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South Africa - its future role in Fluorspar beneficiation
Fluorochemicals

- Fluorochemicals – any chemical with a F in the structure.
- Highly specialised branch of chemistry - $18$ bn global industry
- Major markets are refrigerants (fluorocarbons), Aluminium, fluoropolymers (plastics – Teflon).
- Increasing applications due to demand of high performance materials and growth of electronics industry.
- Around 50% of new drugs contain “F”
Introduction to Pelchem

- Pelchem (Pty) Ltd is a 100% subsidiary of Necsa (The South African Nuclear Energy Corporation Limited)
- Corporatised in 2007
- Pelchem’s purpose is to operate, maintain and grow the portfolio of fluorochemical businesses of Necsa, and to play a leading role in the South African Fluorochemical Expansion Initiative (FEI)
- Preserve HF and F2 technologies for a future South African nuclear program
- Turnover R170m, Staff = 150 , Engineers & Scientist = 4
The fuel rods are used in nuclear reactors to generate electricity.

Nuclear waste in different processes including spent fuel is treated and either reprocessed or disposed off permanently.

Yellow cake \([\text{(NH}_4\text{)}_2\text{U}_2\text{O}_7]\) is converted to uranium tetrafluoride \((\text{UF}_4)\) hydrofluorination \((\text{HF})\) and then to uranium hexafluoride \((\text{UF}_6)\) by fluorination \((\text{F}_2)\).

Enriched \(\text{UF}_6\) is changed to uranium dioxide \((\text{UO}_2)\) and then fabricated into rods.

Uranium ore concentration known as yellow cake is produced.

The amount of \(^{235}\text{U}\) isotope is increased from 0.7% to between 2 and 5%.
Hydrofluoric acid plant

**Hydrofluoric Acid Production**

Reagents: Sulphuric acid, fluorspar ore

Products: Anhydrous hydrogen fluoride, hydrofluoric acid

Markets: Petroleum alkylation, stainless steel, mining, industrial chemicals
Fluorine gas (F$_2$) plant

Fluorine Gas Production

**Reagents:** Potassium bifluoride, hydrogen fluoride, electricity  
**Products:** Fluorine gas on line, compressed fluorine cylinders, fluorine & nitrogen gas mixtures  
**Markets:** Pharmaceutical, laser gas mixtures, semiconductor gases, plastic surface fluorination
Nitrogen fluoride (NF$_3$) plant

Nitrogen Trifluoride Production
Reagents: Ammonium bifluoride, ammonia gas, fluorine gas
Products: Nitrogen trifluoride
Markets: Semiconductor, LCD screens, electronics, solar energy panels
Fluoro organics plant

**Fluoro Organic Compound Production**

**Reagents:** Organic intermediates, fluorine gas  
**Products:** Fluoro organic monomer  
**Markets:** Low temperature fluoro-elastomer to automotive and space industry
Xenon difluoride (XeF$_2$) plant

Xenon Difluoride Production
Reagents: Xenon gas, fluorine gas
Products: Xenondifluoride
Markets: MEMS, display panels, consumer electronics
South Africa’s fluorspar reserves exceed 41 million tons – 2\textsuperscript{nd} largest in the world behind China.

SA supplies more than 10% F-source to the $16bn global fluorochemical industry but earns <0.5% of this revenue.

Under 5% of SA fluorspar is beneficiated locally (by Pelchem).

FEI will address this by expanding the fluorochemical capabilities & skills base at Pelchem, derived from the previous nuclear fuel program, into world class industries for local and export markets.
South Africa’s track record

- XeF$_2$ – world’s first commercial plant – 2008 - success
- NF$_3$ plant developed, designed, built and commissioned – 2003 - success
- Fluorochemical monomer DY02P – unique process – success
- Direct fluorination plant – patented technology - 2000 – success
- Surface fluorination technology - patented – success
- Multiproduct fluoride salts production - success
- Fluorine plant – only one in Southern Hemisphere & Africa - success
- HF plant - 1984– supplies SA’s total demand– success
- Necn UF$_4$ and UF$_6$ production
- AECI HF plant & Refrigerant manufacturing (CFCs, HCFCs)
12.6.5 Investigate opportunities for downstream beneficiation of fluorspar
Nature of the intervention: The establishment of the Hydrofluoric acid (HF) / Aluminium Trifluoride (ATF) plant is the first step in developing a world class fluorochemical industry in South Africa.
**SA Fluorochemical value chain**

**STRENGTHS**
- large & rich fluorspar reserves
- specialised know-how exists
- footprint in first world markets

**OPPORTUNITIES**
- high value added products
- replace imports, expand exports
- impact on chemical trade deficit
- high level skills development
- foreign direct investment

**SA Fluorochemical value chain**

**Fluorspar**
- SA mineral
- <0.5$/kg

**Fluorine**
- >20$/kg

**Hydrogen Fluoride**
- ~2$/kg

**Fluorochemical products**
- >50 USD/kg

**Local and export**
- Industrial/Consumer goods
  - >R20bn/yr
- R1.5bn/yr

**Indirect**
- Industrial/Consumer goods
  - >R20bn/yr

**R35m/yr**

* Based only for a 5,000 tons/yr HF production
Government intervention

- The dti
  - Market studies
  - Policies
  - Trade delegations, facilitate global networking
  - International agreements
  - Incentives
  - Commercialisation

- The DST
  - R&D support
  - Patenting
  - Pilot plants
  - Technology transfer & localization
  - Establishment of Research Chairs (NRF), Centers of Competence
FEI Rollout Plan

