO)_4 + H_2O \rightarrow Na_2HPO_4 + NaOH$$

$$4Na_2HPO_4 + 2Fe + O_2 \rightarrow 2NaFePO_4 + 2Na$$



Environmental Impacts of Liquid Wastes

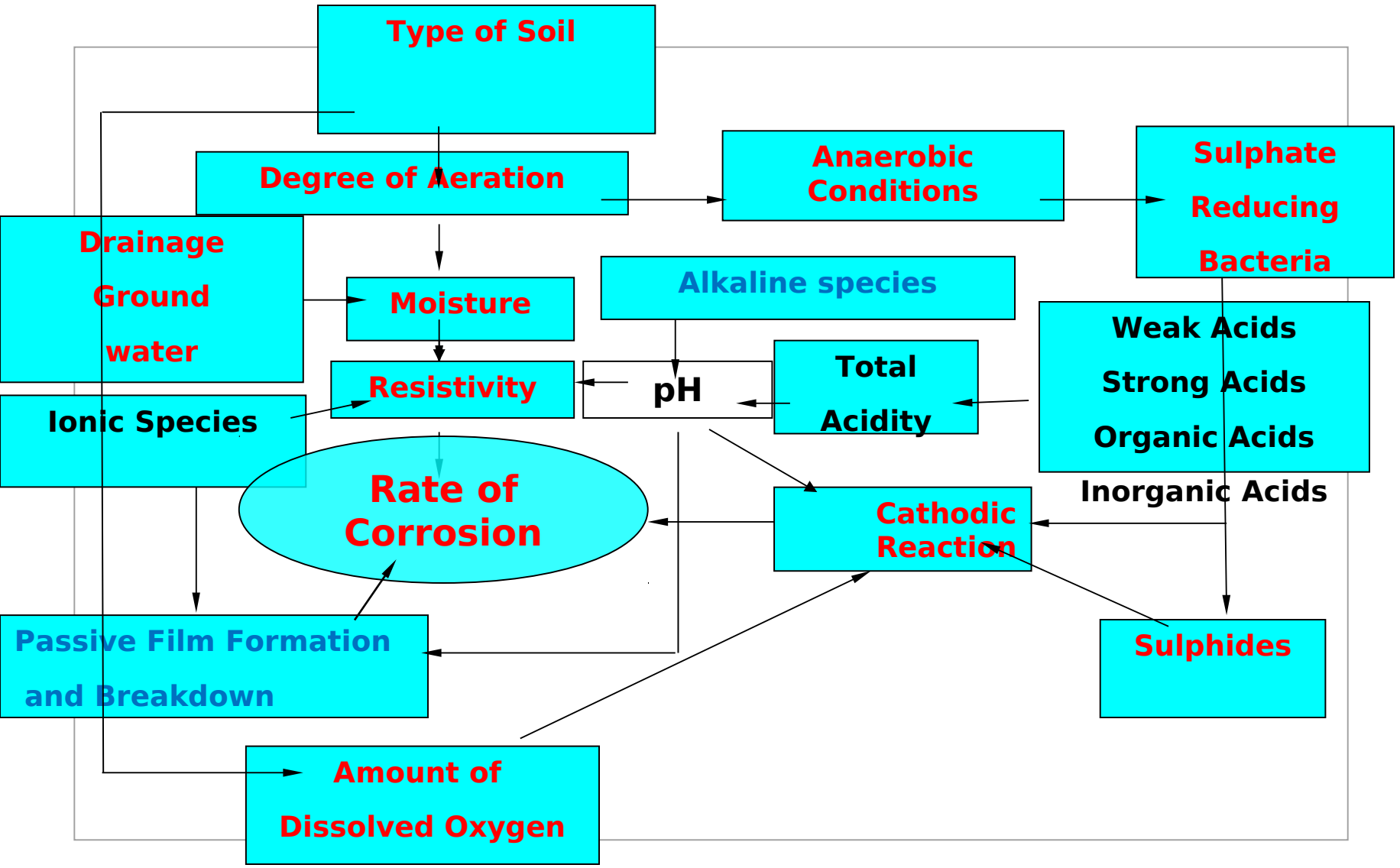
- In general the impacts are: **Lack of oxygen**, affects all livings.
- **Toxicity**, affects human beings and other livings.
- **Fires and Explosions** (due to presence of hydrocarbons)
- **Color and turbidity**, affects health natural water.
- **Temperature affects** water livings and reduces dissolved oxygen



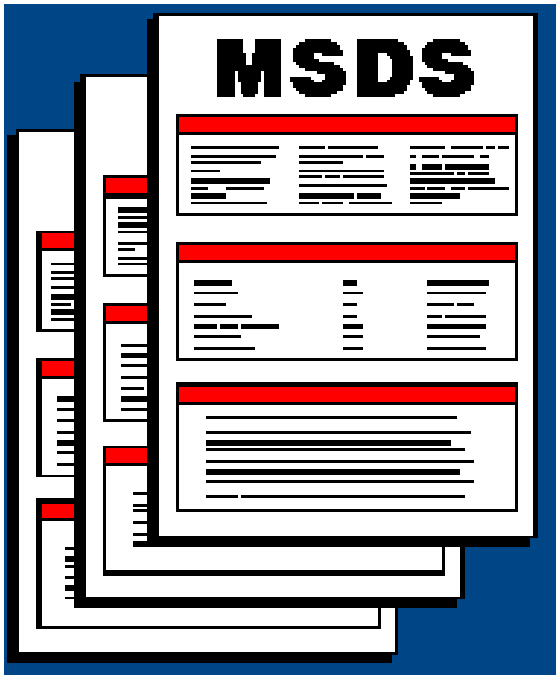
Hydro power stations problems

- Erosion-corrosion, cavitations ,coating Hazards and microbiological corrosion

Rate of corrosion معدل التآكل



Material Safety Data Sheets will tell you the following basic information نشرة بيانات السلامة للمادة

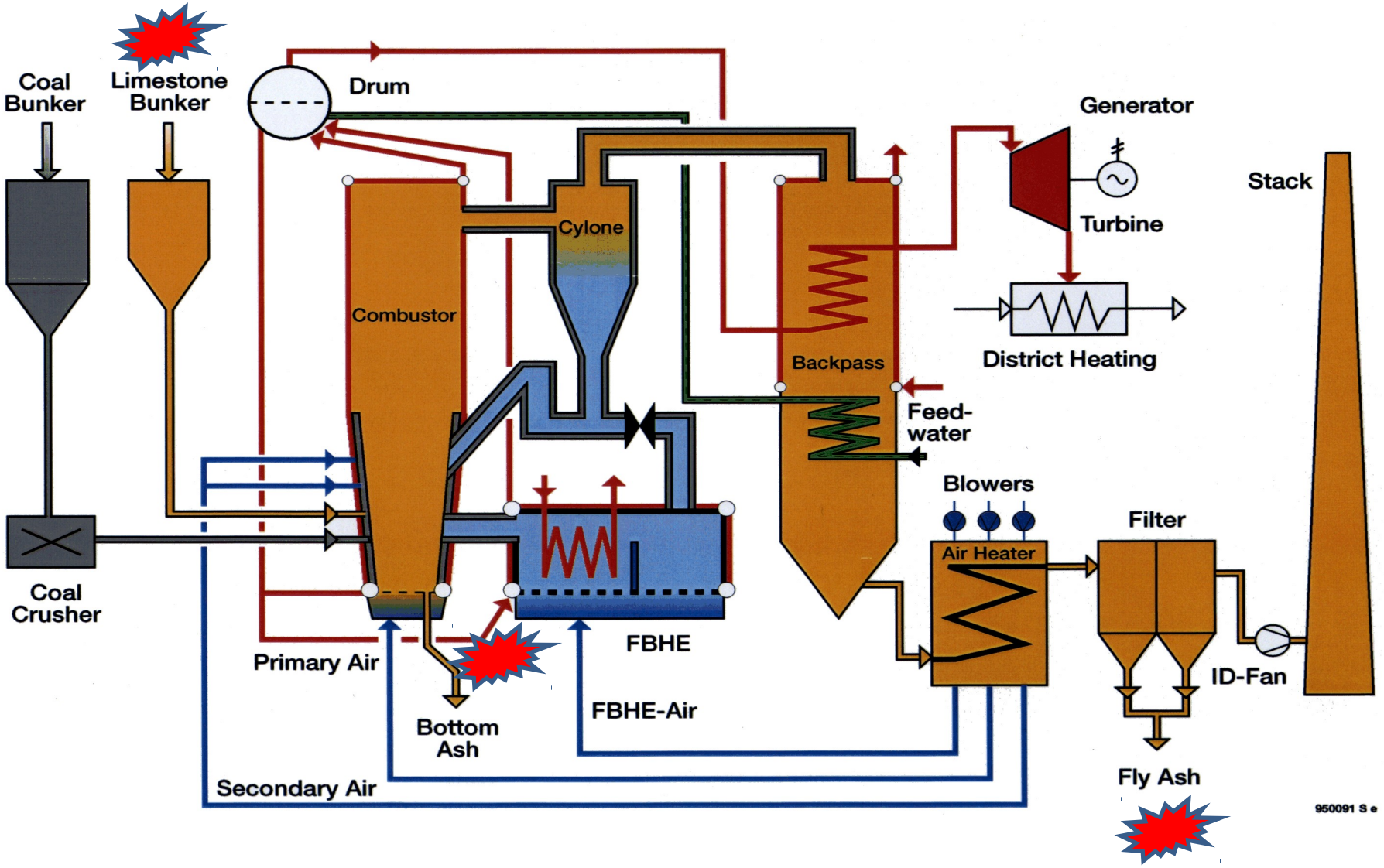


i. **What** it is
ii. **Who** makes it and their address?
iii. **Why** it is hazardous?

iv. **Its** physical and chemical characteristic.
v. **How** to safely handle it?
vi. **What** condition would increase its hazard.
vii. **How** it could affect your health.
viii. **What** personal Protective Equipment to use when handling it.

Petroleum Sponge coke Circulating Fluidized Bed Garri power plant Combustion

دورة الإحتراق بمحطة الفحم البترولي الإسفنجي قري

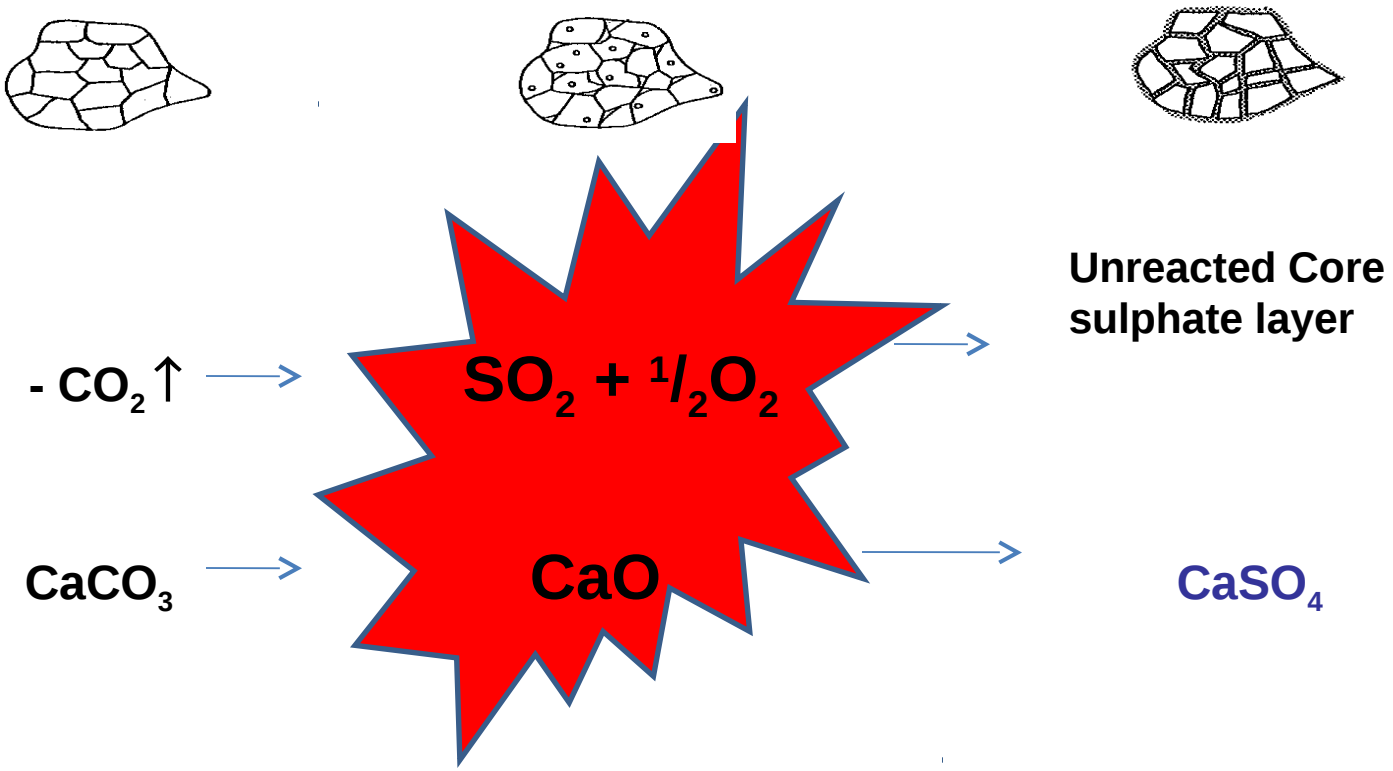


Chemical Reactions of Flue Gas Desulphurization (FGD)

1.1 $CaCO_3 \rightarrow CaO + CO_2\uparrow$ $\Delta H =$ +178 kJ/mol

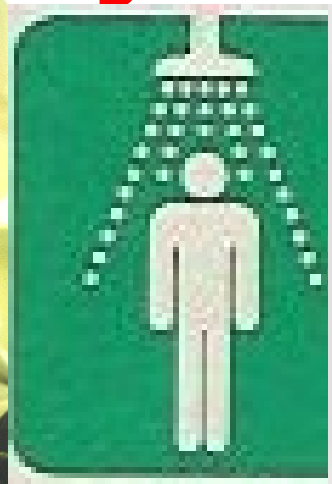
1.2 $CaO + SO_2 + {}^1/_2O_2 \rightarrow CaSO_4$ $\Delta H =$ -500 kJ/mol

2. Physical Effects

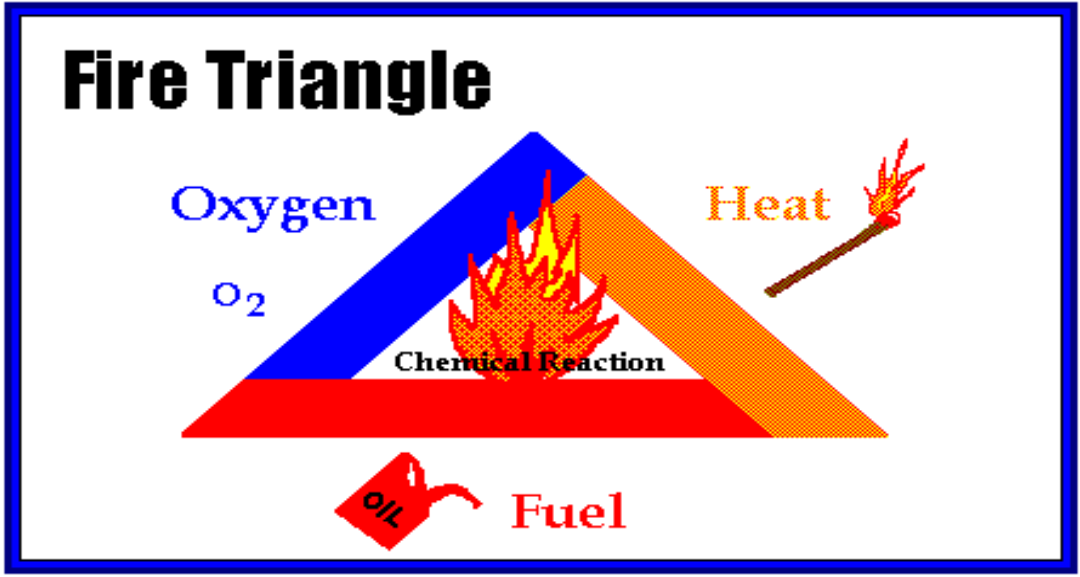


Hazard Communication Standard: (HCS)

- **EMERGENCY AND FIRST AID PROCEDURES**
- **Your health and safety depend on your understanding of the information on the specific hazard communication.**
- **ving Hazardous**



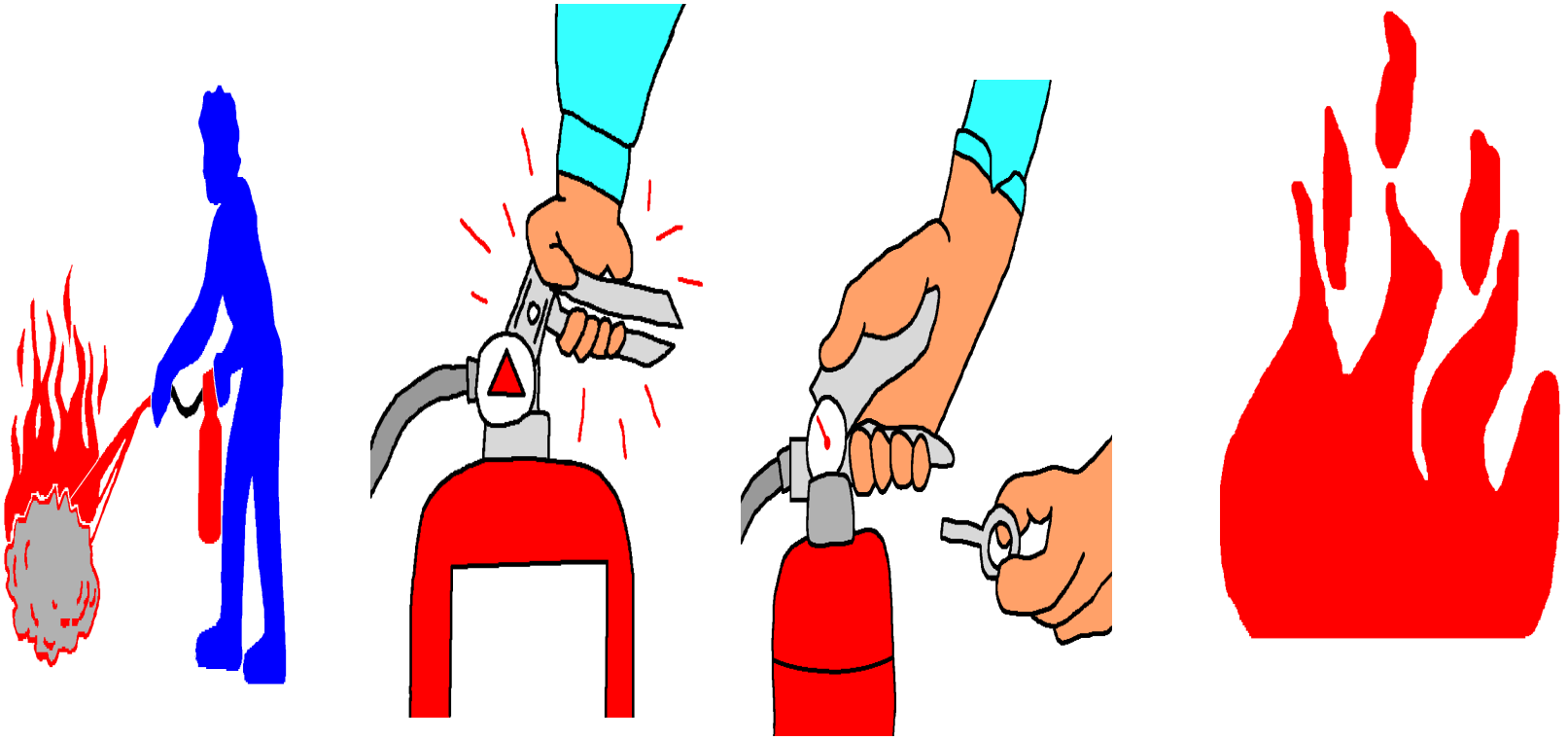
LPG Component (v %



- **METHANE , ETHANE 1.39**
- **PROPANE 6.41**
- **PROPENE 30.27**
- **ISO-BUTANE 16.02**
- **NORMAL-BUTANE 4.31**
- **NORMAL-BUTENE -1 8.91**

