Uranium Unconventional Resources in Brazil

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Uranium Geological Resources

Deposits	t of U3O8		
	Measured/Indicated	Inferred	Total
Caetite/Lagoa Real	94,000	6,700	100,770
Santa Quiteria	91,200	51,300	142,500
Others	39,500	26,600	66,100
Total	224,700	84,670	309,370
Prognosticated: Pitinga (AM): 150,000 Rio Cristalino (PA): 150,000			
Estimated: 500,000			

Brazilian Nuclear Program

Scenario	Power Generation (MW)	Lifetime (years)	Consumption (t U3O8)	
			Annual	Total
Present Situation				
Angra 1	600	30	150	4,500
Angra 2	1,300	50	270	13,500
Planned				
Angra 3	1,300	60	270	16,200
4 New Power Plants	1,000	60	230 (each)	55,200
3 Angra NPP + 4 New Reactors				89,400

Production of Uranium Concentrate

- Lagoa Real Project:
  - Uranium Production: 400 t/year
  - Forecast for 2011: 800 t/year

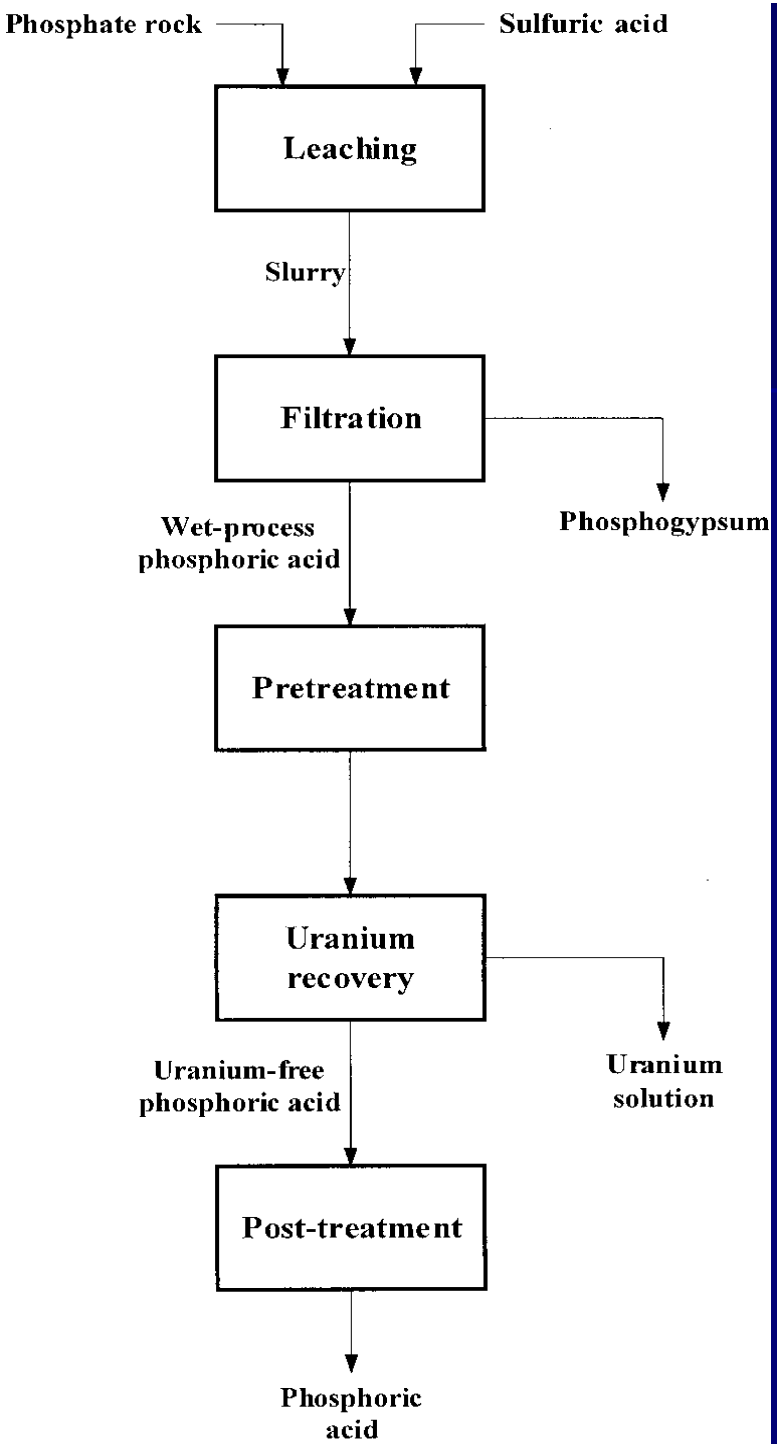
- Santa Quiteria Project (exploitation of the phosphate-uranium deposit)
  - Average contents: 11% P_2O_5 and 0.1% U_3O_8
  - Reserves: Phosphate 9 million t P_2O_5
  - Uranium: 80 000 t U_3O_8
  - Uranium production – 1,500 t/year
  - Entry in production - 2012