- Terms of Reference
- Prefeasibility & Feasibility studies
  - R5m by DST & the dti for HF/ATF (MOA)
- Technology expansion and capacity building
- Technology Refresh
- Skills Development
- DST R30m grant for R&D (2008/9 - 2010/11) + ~kR530 grant for an internship program (2010/11)
- R31m DST grant (2009)
- Per Project Rollout
  - HF/ATF (Sephaku)
  - LiPF₆
  - NdF₃
  - New refrigerants
  - etc
- Multi-Purpose Pilot Plant (MFPP)
- Technology & Market Verification
- Commercialisation

DST, Pelchem, Necsa, UKZN, UP

the dti

Deloitte study
Lithium Ion batteries for energy storage (electrical vehicles, wind, etc)
- electrolytes
- fluoropolymers
- surface fluorination technologies

Super magnets (Neodymium)
- Wind turbine generators
- Electrical vehicle motors
Solar panel manufacturing
- F2 and NF3 as chamber cleaning gases (thin film)
- Fluoropolymer coatings

Specialised F-based solvents
- replaces hazardous & flammable substances
- eliminates emissions

Surface fluorination
- eliminates emissions
Value Chain: Fluoropolymers

- Crude Oil or Coal → Hydrocarbon Polymers
- NaCl → Cl₂
- Chlorocarbon
  - VDF (C₂F₂H₂)
  - HF → Fluorspar
- PVDF
- Lightweight audio Transducers
- Medical applications
- Electrical wire insulation and jacketing
Value Chain: Exotic Metals (Tantalum)

- Tantalum Ore
  - Ta$_2$O$_3$ (Crude)
  - TaF$_5$
    - Ta$_2$O$_3$ (Pure)
      - K$_2$TaF$_7$
        - Ta metal
          - Capacitors
          - Surgical instruments
          - >90%
          - Medical implants
Value Chain: F-containing pharma

- Fluorspar
- HF
- F₂
- Organic Substrates
- Fluorination Technique to give F-Organic compound
- F-Containing API
- Formulation
- F-Containing Pharmaceutical Tablets
Surface fluorination

Crude Oil Or Coal → Hydrocarbon Monomers → Hydrocarbon Polymers

Plastic containers, piping and components → Surface Fluorinated products

Improved resistance to permeability by organic solvents

Fluorspar → HF → F₂

Packaging (Agrochemicals, solvents)

Automotive Components (Fuel tanks, bumpers)

Fuel Industry (piping)
Value Chain: Performance fluoro-organics

- Crude Oil or Coal
  - Hydrocarbons
    - Hydrofluoric Acid (HF)
    - Fluorspar
      - Organic Substrate (1)
        - Partially Fluorinated Compounds
          - Direct Fluorination
          - Partially Fluorinated Compounds
            - Electrochemical Fluorination
              - Organic Substrate (2)
                - Hydrocarbons

- Fire Fighting
- Insulation
- Cosmetics
- Electrical
- Electronics
- Heat transfer fluids
- Refrigerants
- Medical gases
- Etc...
- Pharma
**Value Chain: Fluorinated Anaesthetic gases**

**Local market estimated at 150 tons/yr, Turnover >R300m**
Local public healthcare system slow to embrace these new and improved products likely due to high import prices.

- **Organic Reagent**
- **Fluorinated anaesthetic gases produced at Pelchem**
  - $\text{F}_2$
- **Packaging and specialised delivery units**
- **Export**
- **Local Private Healthcare**
- **Local Public Healthcare**

Currently all of these are imported.
Value Chain: Rare Earth Fluorides ($\text{NdF}_3$)

- Neodymium ore processing
  - Steenkampskraal Mine (W. Cape)
- Fluorspar
- HF
- Fluoride conversion at Pelchem

Neodymium is one of 17 metals crucial to advance green technology. China produces 97% of the world’s supply - and they’re not selling

- $\text{Nd}_2\text{O}_3$
- Nd metal
- $\text{NdF}_3$

- Nd magnets (supermagnets)
  - Cordless electrical equipment
  - Computer Hard Drives
  - Electrical vehicle motor
  - Wind turbine generators

Toyota Prius uses 1kg Nd magnet per motor
Lithium ion batteries

Lithium mining & processing

Li Cathode Material

Li Electrolyte Salt LiPF$_6$ produced at Pelchem

Aluminium Casing

Carbon Anode

Other Materials

F$_2$

HF

Fluorspar

Consumer electronics & electrical products

Li - ion Battery

Electrical vehicle

Ford Tesla uses 450kg Li ion battery pack
NF₃ supporting Solar Build

Ammonia NH₃

F₂

NF₃ production at Pelchem

Pelchem’s existing technology

New cost effective technology

Semiconductor chamber cleaning
- LCD’s
- Chip Manufacturing

Thin film solar panel chamber cleaning

Fluorspar

700 – 1,000 kg NF₃ per MW solar ≈ 2,000 ton NF₃ for 2GW (SA new built)
Fluoropolymers are the new range of plastics finding increasing uses in a wide range of applications including energy sector (solar, electrical generation & transmission), health, clothing, automotive, construction, etc.

Currently all of these materials are imported either as a resin or as finished products.

Pelchem plans to set-up a plant to produce these resins in South Africa for both the local and export markets.

The focus will be on the high value and newer products.

Significant job creation, exports and import replacements.

Resin manufacturing will stimulate a host of spin off industries in the country.
Thank You!!!