Complete flare explosion

How to Use a Fire extinguisher



NFPA Color codes

Health

- 4 - Severe
- 3 - Serious
- 2 - Moderate
- 1 - Slight
- 0 - None

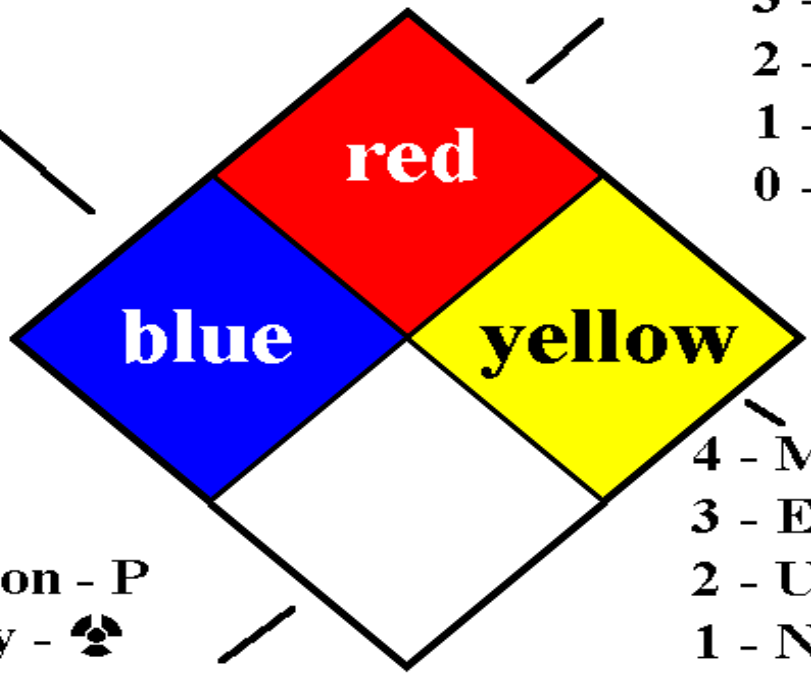
Special Hazards

- ACID
- ALK
- COR
- OXY

Polymerization - P

Radioactivity - ☢

Use No Water - W



Flammability

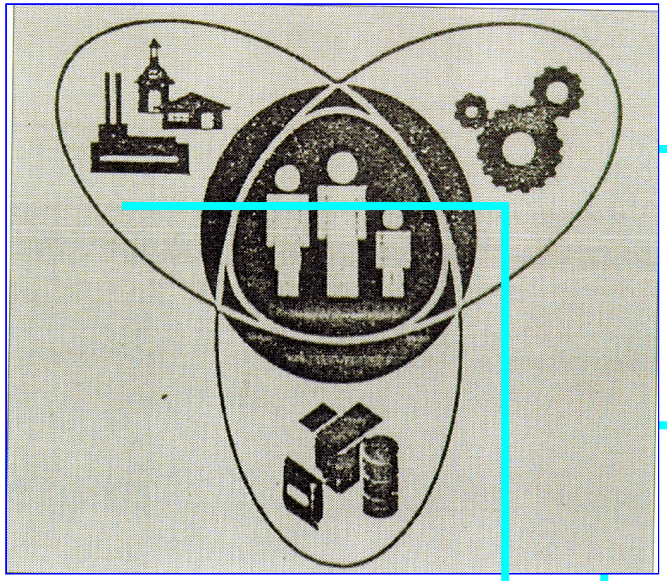
Flash Points

- 4 - <73°F
- 3 -<100°F
- 2 -<200°F
- 1 ->200°F
- 0 - Will not burn

Reactivity

- 4 - May Detonate
- 3 - Explosive
- 2 - Unstable
- 1 - Normally Stable
- 0 - Stable

Johnson's theory



JOHNSON'S THEORY

Sources - Causes - Controls

People

Equipment

Materials

Environmen

Type of Corrosion أنواع التآكل

Corrosion cells may occur at:

- **Points where dissimilar metals connect.**
- **Points of internal stress.**
- **Places where there are differences in oxygen concentration.**
- **Places where there are differences in corroded ion concentration.**
- **On either side of the bending axis on pieces of bent metal.**
- **Stresses from the manufacturing process, or even wrench marks.**
- **Places where there are dings, scratches, stress, or other imperfections have disrupted the uniformity of the metal**

Certain factors accelerate the corrosion process

بعض العوامل لتسريع عملية التفاعل التآكلي

These factors include,

(1) the pH of the water

(2) The presence of dissolved

(3) acid gases (CO_2, H_2S)

(4) Dissolved oxygen (O_2)

(5) Dissolved solids

(6) Suspended solids

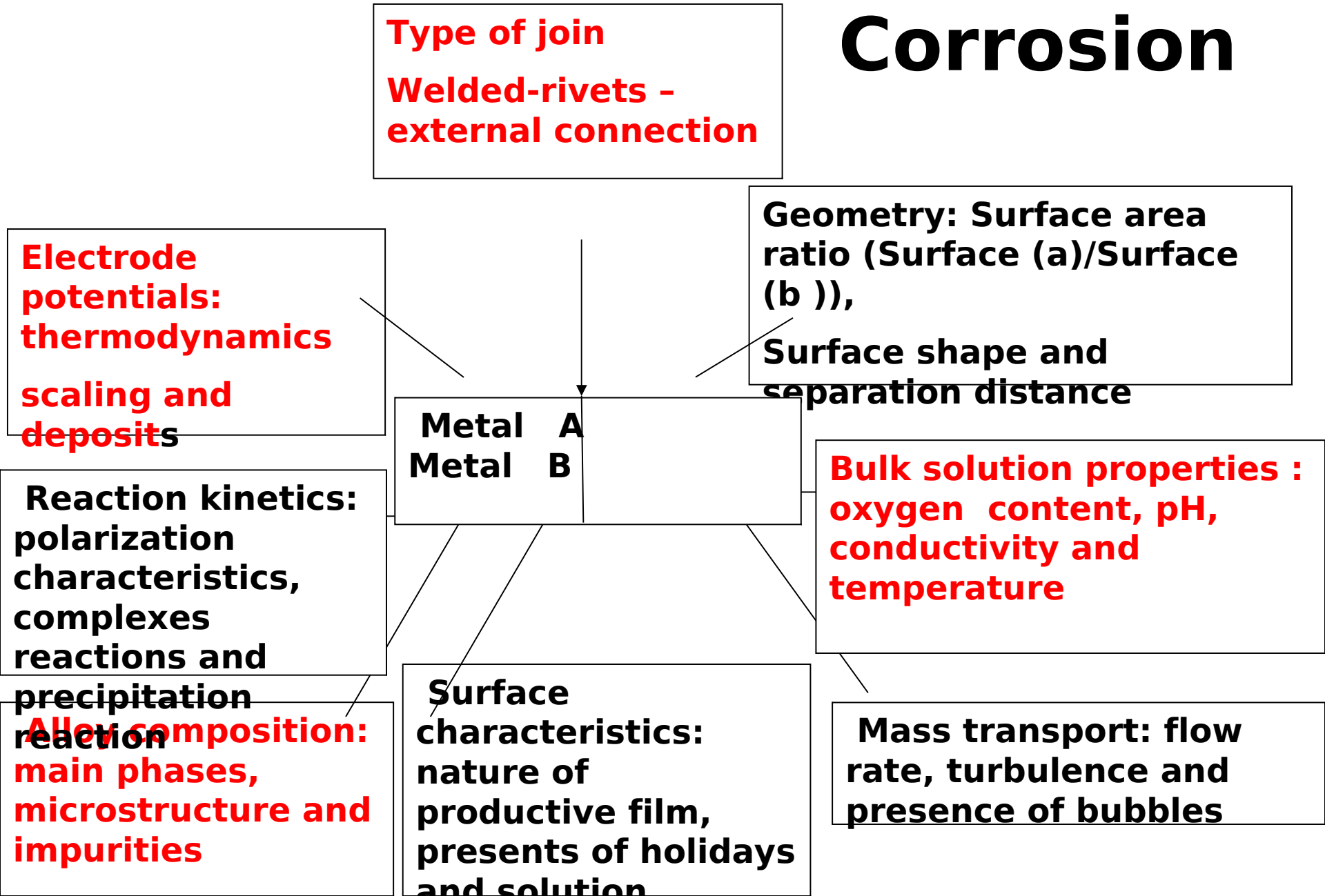
(7) Temperature (affects solubility)

(8) Pressure (affects solubility)

(9) Velocity of fluid through flow lines

(10) Metallurgy (type of metal)

Galvanic Corrosion



Langelier's Saturation Index (LSI or Saturation index) and the Ryznar Stability Index (RSI or Stability index)

- **LSI = pH - pHs**
- **RSI = 2pHs - pH**
  - **This results from the fact that both methods are based upon the saturation of calcium carbonate.**
  - **Indices should be used as scaling rather than**

Interpretation of the Ryznar Stability Index (Carrier, 1965)

Indication	RSI Index Value
Heavy scale	4.0 - 5.0
Light scale	5.0 - 6.0
Little scale or corrosion	6.0 - 7.0
Corrosion significant	7.0 - 7.5
Heavy corrosion	7.5 - 9.0
Corrosion intolerable	> 9.0

(**Langelier's Index** Actual pH - pH_s

Interpretation

+ The tendency is for calcium carbonate to precipitate. Therefore, the water is scale forming.

- The tendency is for calcium carbonate to dissolve. Therefore, the water is corrosive.

0 The tendency is for calcium carbonate to neither precipitate not dissolve. Therefore, the water is neither scale forming nor corrosive.

Calculation of the value for pHs can be done using the monographs found in various references

(Edstrom, 1998) $pHs = (9.3 + A + B) - (C + D)$

Where:

TDS in ppm	$A = (\log(TDS) - 1)/10$
Temperature in ^oC	$B = (-13.12 \log(^oC + 273)) + 34.55$
Ca hardness in ppm (as $CaCO_3$)	$C = (\log(\text{calcium hardness}) - 0.4)$
M. Alk in ppm as ($CaCO_3$)	$D = \log(\text{M. alkalinity})$

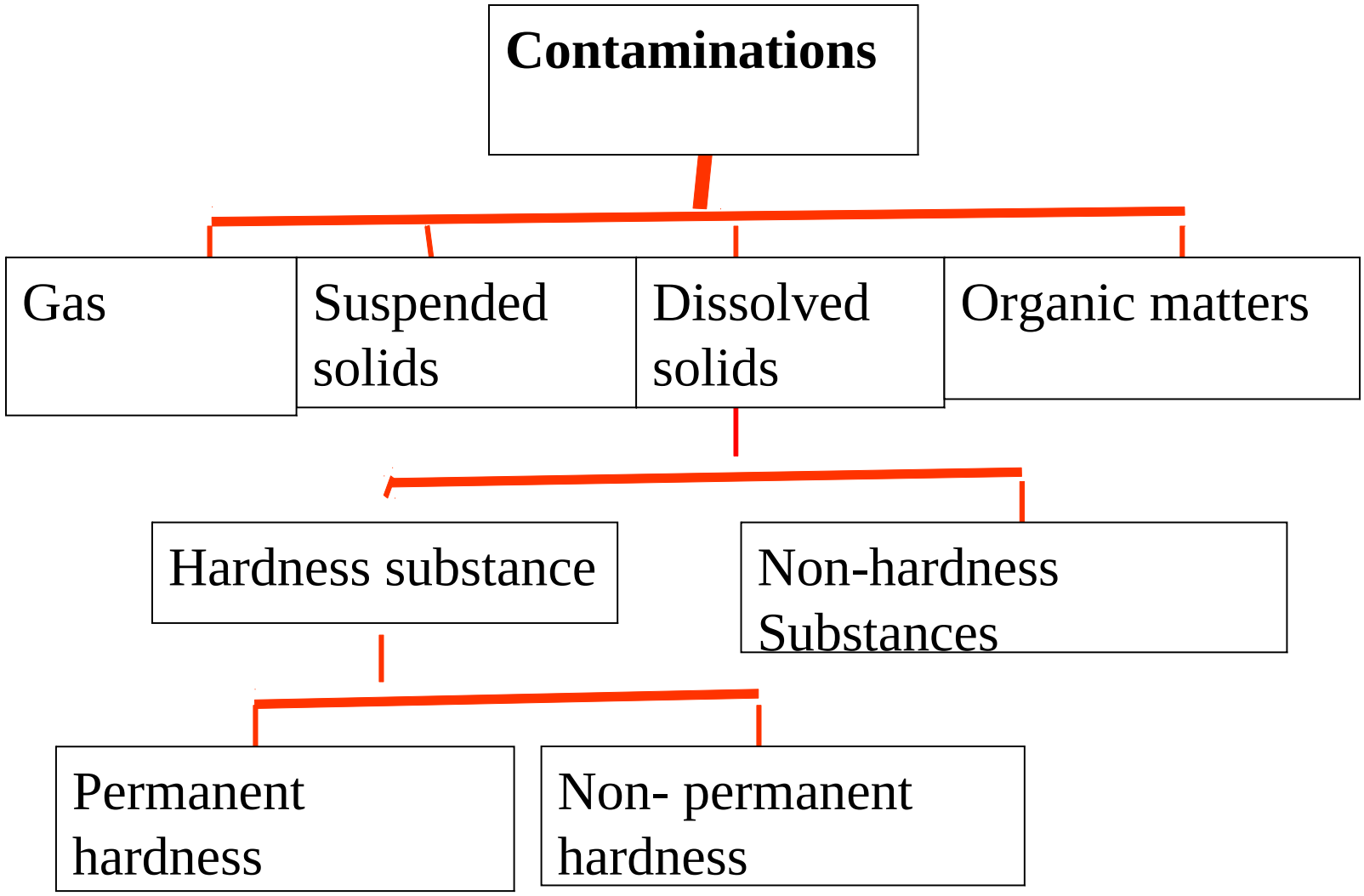
Corrosion by Sulphate Reducing Bacteria (SRB)

- **In order for this reduction to occur, four components must be present:**
  1. **Sulphate reducing bacteria (SRB).**
  2. **Sulphate (SO_4^{-2})**
  3. **An external energy source in the form of free electrons.**
  4. **The temperature of the water must be less than approximately not**

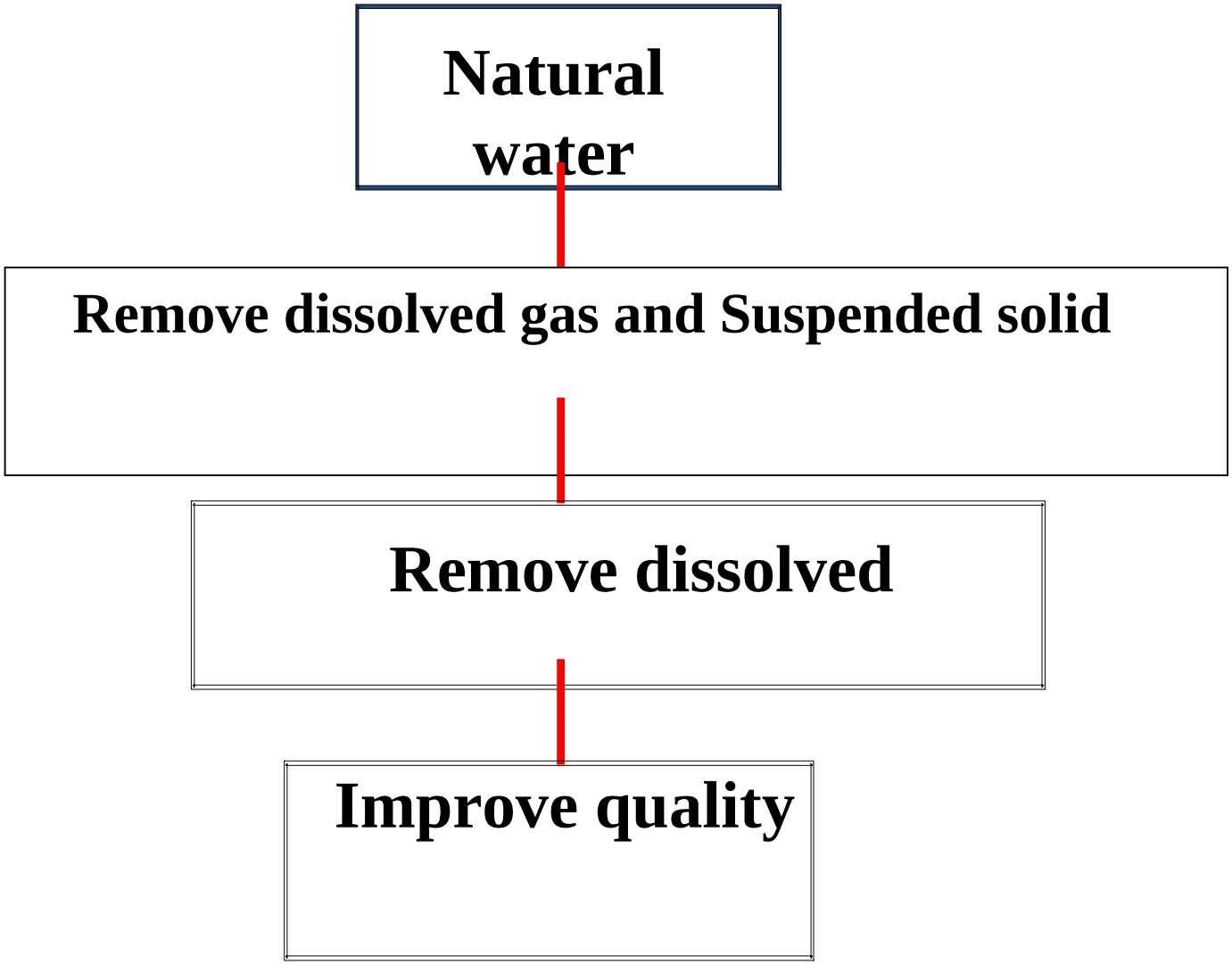
Anaerobic condition

$$4Fe + 4H_2O + SO_4^{-2} \rightarrow FeS + 3Fe(OH)_2 + 2OH^-$$

Composition of contaminant in natural waters



Water Treatment



Sodium Hypochlorite Generator

- **Sodium hypochlorite (NaClO) is a kind of strong oxidant, it cannot only kill bacteria effectively but also restrain algae and microbe grow.**
- **Ionization reaction: $NaCl \rightarrow Na^+ + Cl^-$**

  $H_2O \rightarrow H^+ + OH^-$
- **Electrochemical reaction:**

  Anode $2Cl^- - 2e^- \rightarrow Cl_2\uparrow$

  Cathode $2H^+ + 2e^- \rightarrow H_2\uparrow$
- **Chemical reaction in solution: $Na^+ + OH^- \rightarrow NaOH$**

  $2NaOH+Cl_2 \rightarrow NaClO + NaCl +$

Solution to Boiler and Cooling water problems

- **The desired boiler sludge are form by the following reactions:**

$10Ca^{+2} + 6PO_4^{-3} + 2OH^- \rightarrow 3Ca_3(PO_4)_2.Ca(OH)_2$ (calcium hydroxyapatite)

$3Mg^{+2} + 2SiO_3^{-2} + 2OH^- + 2H_2O \rightarrow 2MgSiO_3Mg(OH)_2.H_2O$ (serpentine).

Both calcium hydroxyapatite and serpentine are relatively nonadherent to boiler metals and easily to remove by manual blowdown.

Boiler tube Failure عطل أنبوب الغلاية

- Sodium sulphite has been used as an oxygen scavenger to form sodium sulphate by the following reaction:

$2\ Na_2SO_3 + O_2 \rightarrow 2\ Na_2SO_4$

- In high pressure boilers the reaction is:

$Na_2SO_3 + H_2O + Heat \rightarrow 2\ NaOH + SO_2\uparrow$

$4\ Na_2SO_3 + 2\ H_2O + Heat \rightarrow 3\ Na_2SO_4 + 2\ NaOH + H_2S\uparrow$

The main problem associated with sulphite breakdown is the formation of SO_2 and H_2S which can cause corrosion

Hydrazine

Hydrazine used as chemical oxygen scavenger in high pressure boiler as:

$$N_2H_4 + O_2 \rightarrow 2H_2O + N_2\uparrow$$

- **The products of the hydrazine reaction are inert and volatile.**
- **Hydrazine will also react with ferric oxide:**

$$N_2H_4 + 6\ Fe_2O_3 \rightarrow 4\ Fe_3O_4 + N_2\uparrow + 2\ H_2O$$

- **And cupric oxide:**

$$N_2H_4 + 2Cu\ O \rightarrow 2Cu_2O + N_2\uparrow + 2\ H_2O$$

- **At 518 ºF (270ºC) degree undergoes rapid thermal degradation:**

$$3\ N_2H_4 + Heat \rightarrow N_2\uparrow +$$

Deposition of corrosion products

- **The presence of iron and copper corrosion products in returned condensate may cause pre-boiler section deposits either by direct adherence or by acting as a binder.**

$$4Fe(HCO_3)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3\downarrow + 4CO_2\uparrow$$

$$Fe(HCO_3)_2 + Heat \rightarrow Fe(OH)_2\downarrow + 2CO_2\uparrow$$

$$4Fe(OH)_2\downarrow + O_2 + 2H_2O \rightarrow 4Fe(OH)_3\downarrow$$

$$2\,Fe(OH)_3 \rightarrow Fe_2O_3$$

Chemical Treatment design philosophy

- **The treatment shall be designed to minimize the formation of scale and build up of micro –organisms, and prevent fouling, and corrosion of the turbine condenser and other heat exchanger.**
- **Scale/Corrosion inhibitor and Bio-dispersant and H_2SO_4 dosing Systems have been designed to dose required quantity of chemical to maintain**

Water Treatment Concerns

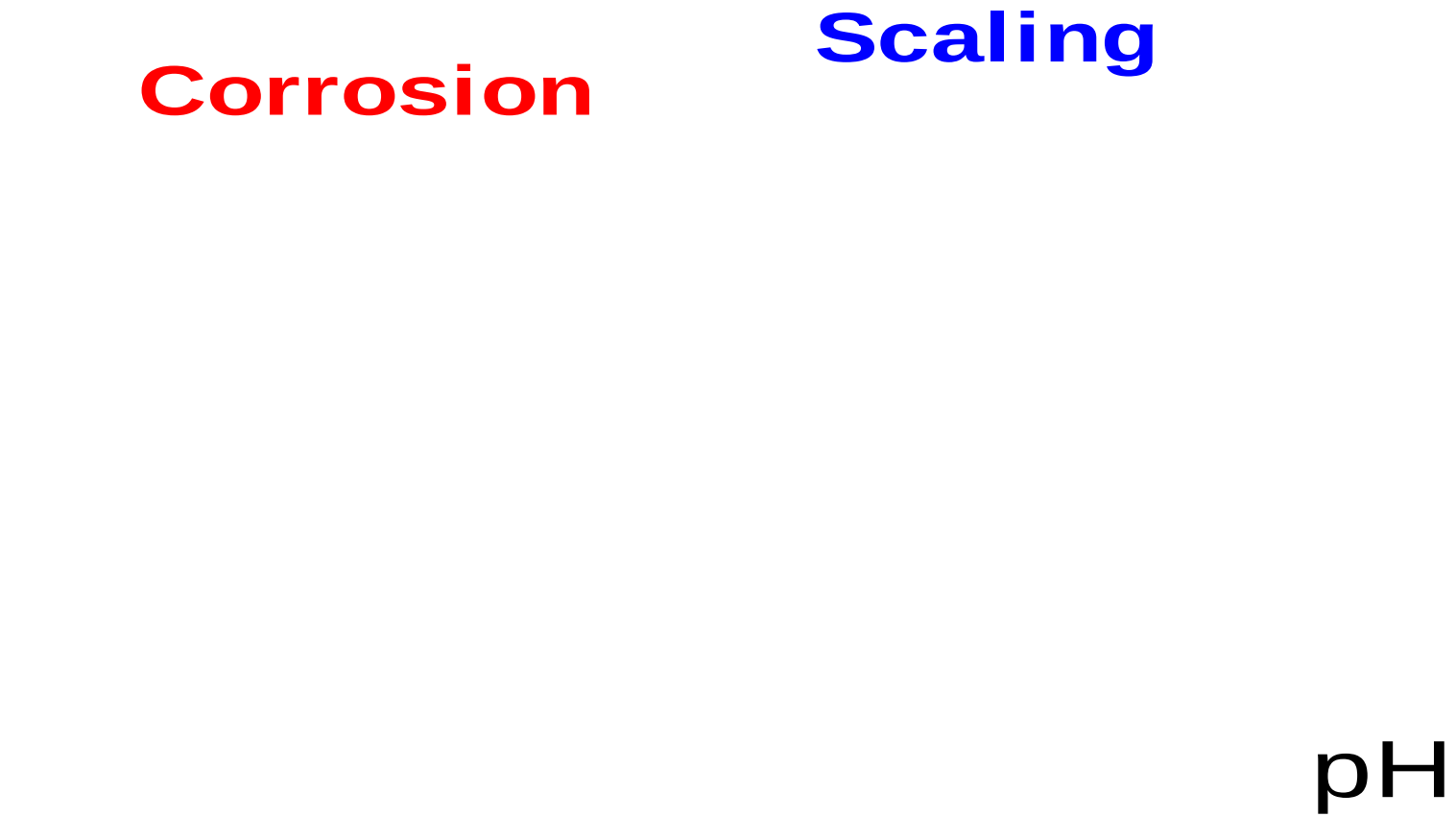
Biofouling

Corrosion Products

Corrosion **Under-Deposit Corrosion** **Deposition**

(*Using Acid for Cooling Water Treatment Program By Chatchavan Boonchoo, Senior Manager, Applied Chemical Department, Chemical Division, EGAT, Thailand, 11.05.2009)*

Using Acid for Cooling Water Treatment Program



Pollution definition تعريف التلوّث

Undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that can harmfully affect the health, survival, or activities of human or other living organisms.