Overall Balance

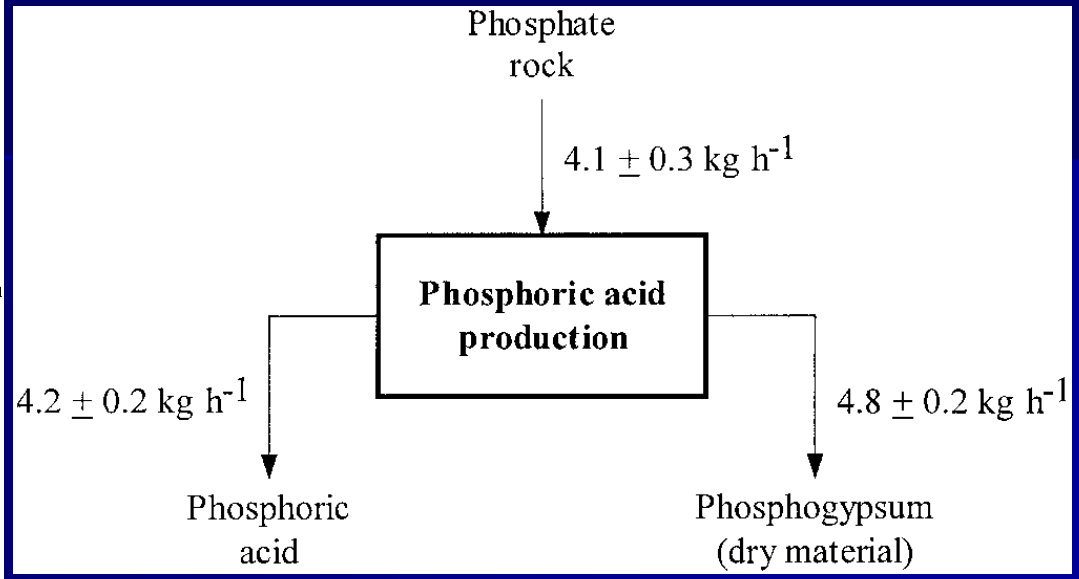
Year - Production	Consumption	Balance
2009 – 400	420 (2NPP)	-20
2010 – 400	420 (2NPP)	-20
2011 – 800	420 (2NPP)	+ 380
2012 – 2300	420 (2 NPP)	+ 1880
2014 – 2300	690	+ 1610
2019 – 2300	920	+ 1380
2021 – 2300	1150	+ 1150
2023 - 2300	1380	+ 920
2025 - 2300	1610	+ 690