Combustion containing substances

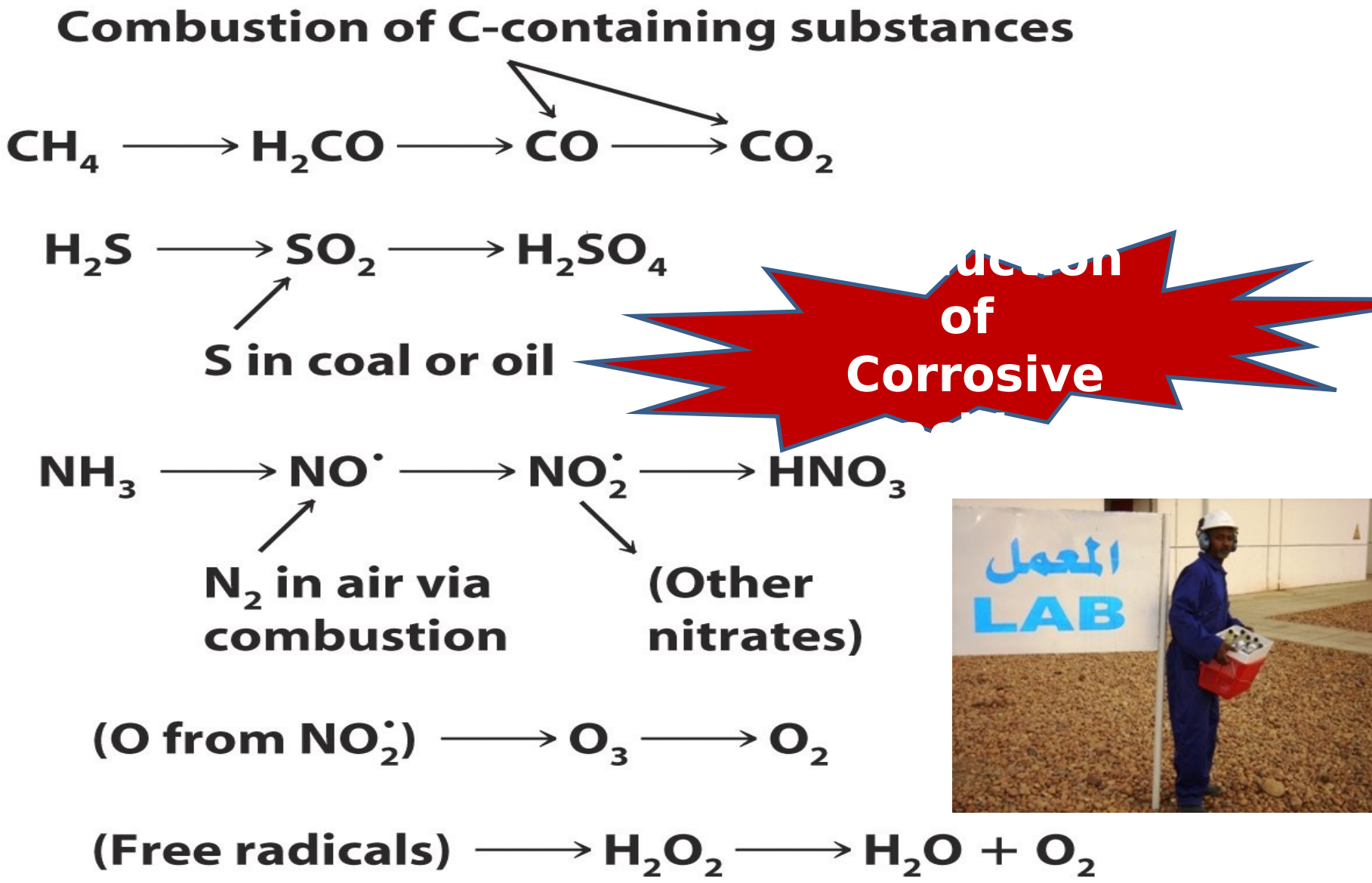


Figure 3-3
Environmental Chemistry, Third Edition

Methodology of experimental work

2.1 Problem: Cube Test Failure

فشل إختبار المكعبات الخرسانية

Chemistry of concrete as construction Material

Location: Kosti Power Station Project

Strength test for *reinforced* concrete footings of boiler unit (1) was done on February 06, 2008 in University of Khartoum by Building and Road Research Institute Concrete core crushing strength according to British standard (BS) 1881- 120 (1983) and (BS) 8081

Cleaning the mould

Preparing the mould

Compacting the concrete in the cube mould (For 150 mm cube at least 35 tamps per layer)

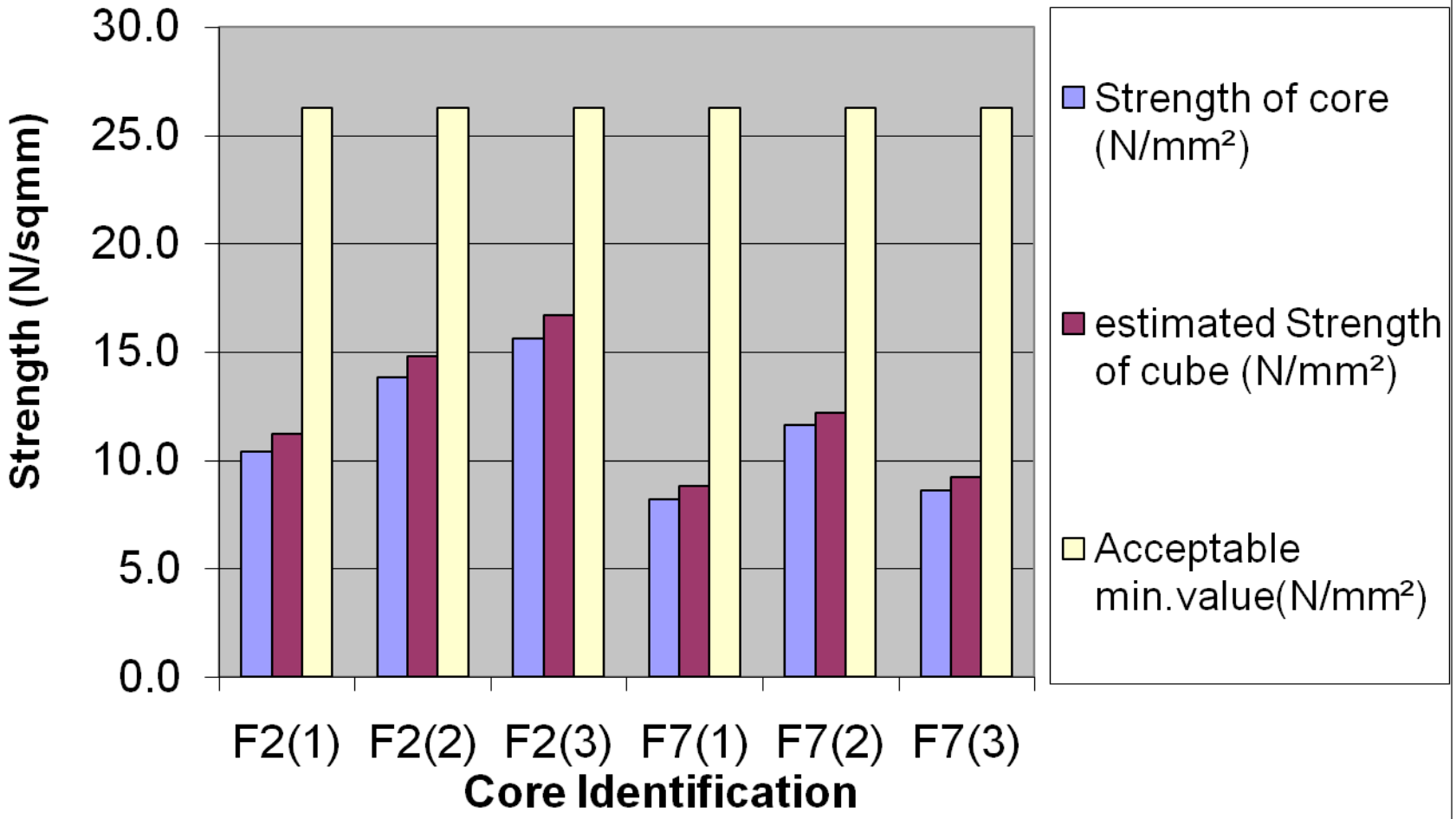
Finishing

Plate 2.1 Monitoring of cube sample during compressive strength test procedure

Sample preparation as per testing concrete; in “HOCHSCHULE FUR University of Technik Stuttgart Applied Science” testing of hardened concrete (German National Standard) / 01-Jun-1991 / 8 pages DIN 1048

Test Result (Building and Road Research Institute University of Khartoum)

Fig. 2.1 Comparisons between actual, estimated, and acceptable strength values



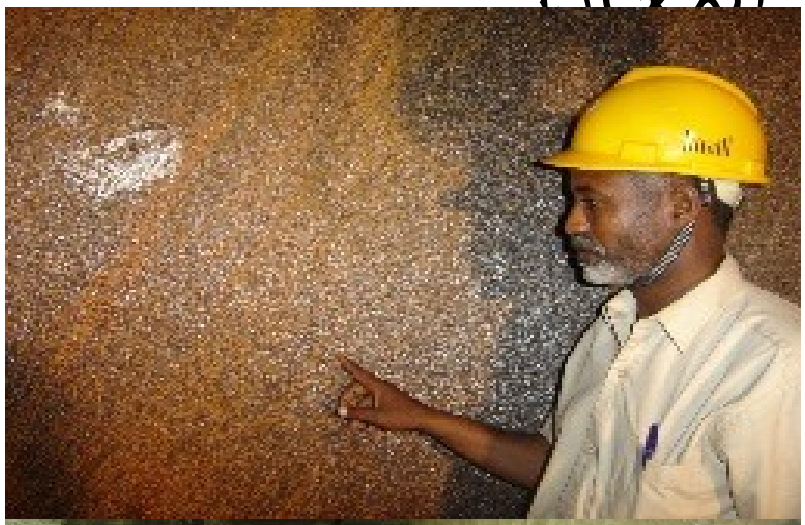
Microorganism colonies corrosion built

2.2 Problem Environmental corrosion in hydro power plants

التآكل البيئي بمحطات التوليد المائي

Coating material :

"IRATHANE POLYUETHANE" مواد طلاء أسطح المعادن



Material Safety Data Sheets (IRATHANE C155)

Composition / Information on ingredients

problem (2): Hazard identification

- **chemical hazard: Highly Flammable,**
- **Human health: May cause cancer**

Name	Content
4,4'-Methylenedianline	1-10%
Butanone	30-60%
Trichloroethylene	10-30%

problem Jebel Aulia Hydro Matrix 2.3 Power Station Corrosion Defects

أولياء مشاكل التآكل

التوربينات المصفوفة المائية

2.3.1 Chemical attack and the physical abrasion because of the fluid motion

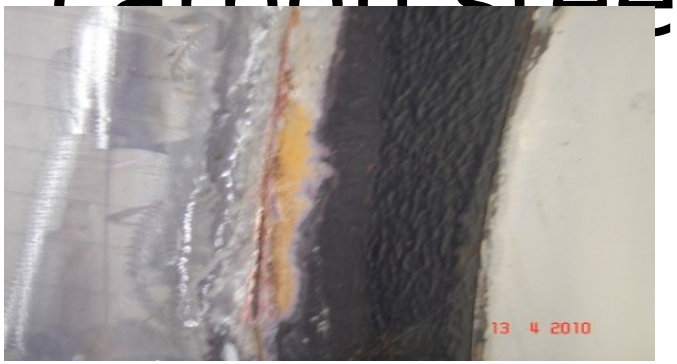
During the meeting, the report from technical university Vienna was explained the defects are classified as an erosion-corrosion problem.

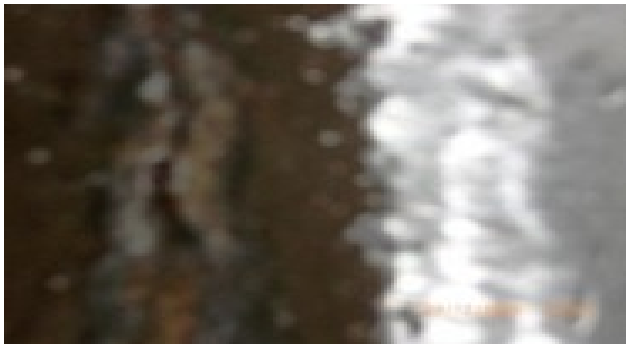
Jebel Aulia Hydro Matrix Power Station Corrosion Defects

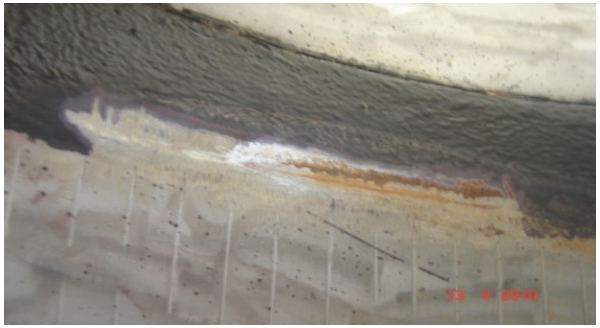
2.3.2 Problems : defects appeared to the second time at the joint plates

Sharp Crack defects appeared to the second time at the plates joints (carbon steel) between the modified runner chambers and draft tubes (stainless steel) exactly in the welded areas. Galvanic (Two Metal) Corrosion occurs when two dissimilar metals are immersed in a conductive medium

Corrosion appeared at the area of modified stainless steel and carbon steel plate joints







Problem (2.3.3): Microbiological corrosion penetrates the sling robes layers

The resultant accelerated corrosion mechanism of iron by the sulphate reducing bacteria is illustrated in equations 1, 2, 3, 4 and 5 are conceder as:

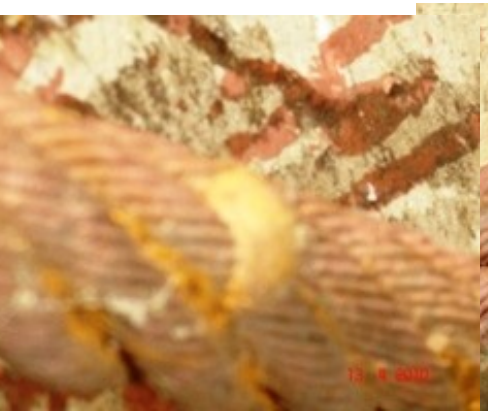
(1) $SO4^{-2} + 8\ H^{+} = S^{2-} + 4\ H_2O$ **(Cathodic depolarization by SRB)**

(2) $8\ H_2O = 8\ OH^{-} + 8\ H^{+}$ **(dissociation of water)**

(3) $2\ H^{+} + S^{2-} = H_2S$ **(reversible reaction)**

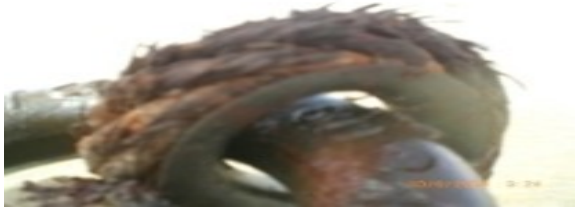
(4) $Fe^{+2} + S^{-2} = FeS$ **(anode corrosion product)**

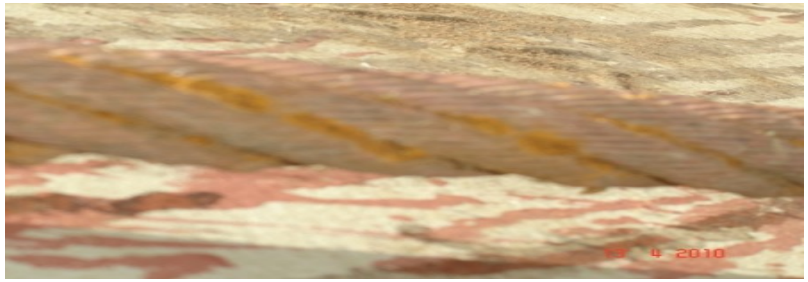
(5) $3\ Fe^{2+} + 6\ (OH)^{2-} = 3\ Fe(OH)_2$ **(anode corrosion product)**




Jebel Aulia Hydro Matrix Power Station Sling robes corrosion









2.4 Gas Turbines Hot Gas Path (combustion) Parts problems

التآكل في أجزاء الإحتراق بالتوربينات الغازية

Problem (1) Failure due to hot corrosion

- **General electric (GE) specification: GE1-41047H**

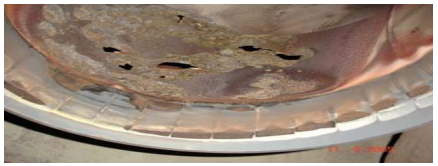
Sodium plus potassium (Na + K)	1	ppm, (max.)
Vanadium (V)	o.5	ppm, (max.)
Lead (Pb)	1	ppm, (max.)
Calcium (Ca)	2	ppm (max.)