Santa Quiteria Project

- the mineralization is concordant with the main metamorphic foliation/banding of the host rocks crosscutting small bodies;
- the ore occurs as thick bodies (up to tens of meters) of massive collophanite (microcrystalline apatite) and as collophanite disseminated in the carbonate and migmatitic paragneiss associations
- grades: collophanite (U_3O_8=0.19%, P_2O_5=26.35%), carbonaceous breccia (U_3O_8=0.63%, P_2O_5=11.23%);
- reserves: 142,500 tons of U_3O_8, 64% of which is measured ore. The phosphate reserves are ca. 100 times larger;
- genesis: uncertain, probably related to hydrothermal and metasomatic fluids from deep alkaline or granitoid intrusions. Alternatively, re-concentrations resulted from metamorphism and deformation or even from supergenic remobilizations.



Flow chart of phosphate rock milling processes



Main flows in the phosphoric acid production.

Process

- Phosphoric acid is to be produced by a wet-process using the dihydrate method. The phosphate rock was reacted with sulfuric acid (73%w/w) in a leaching reactor operating continuously with a residence time of 5 h.
- The slurry produced is a mixture of phosphoric acid and dihydrated calcium sulfate (phosphogypsum). SO4 concentration (25–35 g L−1) and P_2O_5 concentration (27%–30%) was controlled by returning a portion of the phosphoric acid produced, which was separated from the phosphogypsum by a filtration step. The com
- $Ca_{10}(PO_4)6F_2+10H_2SO_4+20H_2O\rightarrow$ 10 $CaSO_4$ ·$2H_2O+6H_3PO_4+2HF$
- The uranium was recovered from the oxidized phosphoric acid by solvent extraction in a counter-current mixer-settler system, using an organic solvent consisting of DEHPA (di-2- ethylhexyl phosphoric acid) and TOPO (tri-octyl phosphine oxide) in an aliphatic diluent (kerosene).

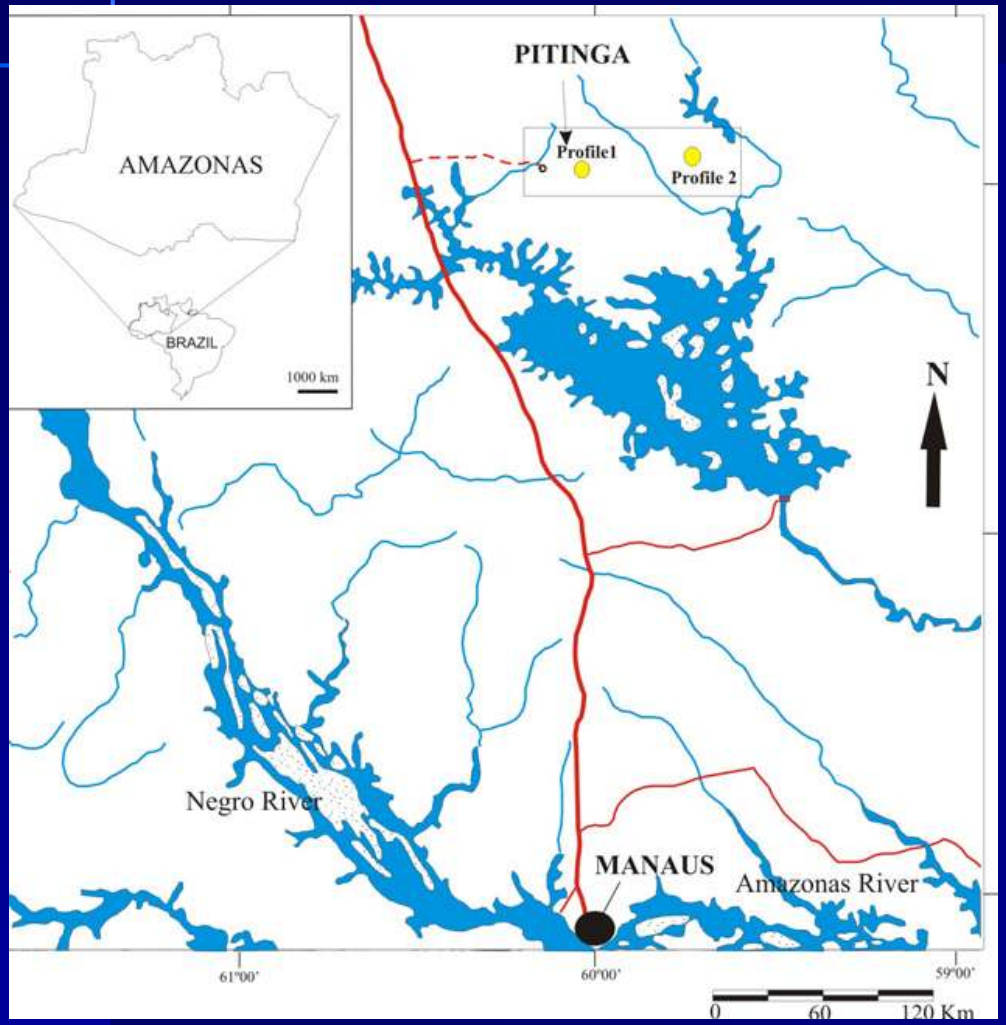
Chemical Analysis of Materials in the Phosphate Rock Milling Process