Corrosive metals in existing light diesel oil are

Corrosive metals in existing light diesel oil are:

Na	4.42 - 10.92	ppm
K	0.18 - 1.76	ppm
V	< 1.00	ppm
Pb	2.26	ppm

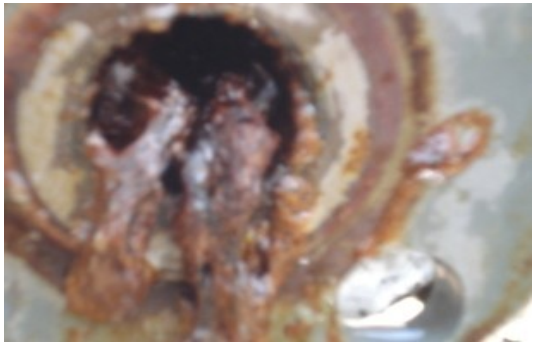
Heavy hot corrosion in different areas through combustions components of gas turbine




2.5 Gas turbine Nozzles corrosiveness of the deposits

الترسبات المحفزة للتآكلات برواشح و قود الوربينة









2.6 Corrosion and scale effects to the cooling tower water system

تأثيرات التآكل والـ قشـور لنـظام مياه التبريد

2.5.1 Problem (1) fouling of systems and heat exchangers in Kassala Power Station

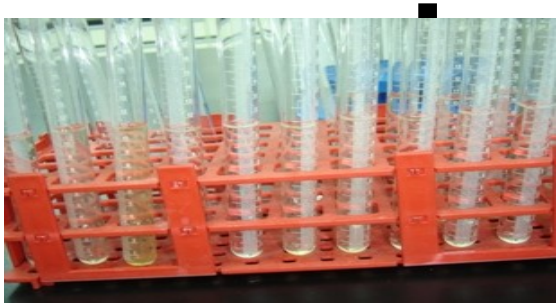
There are five types of deposits, which form in cooling water systems. They are; Inorganic scale, which forms due to over – saturation of a relatively insoluble salt, corrosion products which are insoluble, suspended solids or oils, biological growths, and insoluble products

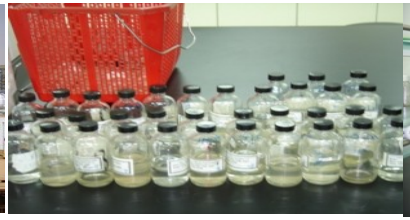
2.6.2 Problem (2) internal pipe wall deposits for water supply report

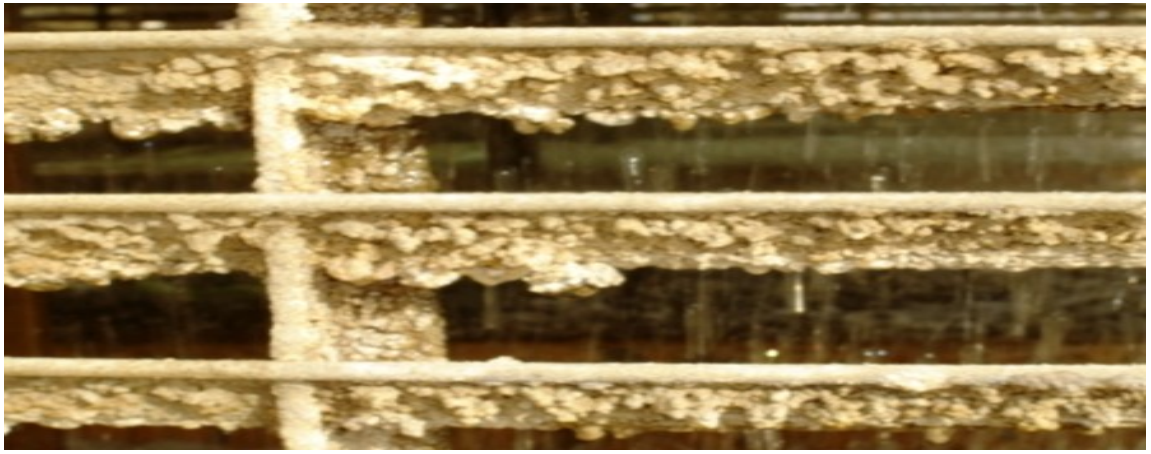
Problem (1) Garri Power plant generator air cooler sample analysis.
Problem (2) internal pipe wall deposits for water supply report

Condenser zinc plate scale fouling

2.7 Problem : The effects of ammonia Emission to the

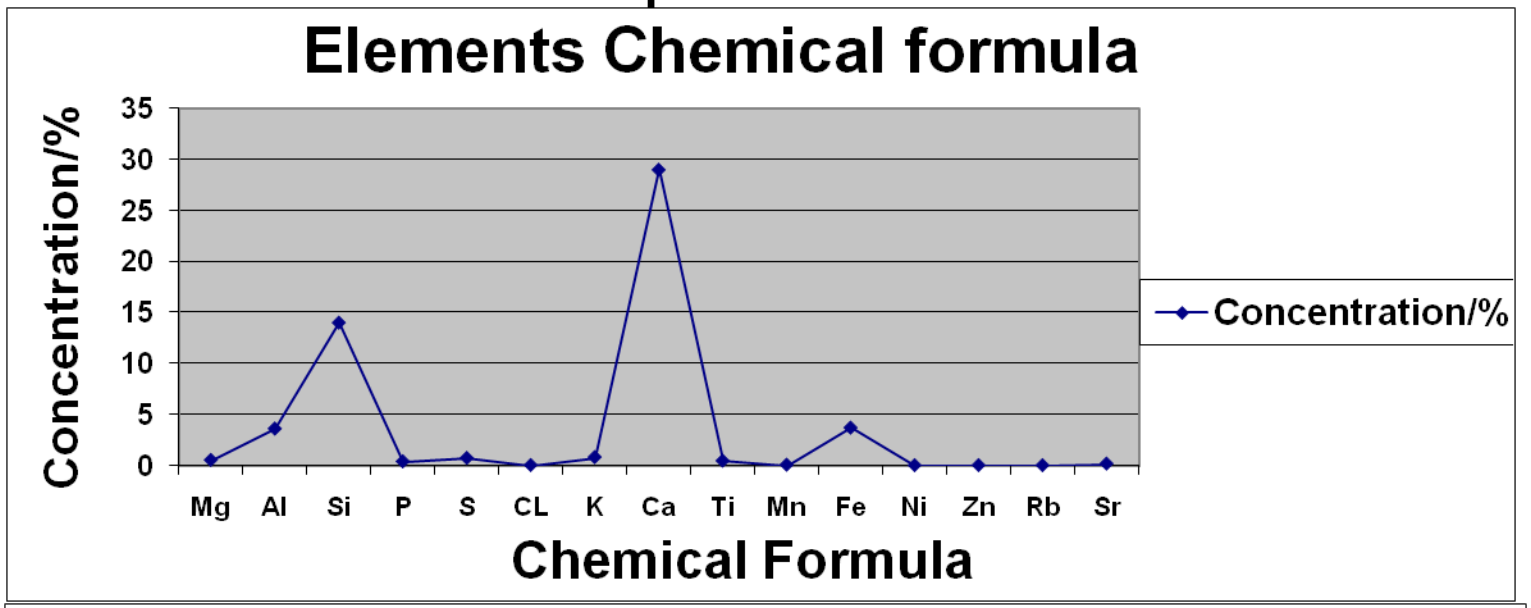


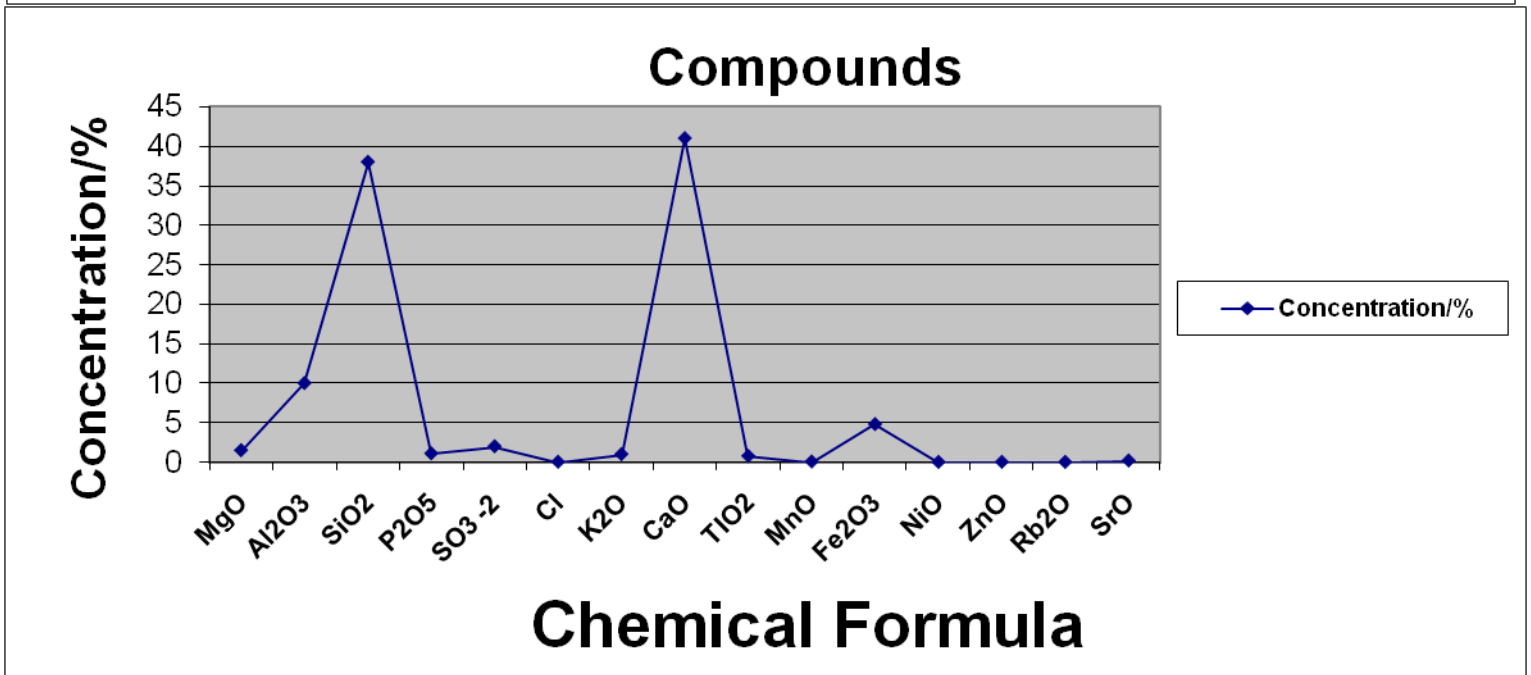




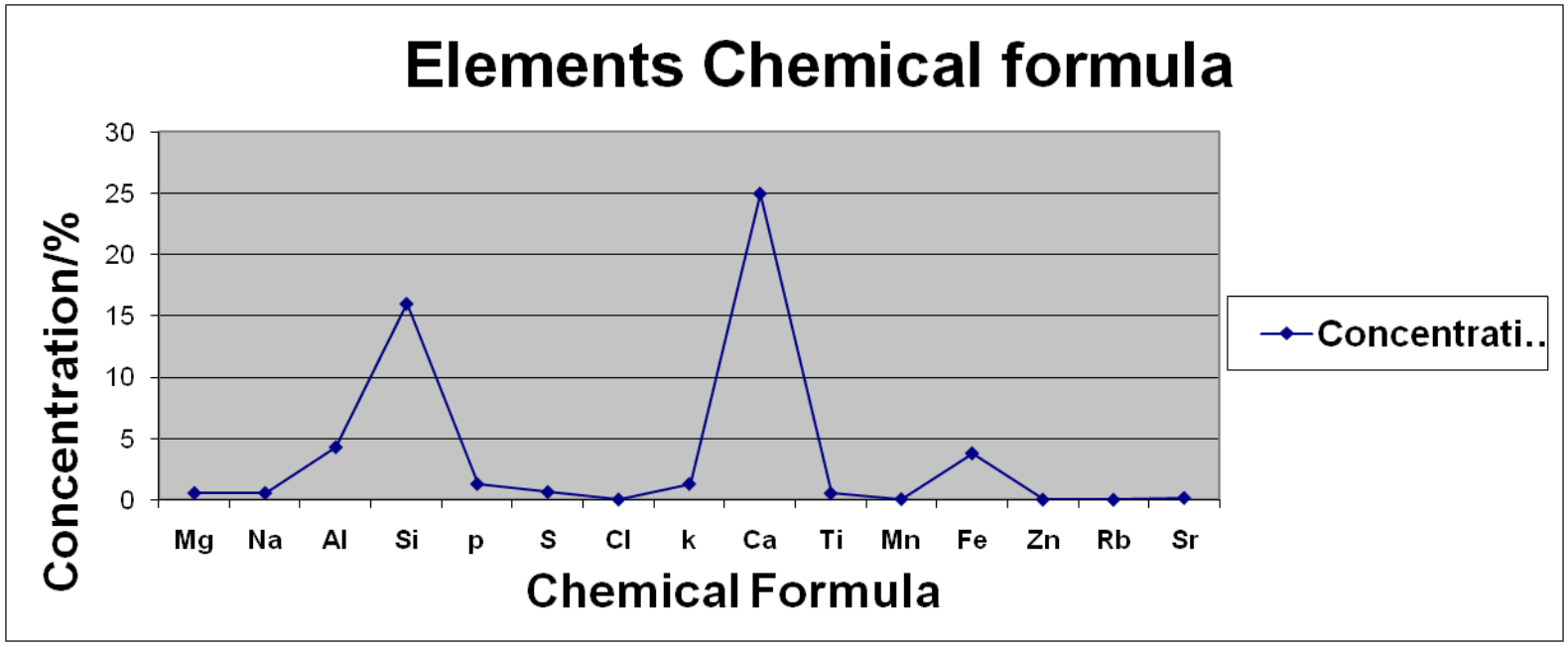
Results

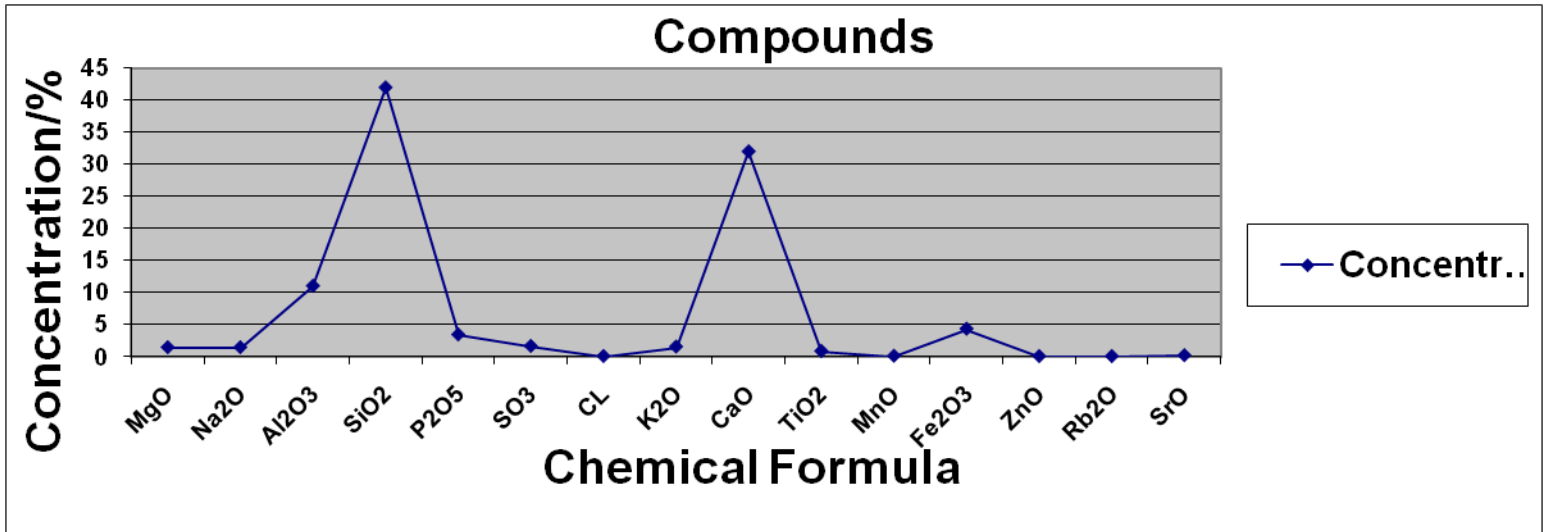
Kosti Thermal power Station Concrete Sample no.2



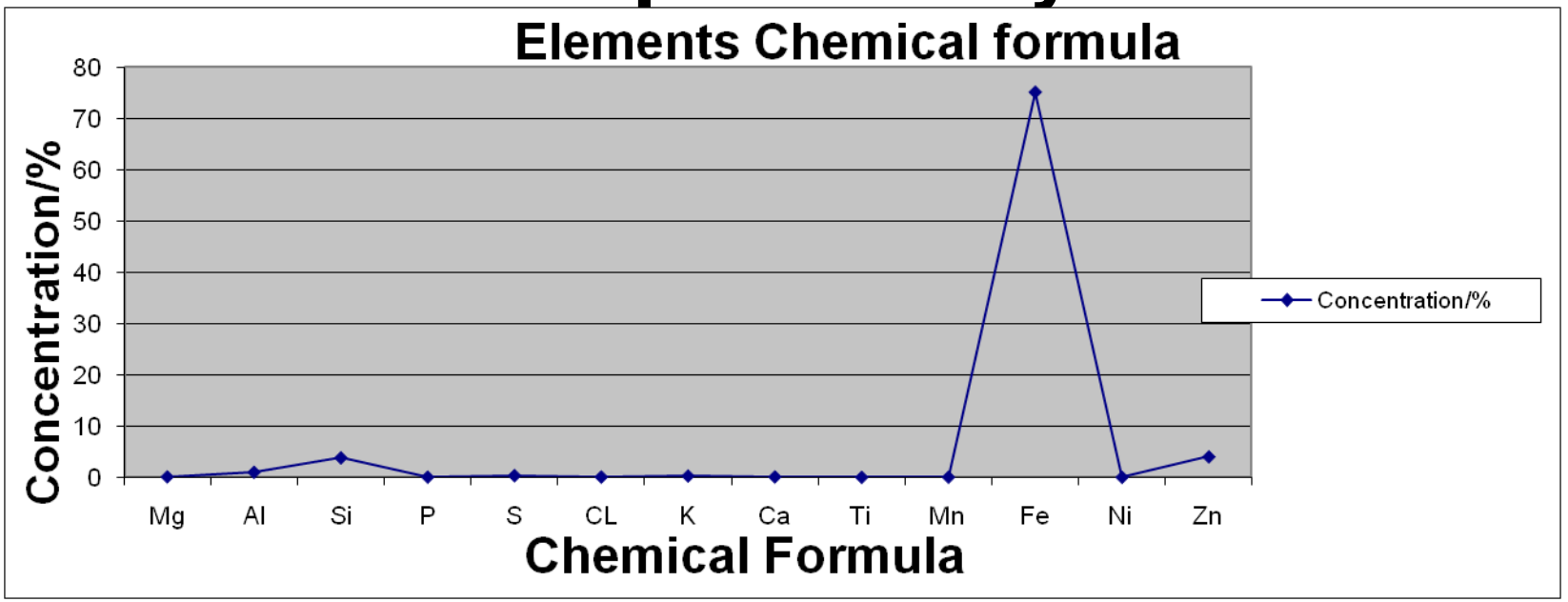


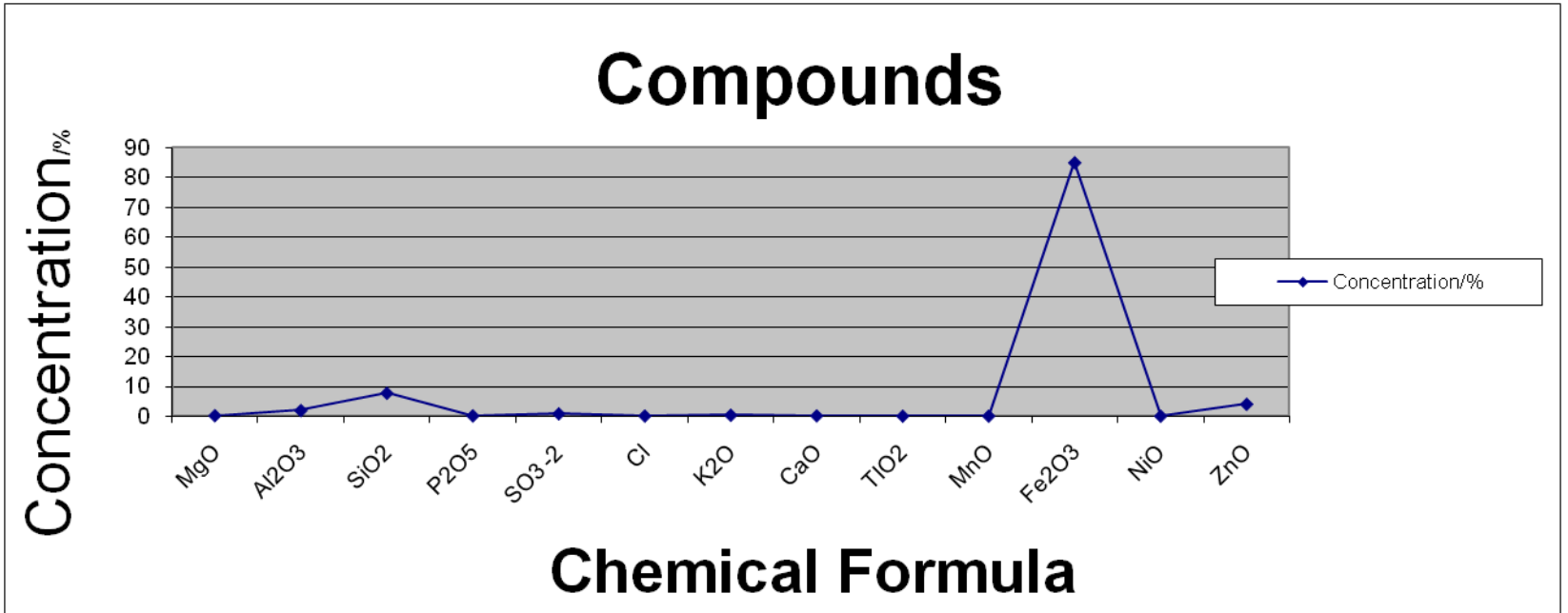
Kosti Thermal power Station Concrete Sample no.3



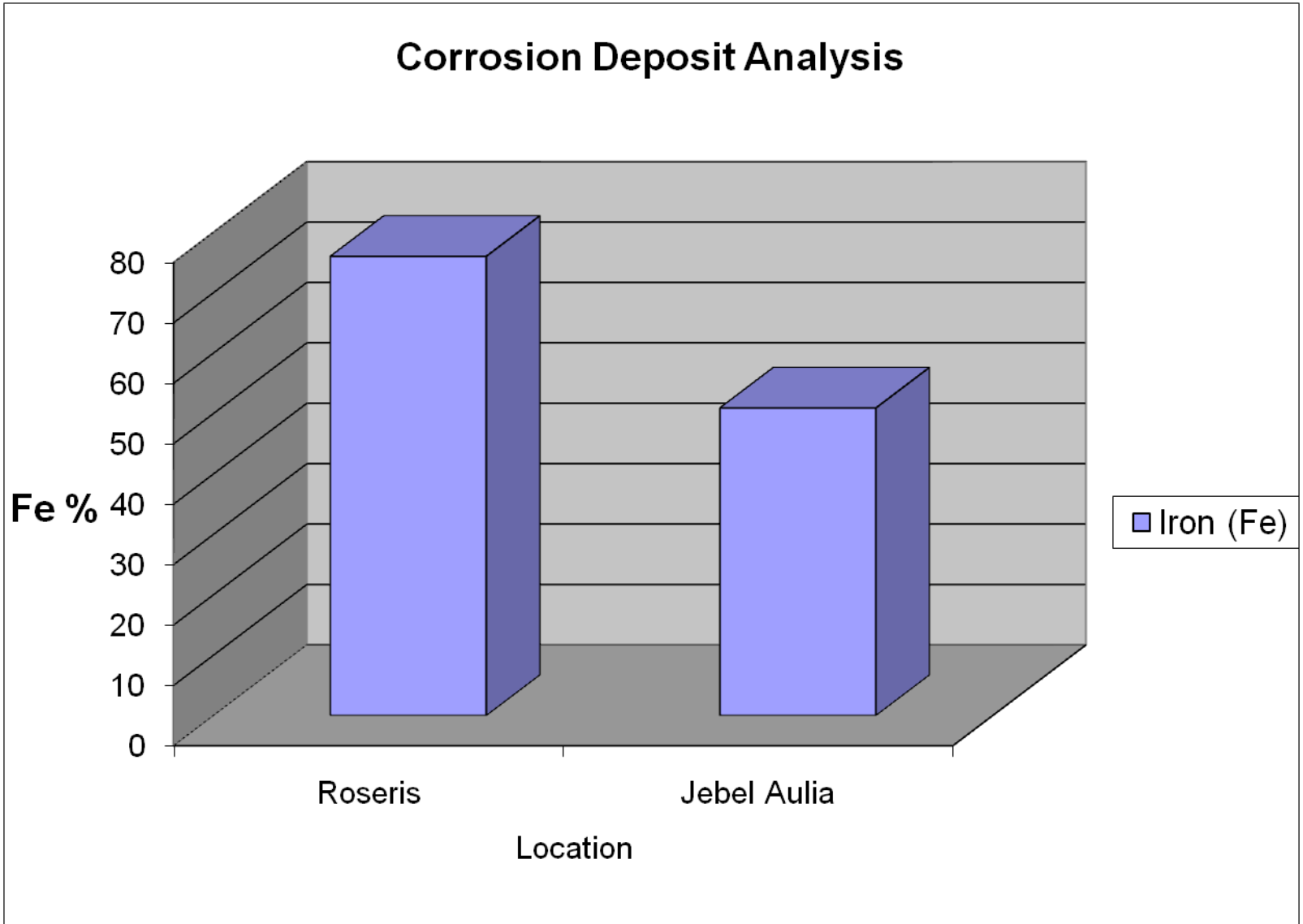


Roseris Power Plant Intake door corrosion deposit analysis

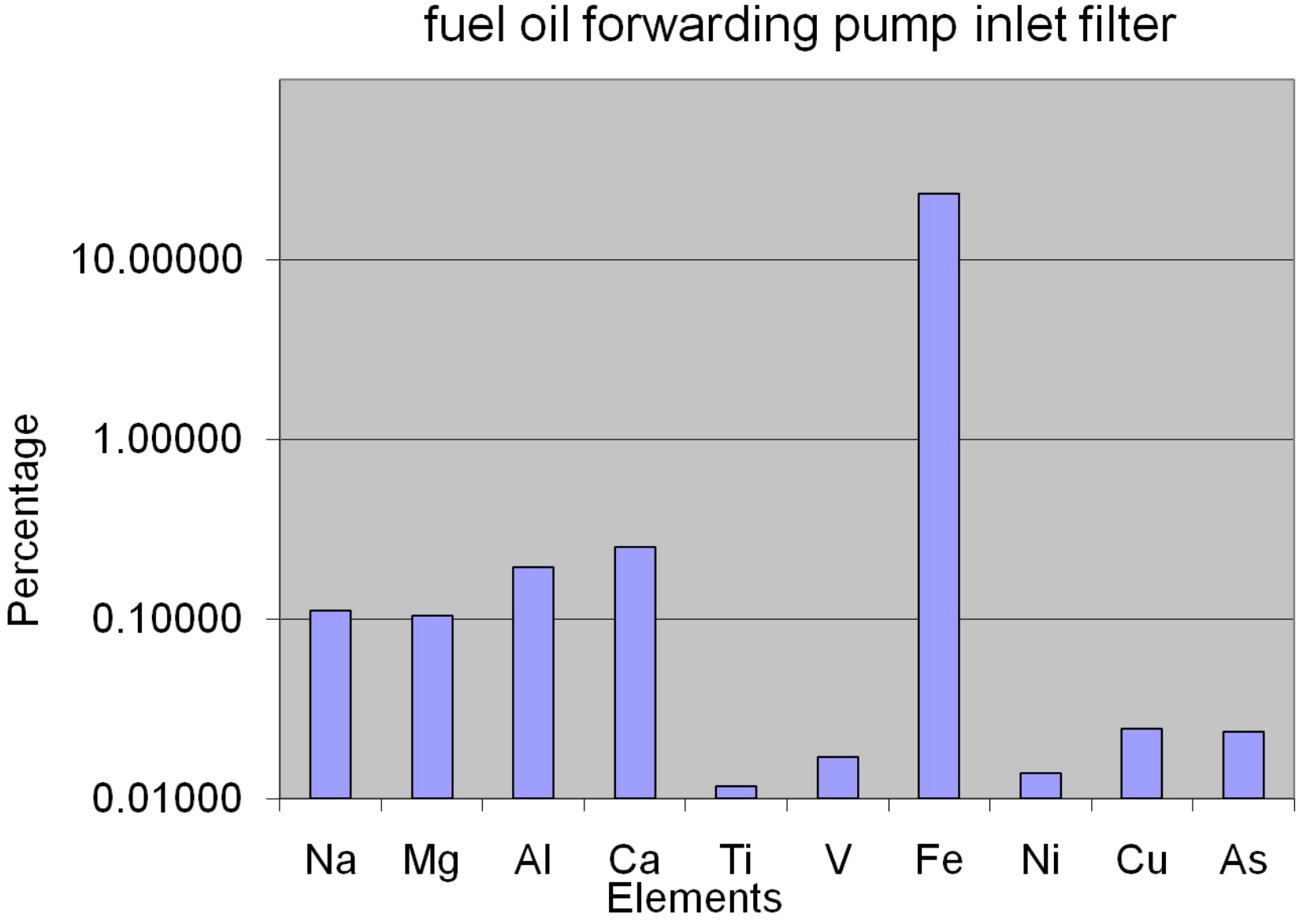




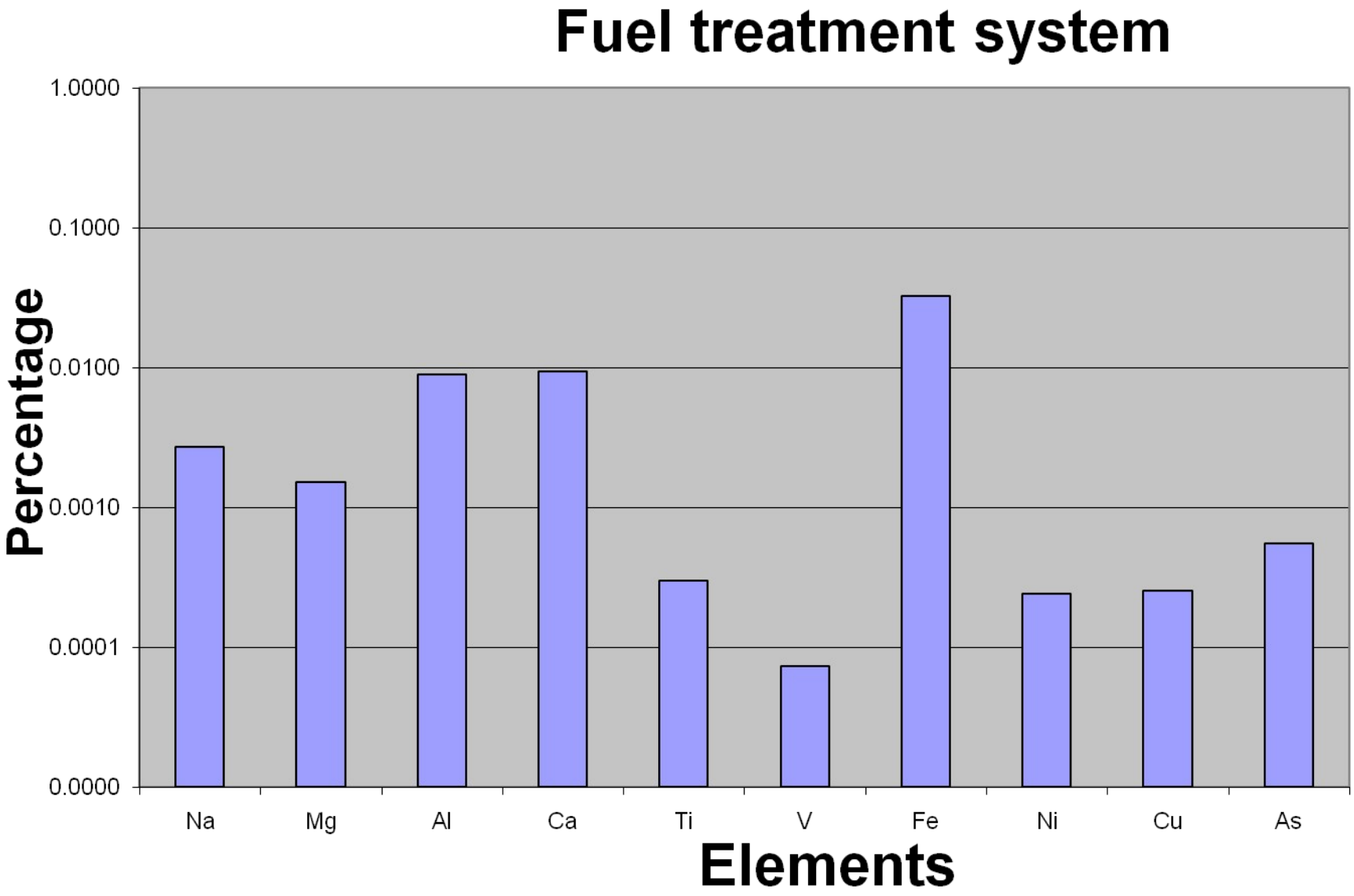
Hydro Power Plants corrosion deposits analysis (Roseris and Jebel Aulia Matrix)



Light diesel oil (Light Diesel Oil) Forwarding Pump Filter

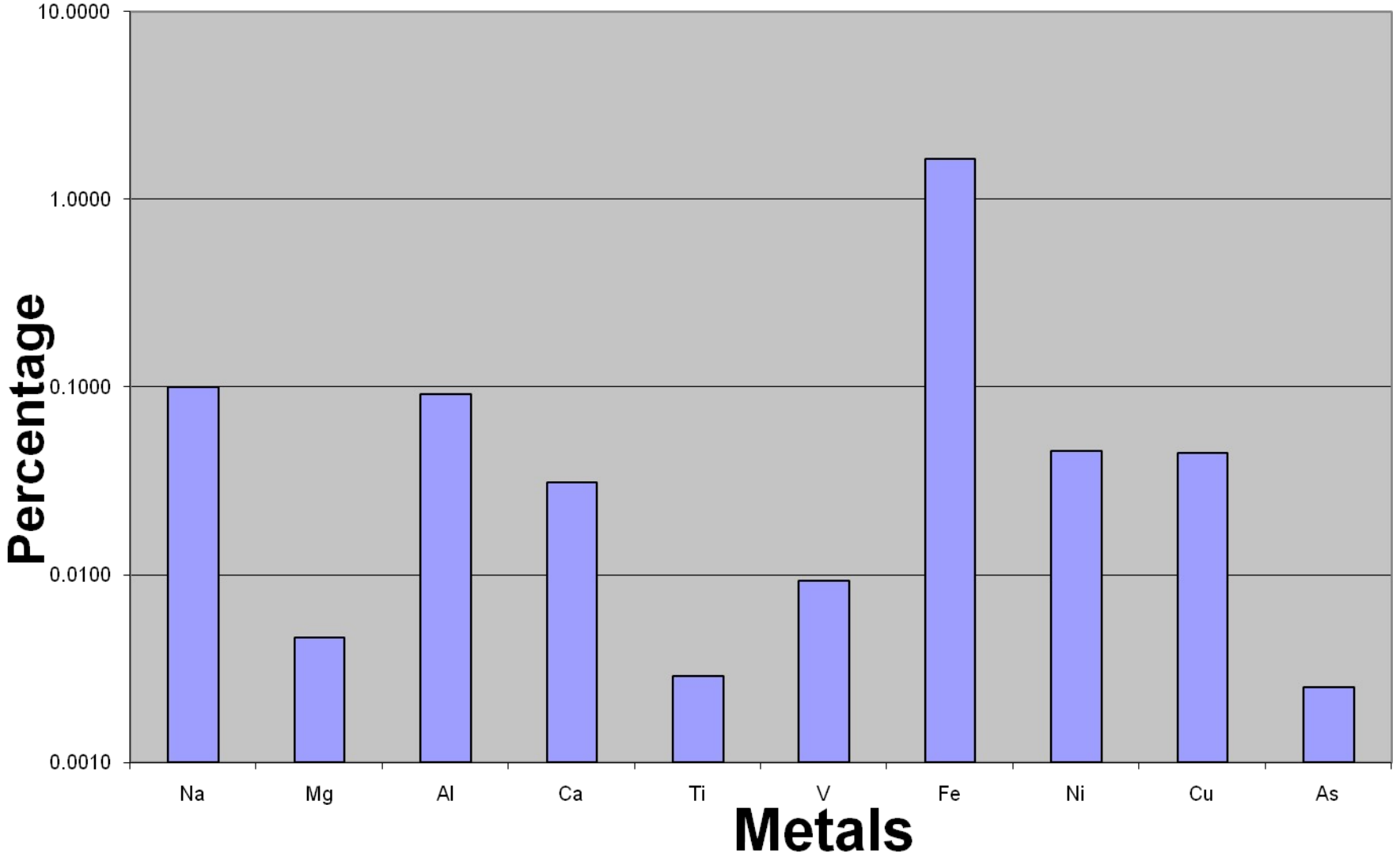


Fuel Oil Treatment System - Oil Separator

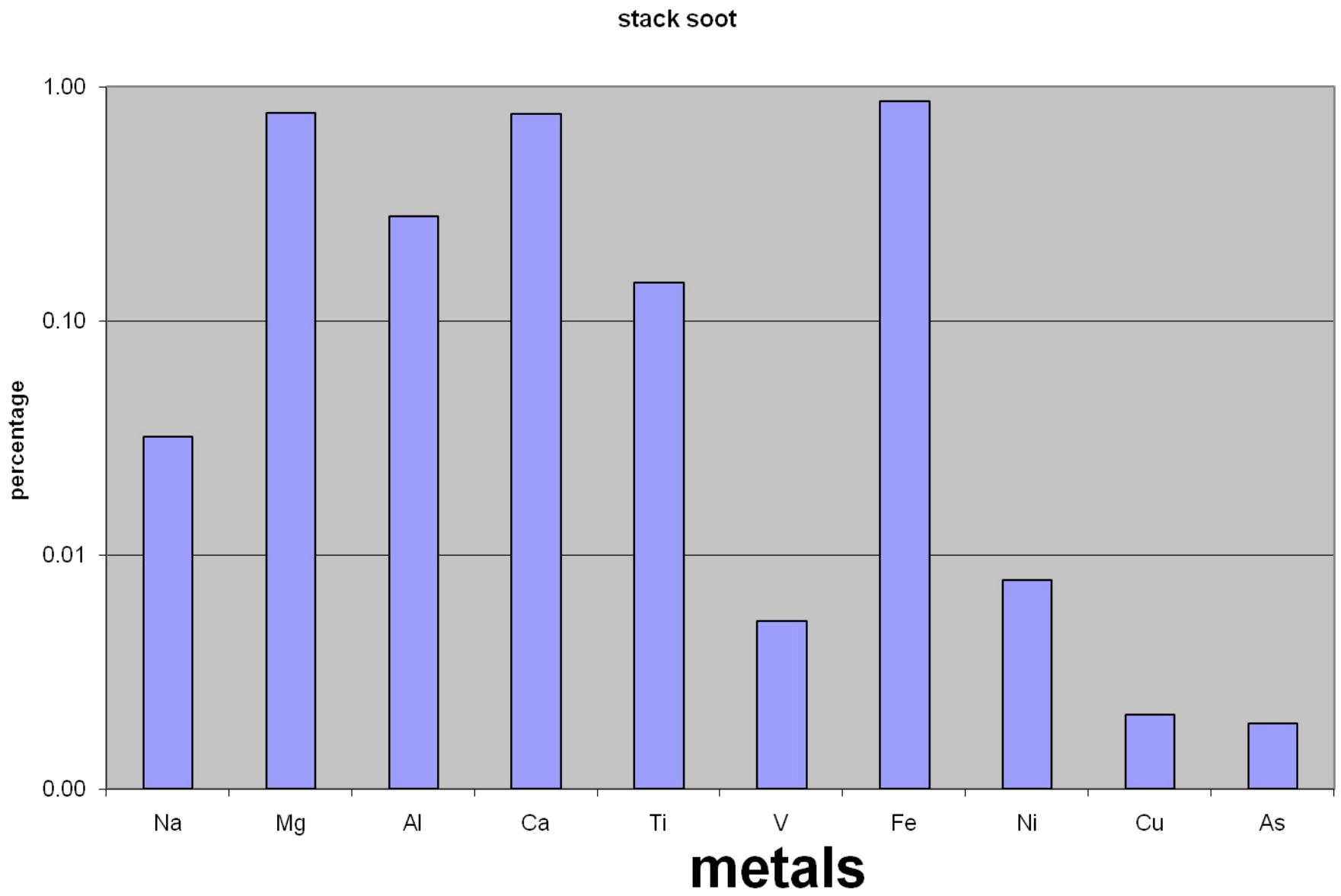


Gas turbine (Gas Turbine-4) liquefied petroleum gas (Liquefied Petroleum Gas) Nozzle

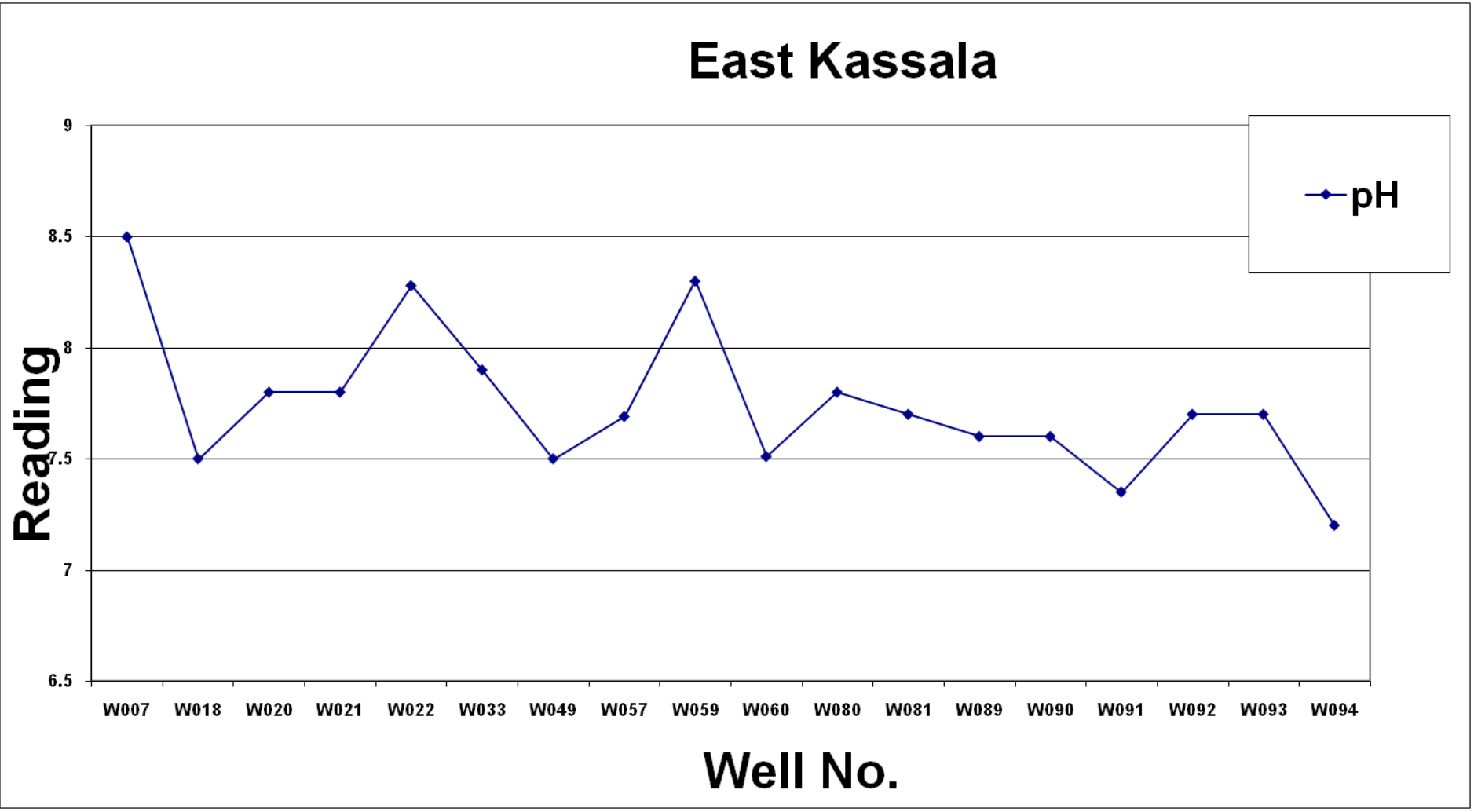
LPG



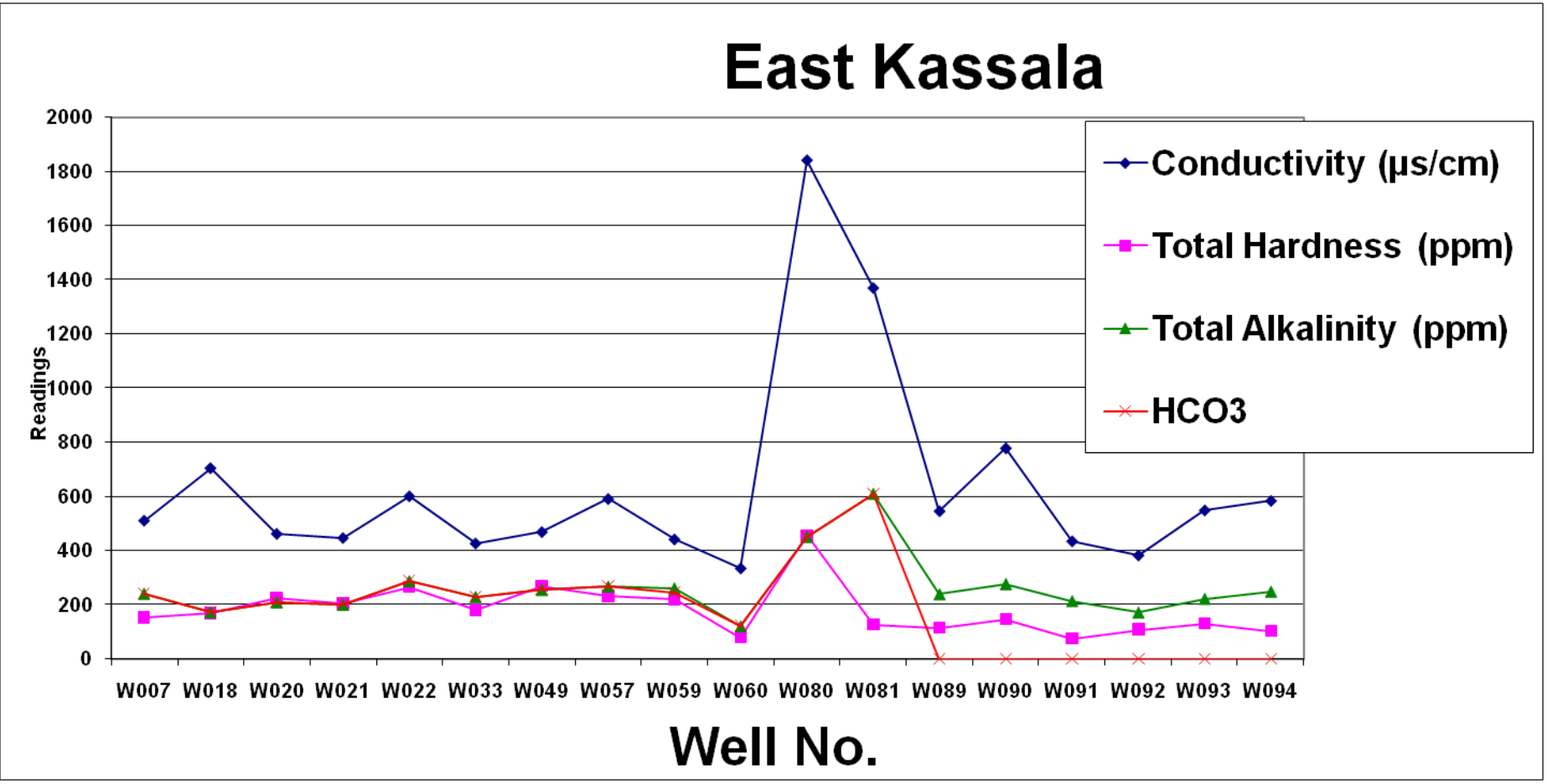
Stack Soot heat recovery steam generator Heat Recovery Steam Generator(6).