Species	Concentration (%)			
	Phosphate rock	Phosphogypsum	Phosphoric acid	U-free phosphoric acid
P_2O_5	28.2	0.61	27.9	27.6
U_3O_8	0.179	0.0036 (^{238}U – 0.4 Bq.g^{-1})	0.173 (^{238}U – 18.0 Bq.g^{-1})	< 0.0002 (^{238}U < 0.02 Bq.g^{-1})
ThO_2	0.014	0.0007	0.0135	0.0135
CaO	40.7	31	0.055	-
SO_4	0.46	54	2.0	-
F^-	1.7	0.35	1.08	-

Uranium Associated with REE-minerals

- The Brazilian resources of rare earth's were studied and classified by CETEM/CNPq, into four categories:
  - 1) Deposits under production - marine placers in Rio de Janeiro and Bahia;
  - 2) Deposits economically feasible - fluvial placers in **Pitinga** (AM) (as byproduct of tin, zirconium and tantalum-niobium), and Rio do Sapucaí (MG) (byproduct of zirconium, titanium, and gold); lateritic soils in Tapira (MG) (byproduct of titanium) and marine placers in Bahia, Ceará, Piauí (monazite as byproduct of ilmenite, zirconite and rutile);
  - 3) Deposits for which economic feasibility has not yet been determined and where rare earth's are the main product: in Córrego do Garimpo, Catalão (GO), Morro do Ferro, Poços de Caldas (MG), "Área Zero", Araxá (MG) and Mato Preto (PR);
  - 4) Other deposits not yet explored, with rare earth's as byproduct's.