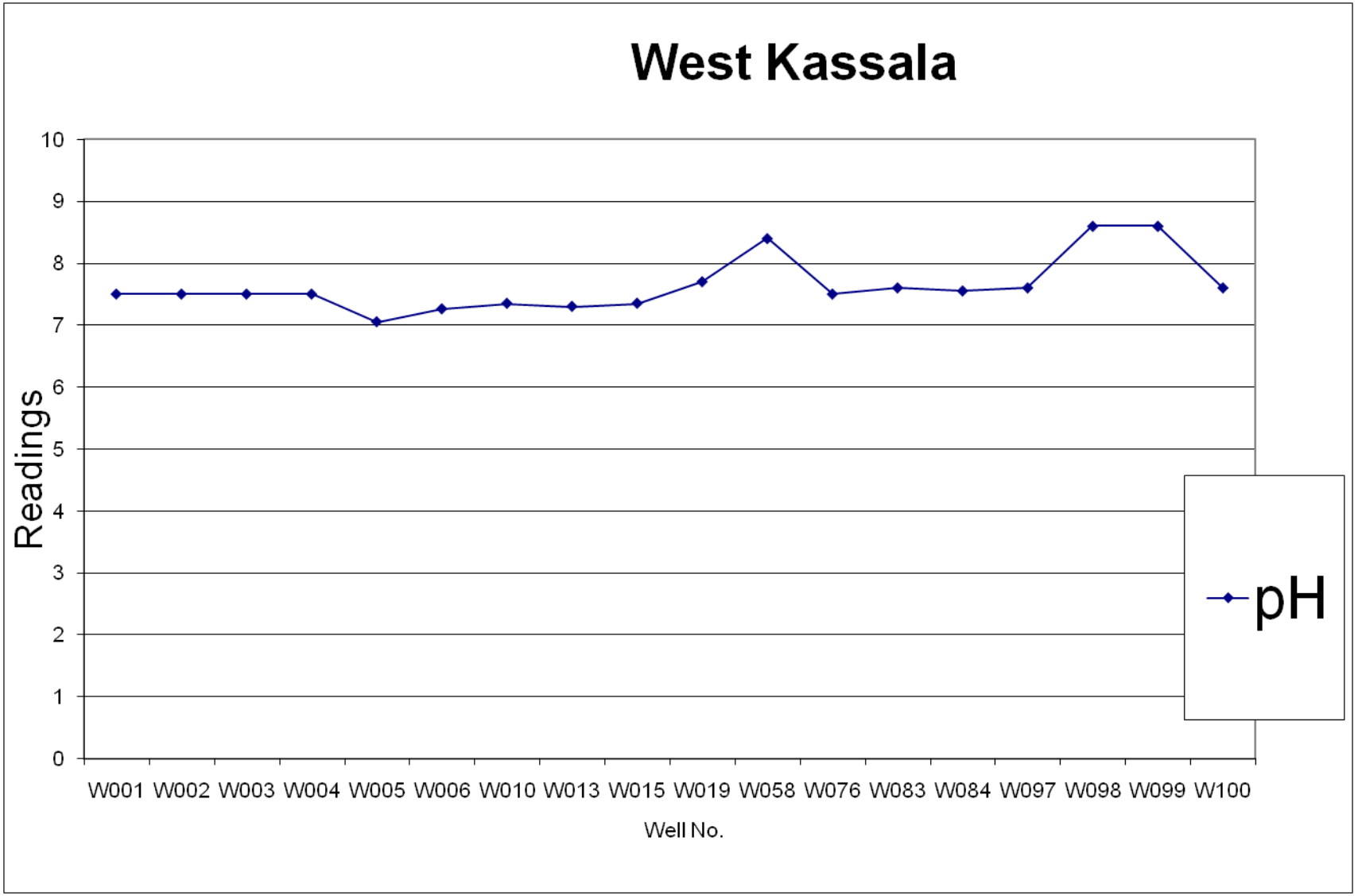
East Kassala underground wells water analysis



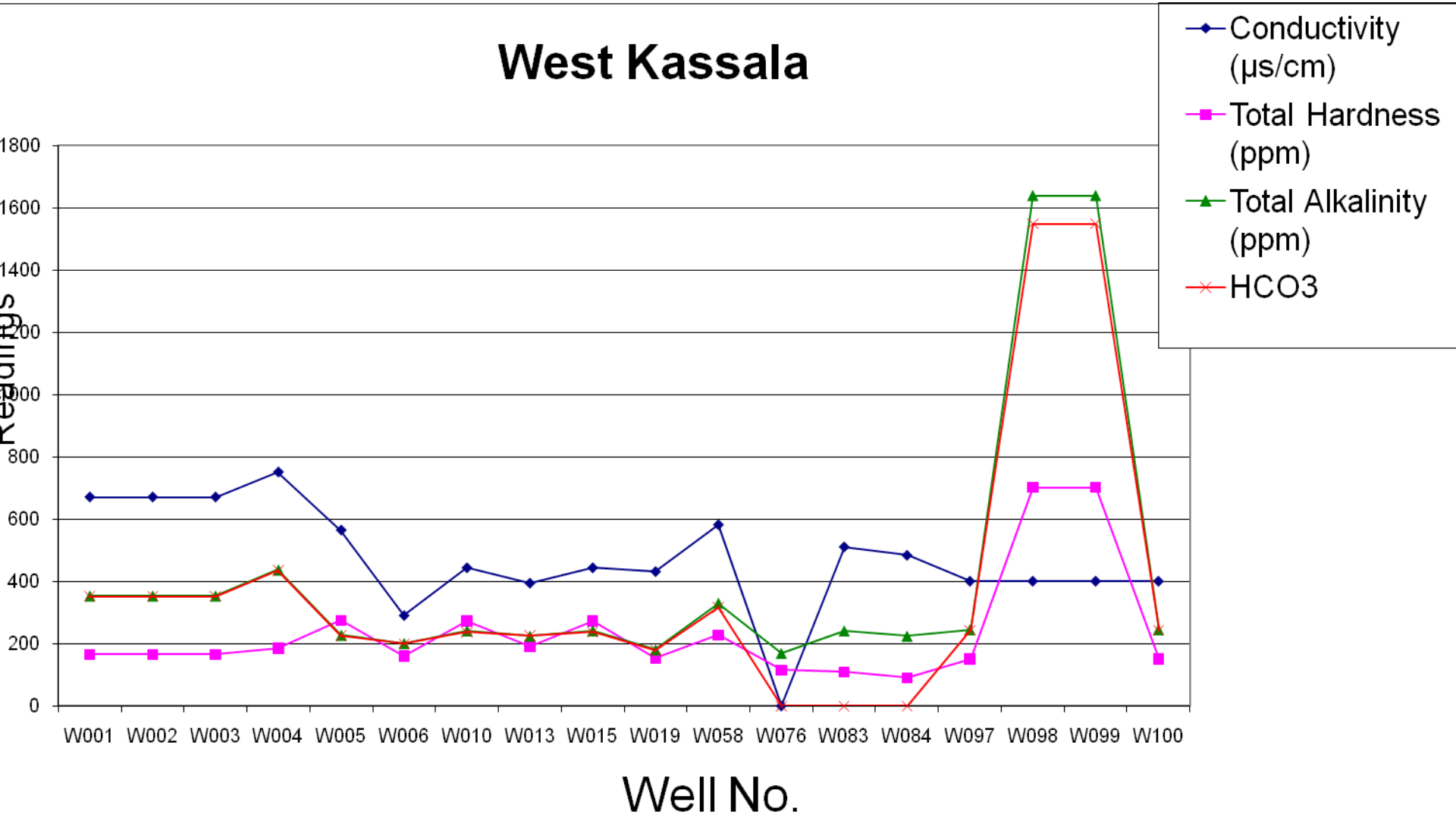
East Kassala underground wells water analysis



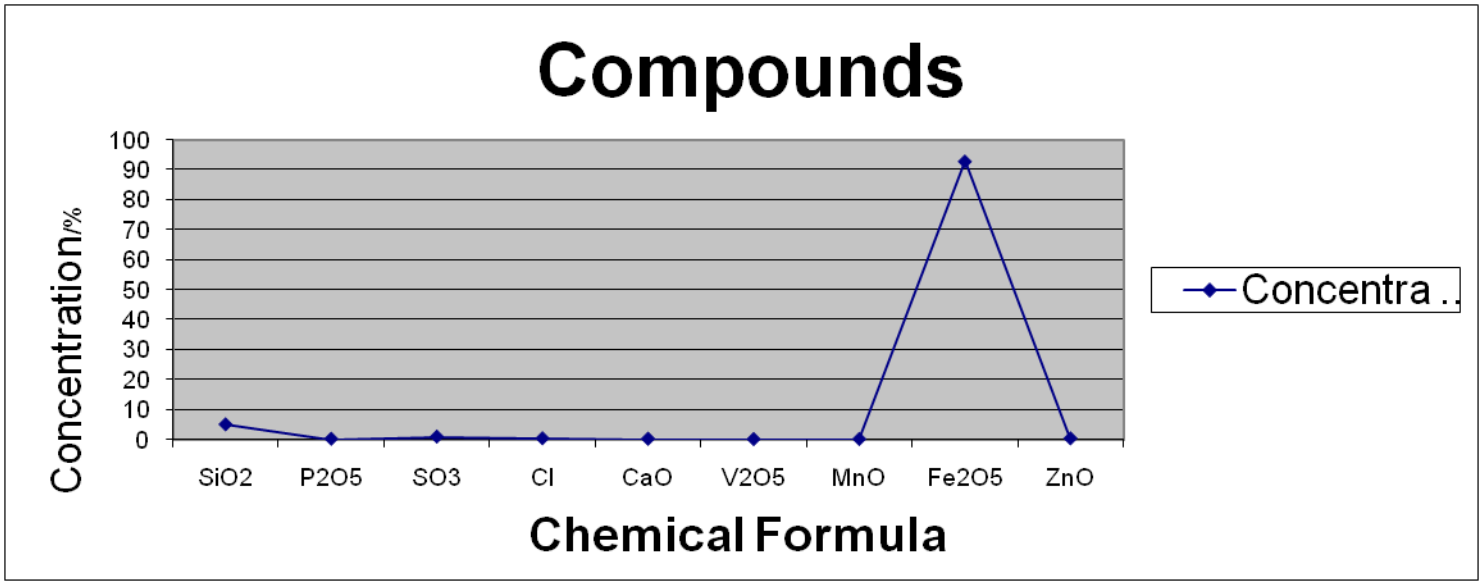
West Kassala underground wells water analysis

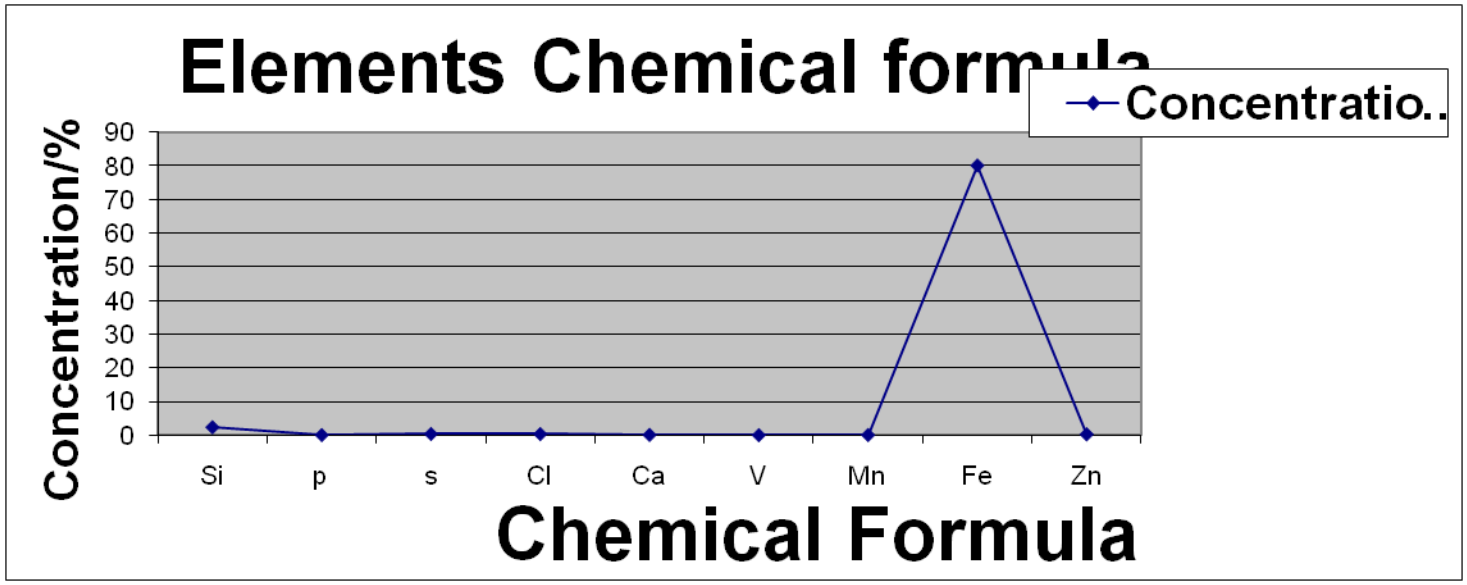


West Kassala underground wells water analysis

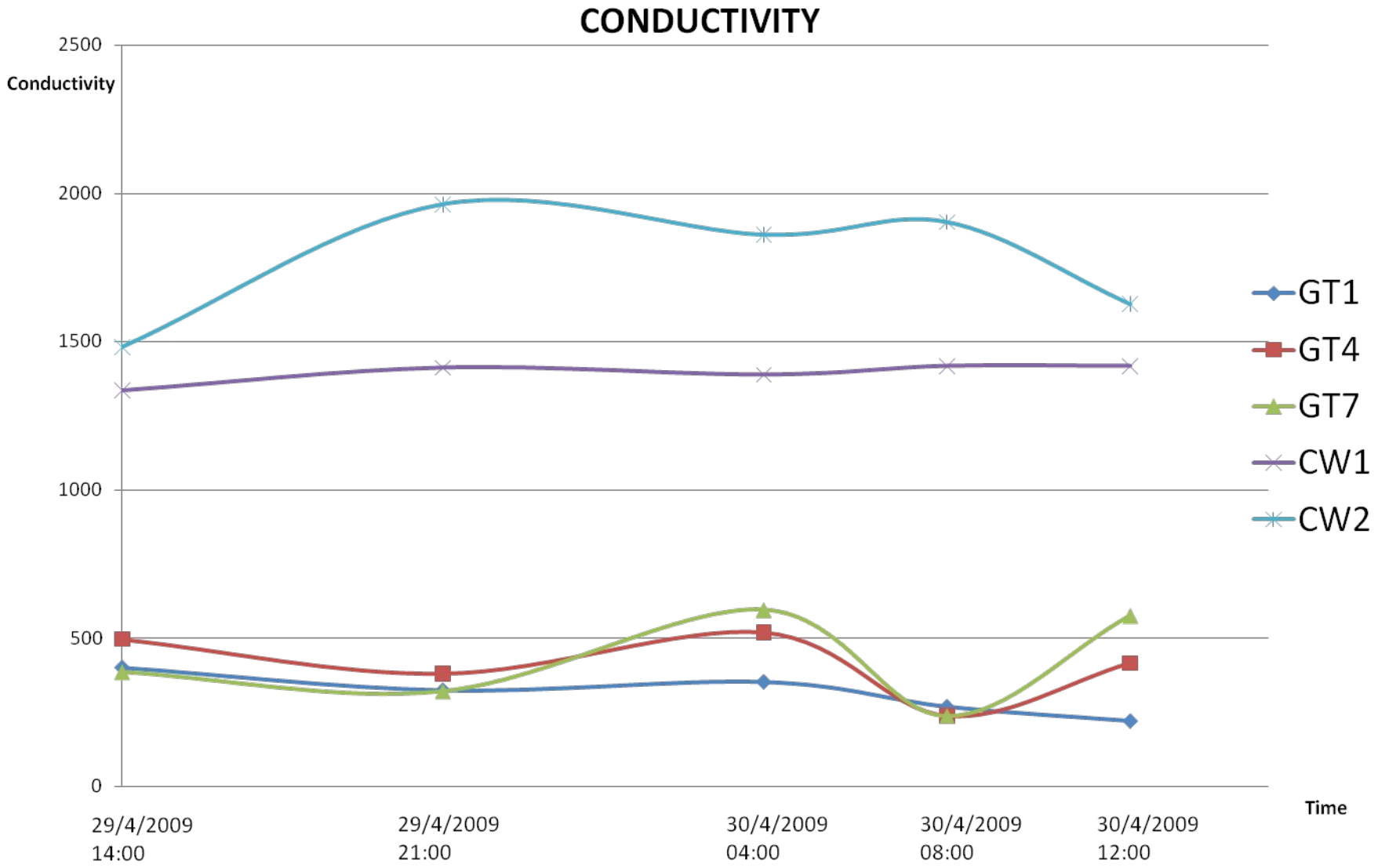


Kassala Town Water -Well pipes deposits

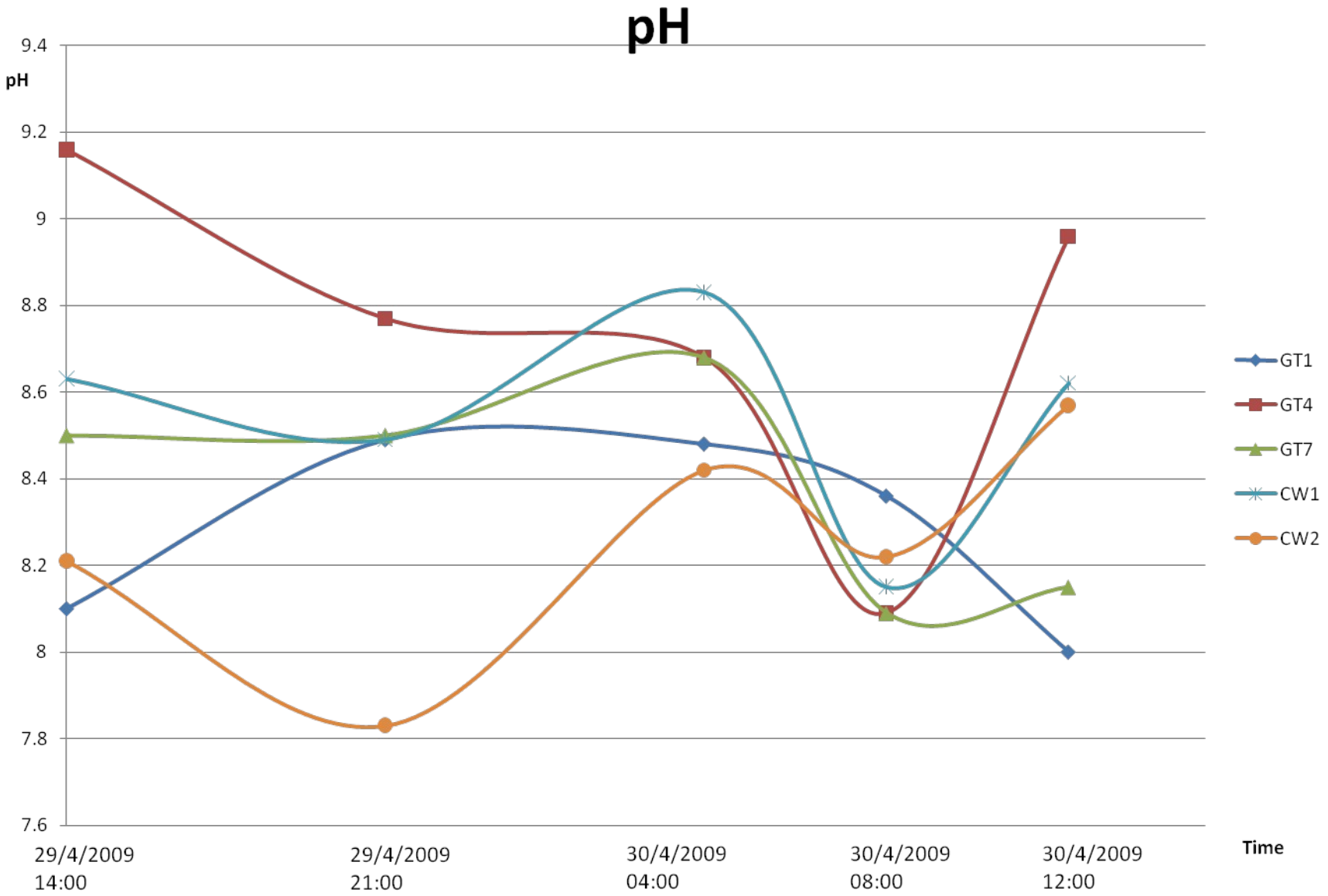




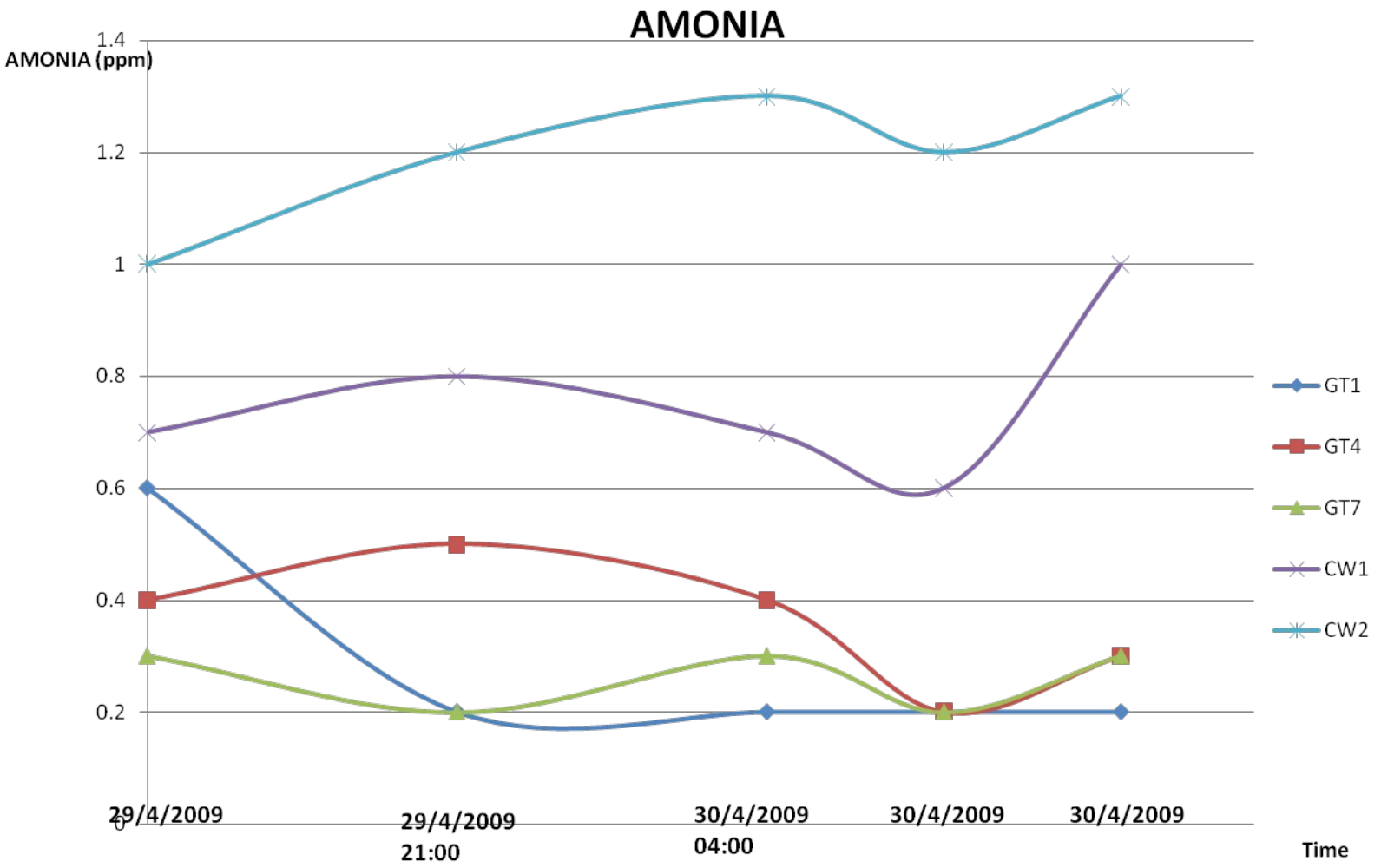
ANALYSIS OF DESOLVED AMONIA, pH & CONDUCTIVITY OF GARRI POWER PLANTS OPEN WATER SYSTEMS



ANALYSIS OF DESOLVED AMONIA, pH and CONDUCTIVITY OF GARRI POWER PLANTS OPEN WATER SYSTEMS

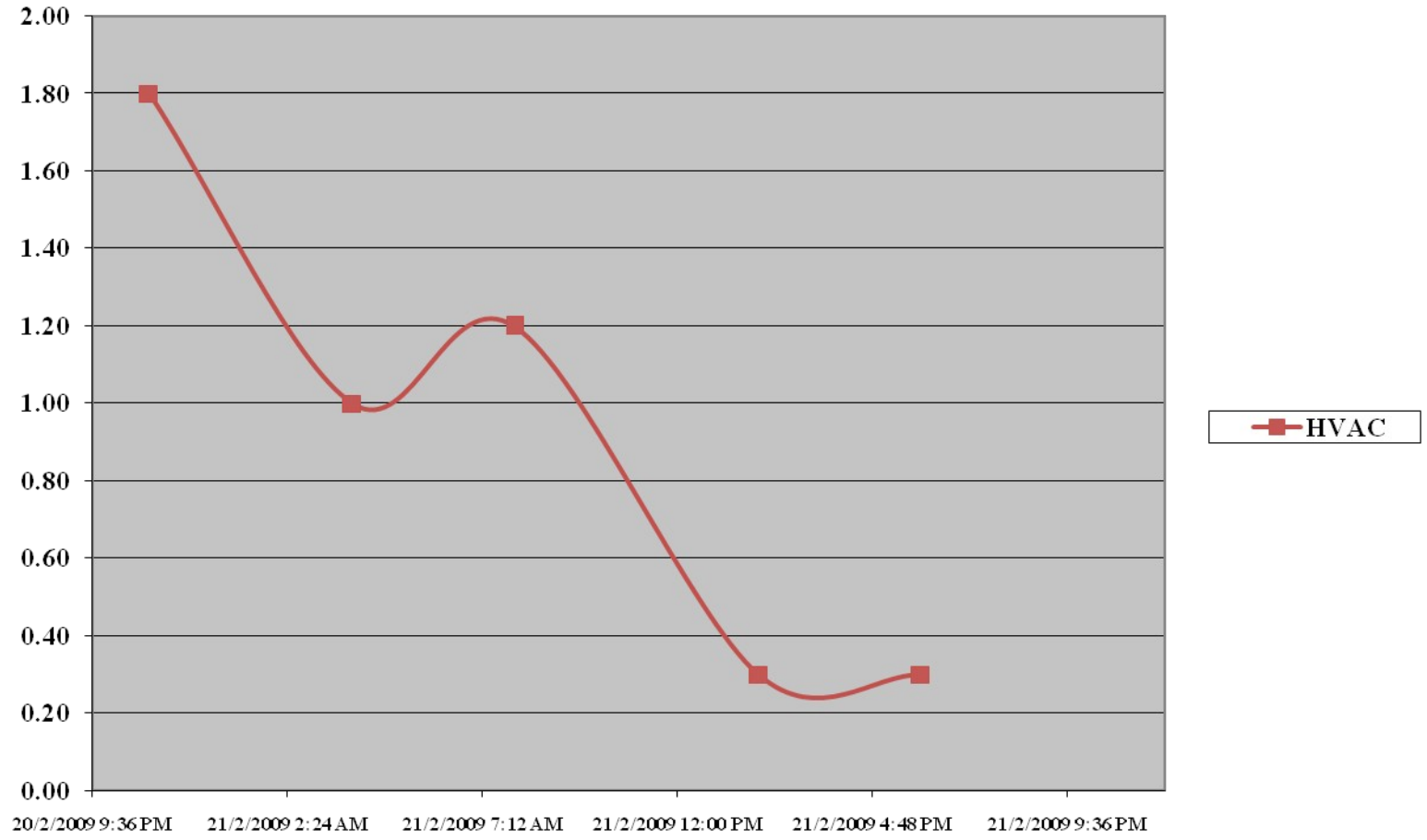


ANALYSIS OF DESOLVED AMONIA, pH and CONDUCTIVITY OF GARRI POWER PLANTS OPEN WATER SYSTEMS



HVAC COOLING WATER SYSTEM IN PLANT 1

Fig. 3.22 NH3 Values HVAC COOLING WATER SYSTEMS



Final water pipe line deposits corrosion analysis by using semi-quantitative Wavelength Dispersive X-ray micro-analysis (WDX)

WDX separates the X-rays by wavelength using a diffracting crystal spectrometer ■

Table 3.13 Analyzed Pipe Wall Deposit Samples:

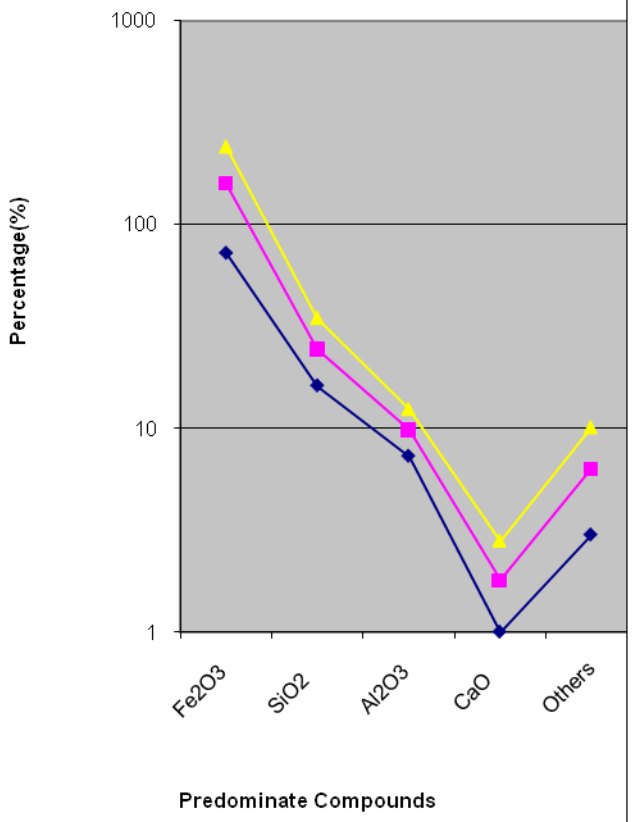
A. Suction pipe of Nile water intake pump on the barge upstream of the Water Pre-Treatment Plant (NEC sample 14).

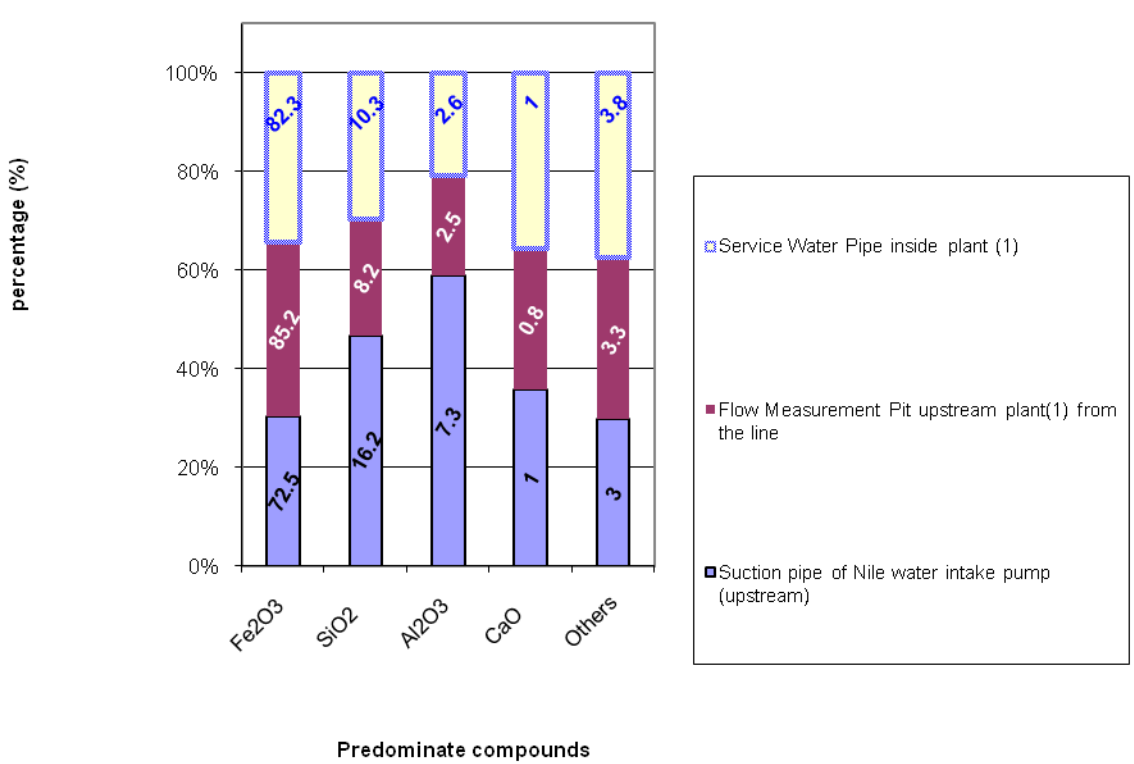
B. Flow measurement pit upstream Plant 1 from line opening on Dec. 31, 2008 (NEC sample 16).

C. Service water pipe inside Plant 1 (NEC sample 7)

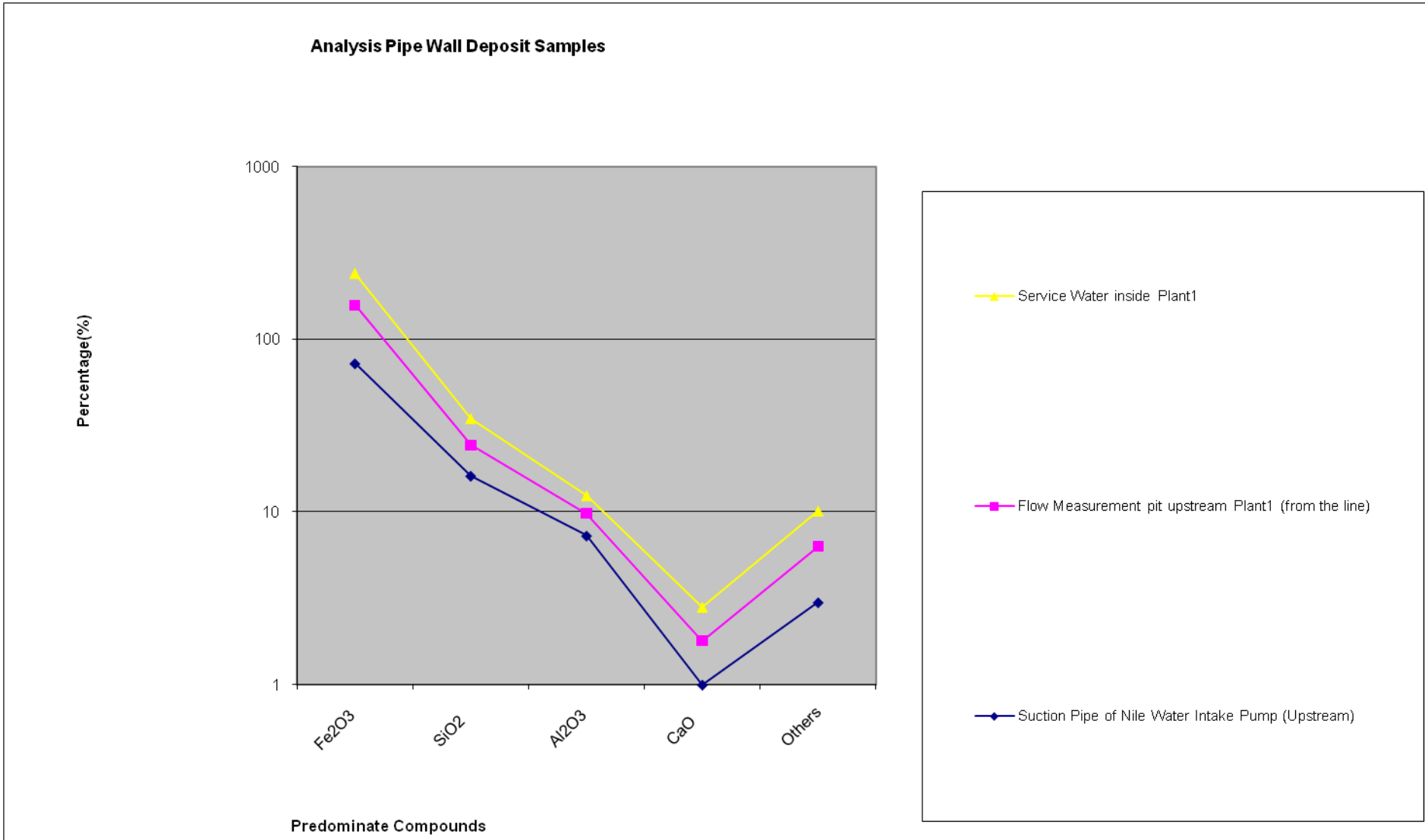
	A [%]	B [%]	C [%]
Fe_2O_3	72.5	85.2	82.3
SiO_2	16.2	8.2	10.3
Al_2O_3	7.3	2.5	2.6
CaO	1	0.8	1
Others	3	3.3	3.8

water pipe line deposits corrosion analysis





Sample locations deposits increase gradually
River site intake pump < pipeline internal wall near power plant < service water inside the power plant



Corrective actions

Cube Test Failure Problem

Corrective actions

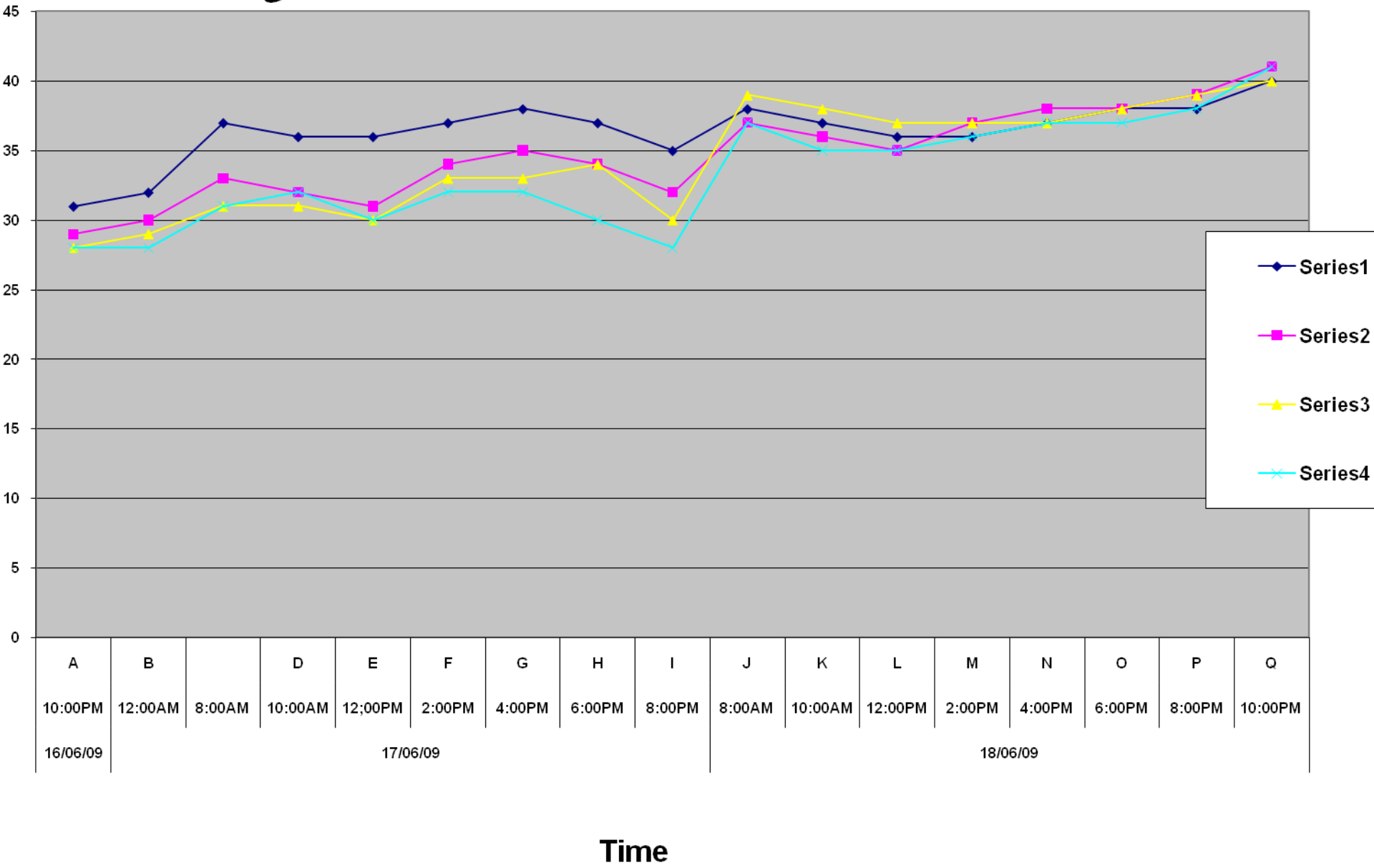
Material Selection

- (1) Changed for material
- (2) Pre-cooling
- 3) Using low alkali-cement. (4) Changed mix design.
- (5) water quality

- Equipments concrete patching plant
- implement regular calibration for batching plant to insure quality.
- Establishment of central laboratory on site.
- Quality control measure

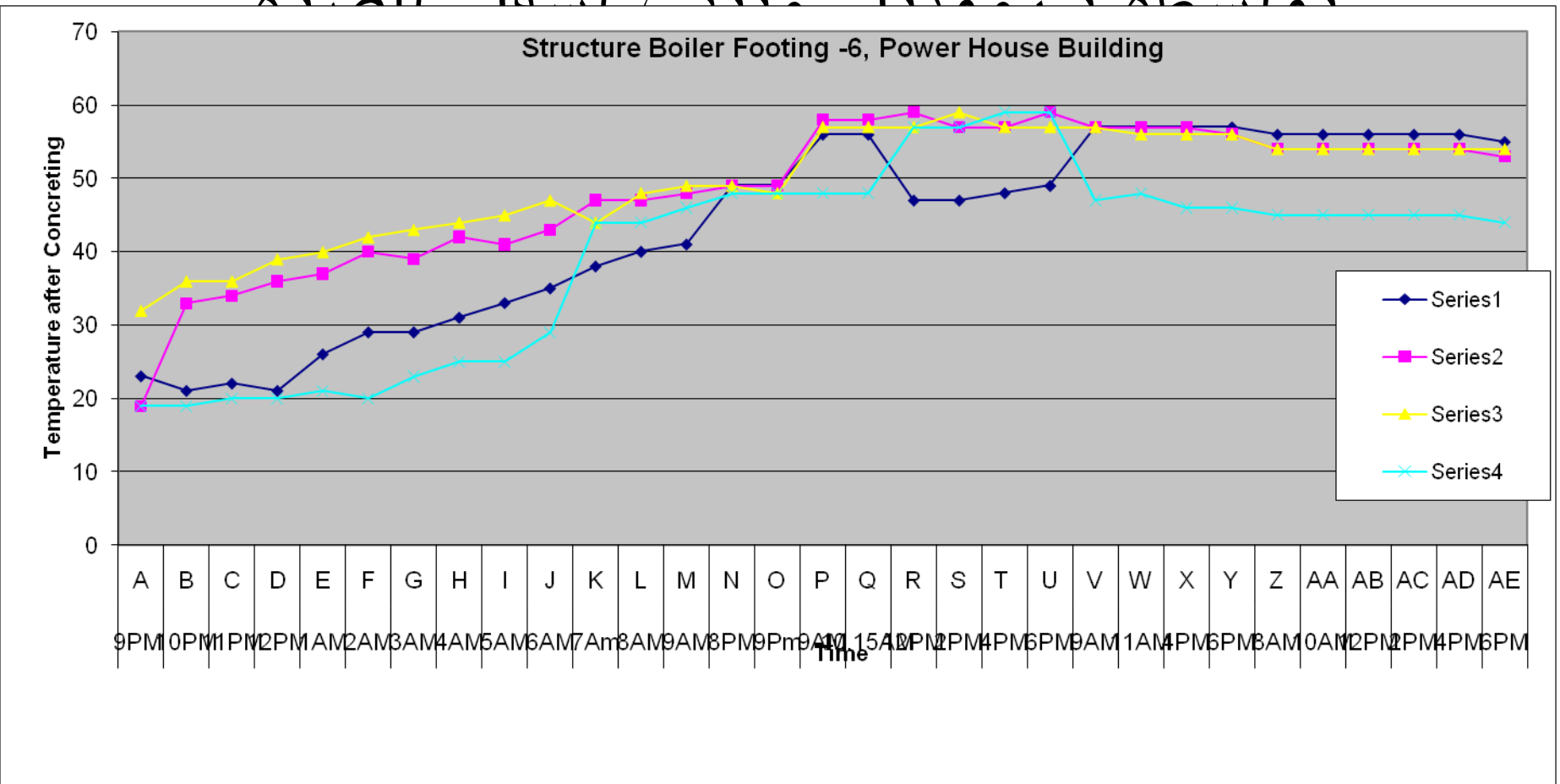
Structure Turbine Generator Raft-4

قراءات درجات الحرارة بالثيرموكبل للقواعد الخرسانية من أعلى الصبة



Concrete Temperature after Reinforced Concrete Cement casting

قراءة درجات الحرارة بواسطة ثيرموكبل مثبت أسفل الصبة



Corrective actions

Ice making unit for cooling mixed concrete

Establishment of central laboratory

failure foundation

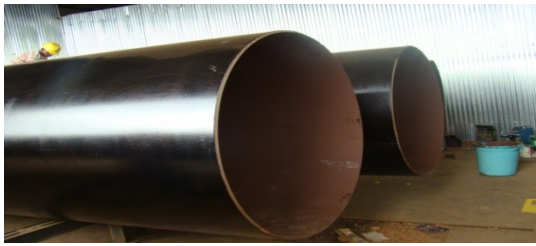










New foundations after corrective actions

Roseris hydro power station Problem

- Environmental corrosion Problem
  - Sulphate bacteria and iron reducing bacteria corrosion types.
  - Hazardous of the Coating materials

Roseris Hydro power station problems solutions

- Use protective coatings
- A very effective control procedure this usually involve physically cleaning production units during shutdown.
- Coating materials hazards , safety measurement should be complied

Hydro Matrix Power Station Jebel Aulia Problems

-Erosion-corrosion

- **galvanic corrosion (**points where dissimilar metals).

Certain factors speed up the rate at which corrosion occurs is; Dissolved solids, Suspended solids and Velocity of water through flow duct.

- **Microbiological** corrosion attack the slings robe and units covers surfaces.

Hydro Matrix Power Station Jebel Aulia Problems solutions

1. **Avoid combinations of a small anode and large cathode**
2. **design thicker anodic parts or make them easy to replace**
3. **Apply coating with caution. Keep the coatings in good repair, particularly coatings on anodes**
4. **Install a third metal that is anodic to the two metals in contact**
5. **Cathodic protection Proper welding materials should be provided and qualified welder is required.**

Microbiological corrosion prevention

Clean all slings robes

- **Brushing very effective**
- **Clean by Hot water temperature ≥ 65ºC**
- **The slings robes should be kept dry**
- **Paint using water proof and corrosion resistant paint three layers**
- **Regular**
- **Remove and scrap any damage robe immediately**
- **Implement and comply safety regulation**
  - **PPE**
  - **permit to work**
  - **confined, cutting and welding.**
  - **working at height Procedures**
  - **Lifting procedure**

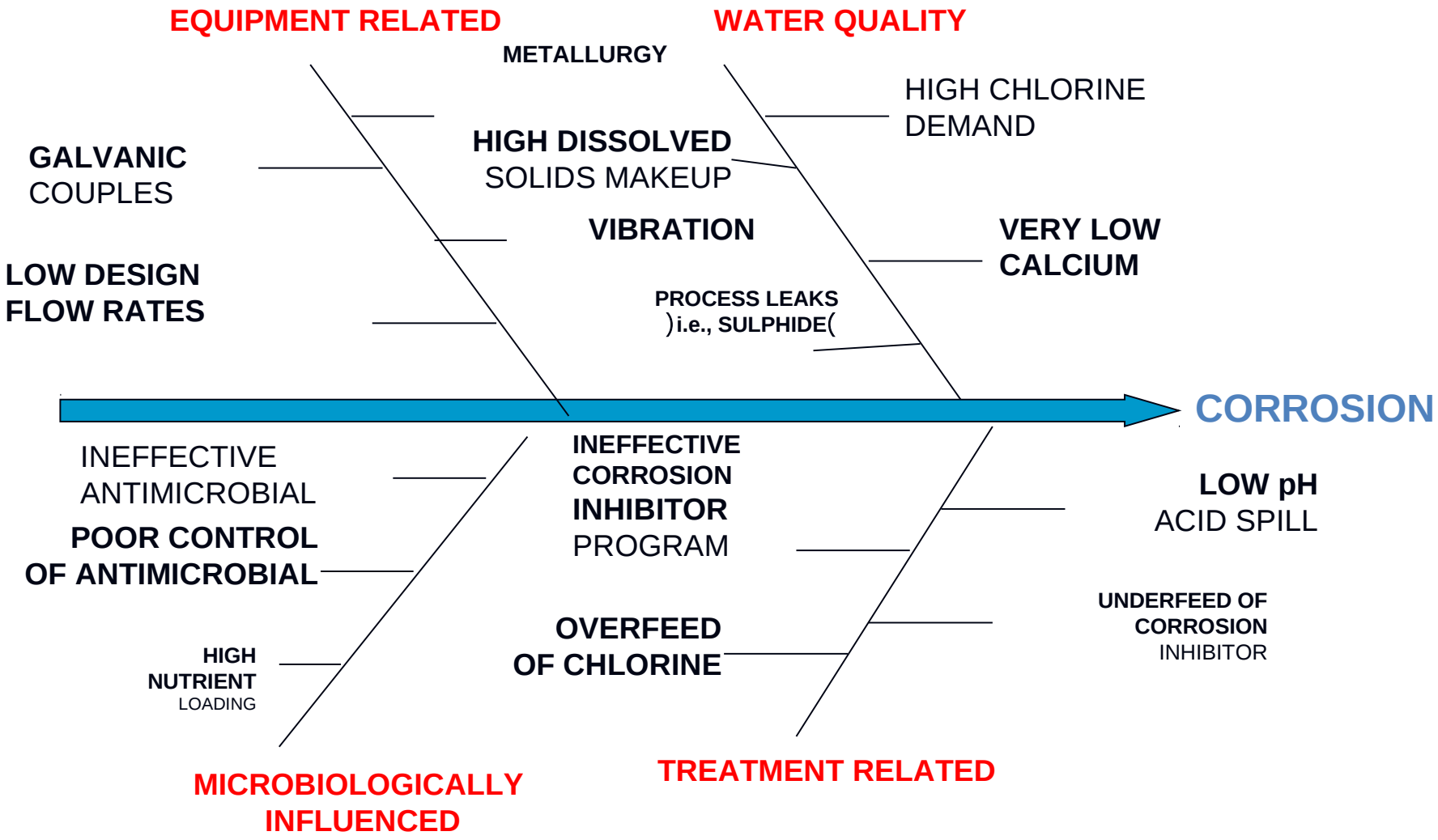
Gas Turbines Hot Gas Path (combustion) Parts Failure due to hot corrosion Solutions

- **Fuel Oil Treatment Plant**
  - reduce the level of Sodium and Potassium salts (as NaCl and KCl)contaminant the fuel to permissible range.
- **Permanent solution**
  - Khartoum Refinery Company concerning fuel , installation of new treatment systems, by injection chemicals; trade name is FOA – 31 A NALCO (Monoethanolamine), through the refining process improving fuel quality.

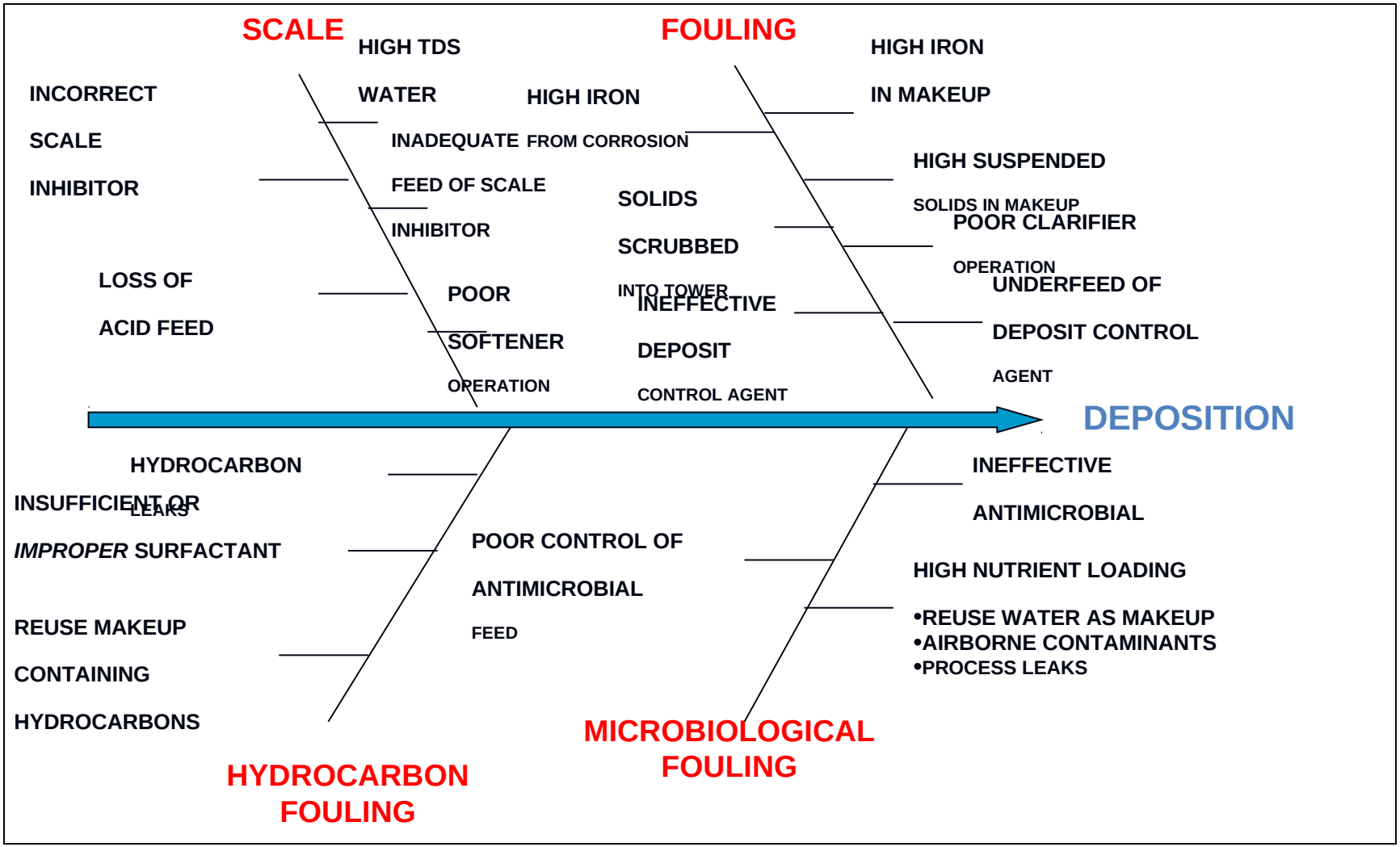
Cooling tower and water quality in Kassala Power Station

- **Microbiological and biofouling control**
  - Rehabilitate the well and the lines
  - Maintain the well microbiologically
  - Chemically clean the piping of the water system
- Closed systems - very little loss of water or chemicals
- using the strongly acidic cation exchange resin system (softener).

Corrosion problems in Garri Combined Cycle P. Plants cooling systems and water supply quality



Deposition


SCALE
HIGH TDS WATER
INCORRECT SCALE INHIBITOR
INADEQUATE FEED OF SCALE INHIBITOR
LOSS OF ACID FEED
POOR SOFTENER OPERATION
FOULING
HIGH IRON IN MAKEUP
HIGH IRON FROM CORROSION
HIGH SUSPENDED SOLIDS IN MAKEUP
SOLIDS SCRUBBED INTO TOWER
POOR CLARIFIER OPERATION
INEFFECTIVE DEPOSIT CONTROL AGENT
UNDERFEED OF DEPOSIT CONTROL AGENT
DEPOSITION
HYDROCARBON INSUFFICIENT OR LEAKS
IMPROPER SURFACTANT
REUSE MAKEUP CONTAINING HYDROCARBONS
POOR CONTROL OF ANTIMICROBIAL FEED
INEFFECTIVE ANTIMICROBIAL
HIGH NUTRIENT LOADING
•REUSE WATER AS MAKEUP
•AIRBORNE CONTAMINANTS
•PROCESS LEAKS
HYDROCARBON FOULING
MICROBIOLOGICAL FOULING

Hidden problems

Types: of Trees penetrate their roots and developed through water pipes (It is an adequate microbiological colonies environment)

The effects of ammonia emission to the environment

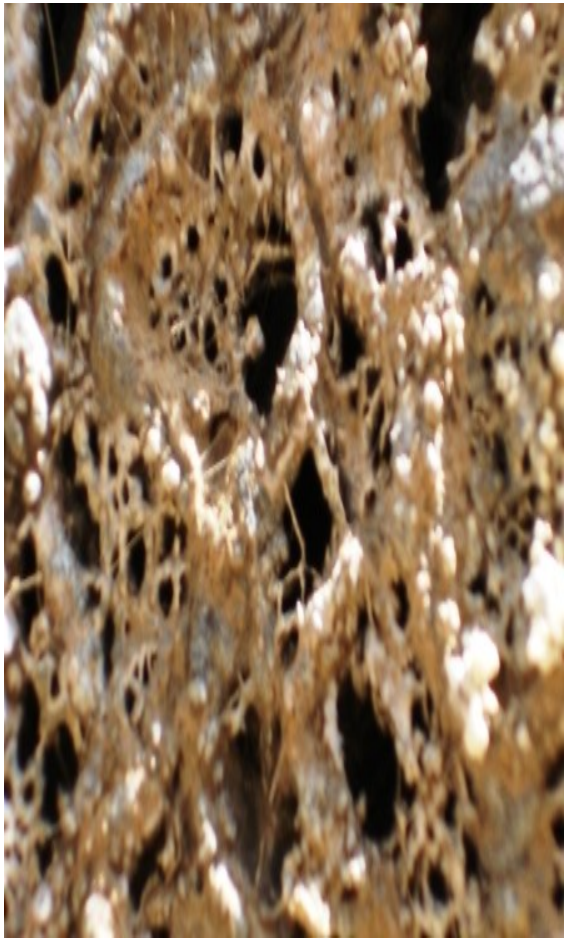
- **Emission monitoring**
  - proper supervision
    - (1) NO_x **i**n flue-gases.
    - (2) SO_2 in flue-gases
- **Sour water treatment in Khartoum Refinery Company**

Monitoring and control of cooling water treatment

- Choice and application of proper treatment chemicals
- Needs to fine-tune treatment programs.
- Continued monitoring is necessary .
- The best program requires good control of cycles, pH, and treatment levels

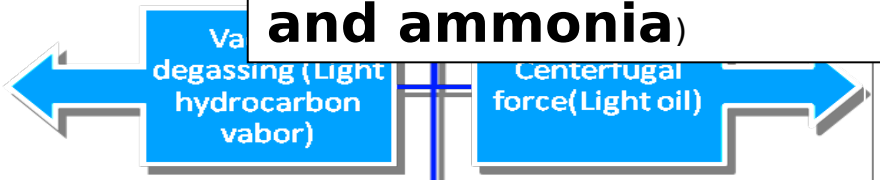
- PFS ($Fe_2(OH)_n(SO_4)_{3-n/2}$) is not recommended to be used as a chemical coagulant in pretreatment.
- Hypo chlorite system should be operated
- Organic phosphates, also called phosphonates can be used to inhibit calcium carbonate scale or other type of scale
- Installation of booster

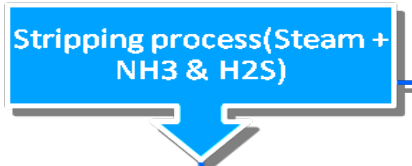
Open system affected by environment pollution



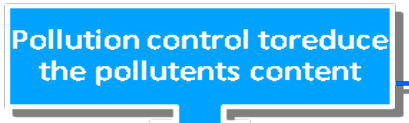
Sour water treatment in Khartoum Refinery Company

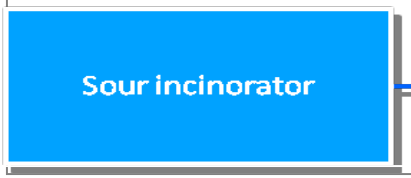
Sour water (This water contains impurities most notably sulphur compounds and ammonia)





Sour water free of light hydrocarbon and light oil





Stripping process (steam + NH_3 and H_2S

Visit Central laboratory in Thailand

Experts from Chemical division Electricity Generation Authority of Thailand and EGCO Engineering and Services Co.ltd. Thailand

Side from EGAT Lab

Future cases studies

1. Analysis of possible anaerobic bacteria microbiologically influenced corrosion (MIC) in industrial equipment failures.
2. Effectiveness of sulphate treatment dose in enhancing microbiological corrosion deposits in cooling water system.
3. The role of chlorine dose for inhibition microbiologically influenced corrosion in industries materials.
4 – Relation between phosphate hideout phenomenon and boiler tubes failures

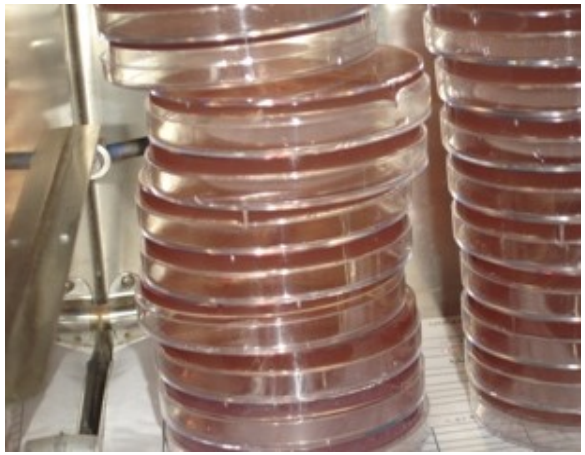
Magnetite film in High pressure drum

The central public health laboratory – Khartoum state received eight water samples from different site collection, for detecting bacteria that cause corrosion for metals .pipelines water

All samples insulated in Luaryle Treptose Broth medium for 48hr. then sub :cultured on MacConky agar and identify the isolated colonies, the results as follow

.No	Site of samples	Isolated organism
1	Kassala power station , makeup water analysis	*Pseudomonas aeruginosa*
2	Kassala power station , cooling tower water analysis	*Enterobacter cloacae*
3	) Garri power station, cooling tower water(1	*Klebsiella pneumoniae*
4	)Garri power station, cooling tower water(2	*Proteus mirabilis*
5	Garri power station, waste water analysis	*Klebsiella terrigena*
6	Garri power station, waste water analysis Pre-treatment plant	*Enterobacter cloacae*
7	Garri power station, Service water line analysis	*Flavimonas aryihabitans*
8	Garri power station, Pre-treatment service water analysis	*Pseudomonas aeruginosa*

Cultures



Experimental for metal alloy rods in corrosive water media since 31 October2009