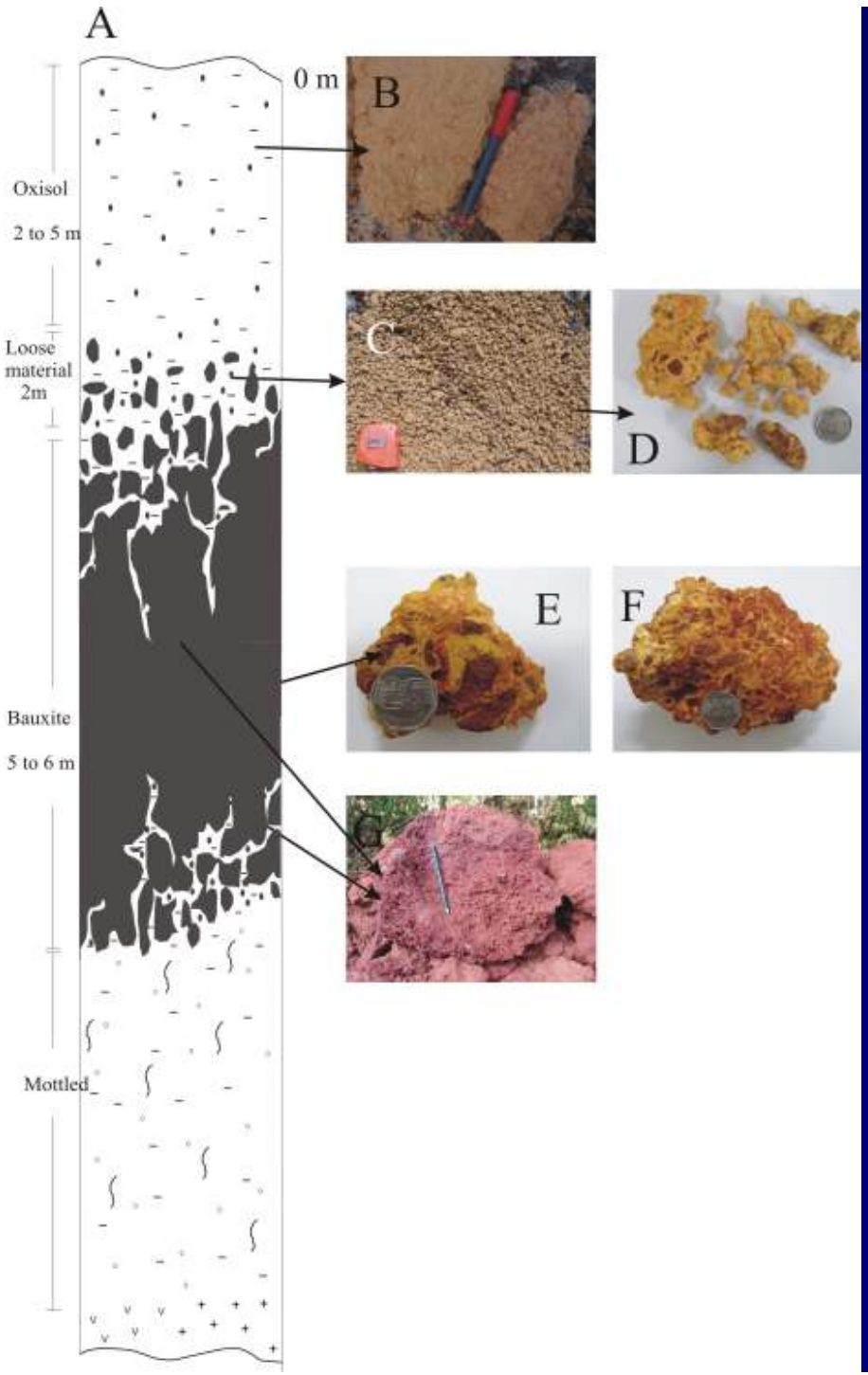
Pitinga Project



Location of the studied profiles in Pitinga mine

- The Pitinga mine, situated approximately 300 km from Manaus city, hosts the main Sn, REE minerals (Zr, Nb, Th, Ta, Y and REE) and cryolite deposits of Brazil.
- In the Pitinga region, Sn deposits are associated with bauxite

- Mineracao Taboca SA, the Brazilian-based tin mining and processing subsidiary of Peru's Minsur, is looking to generate revenue from rare earths as well as tin, niobium and tantalum.
- Minsur acquired the operation for 850 million reais (US$374 million). Pitinga produced 6,257 tonnes of tin-in-concentrate last year.



•The geochemical characteristics of each profile are directly related to the parent rock since they were formed under similar weathering and good drainage conditions that promote the leaching of Si, Ca, Na, K, and Mg, and alteration of kaolinite to gibbsite.

•The trace elements (Zr, Th, Nb, Ga, Hf, Y, Sn, Sc, W, Pb, Ta, U and REE) associated with resistant minerals increase towards the Oxisol surface.

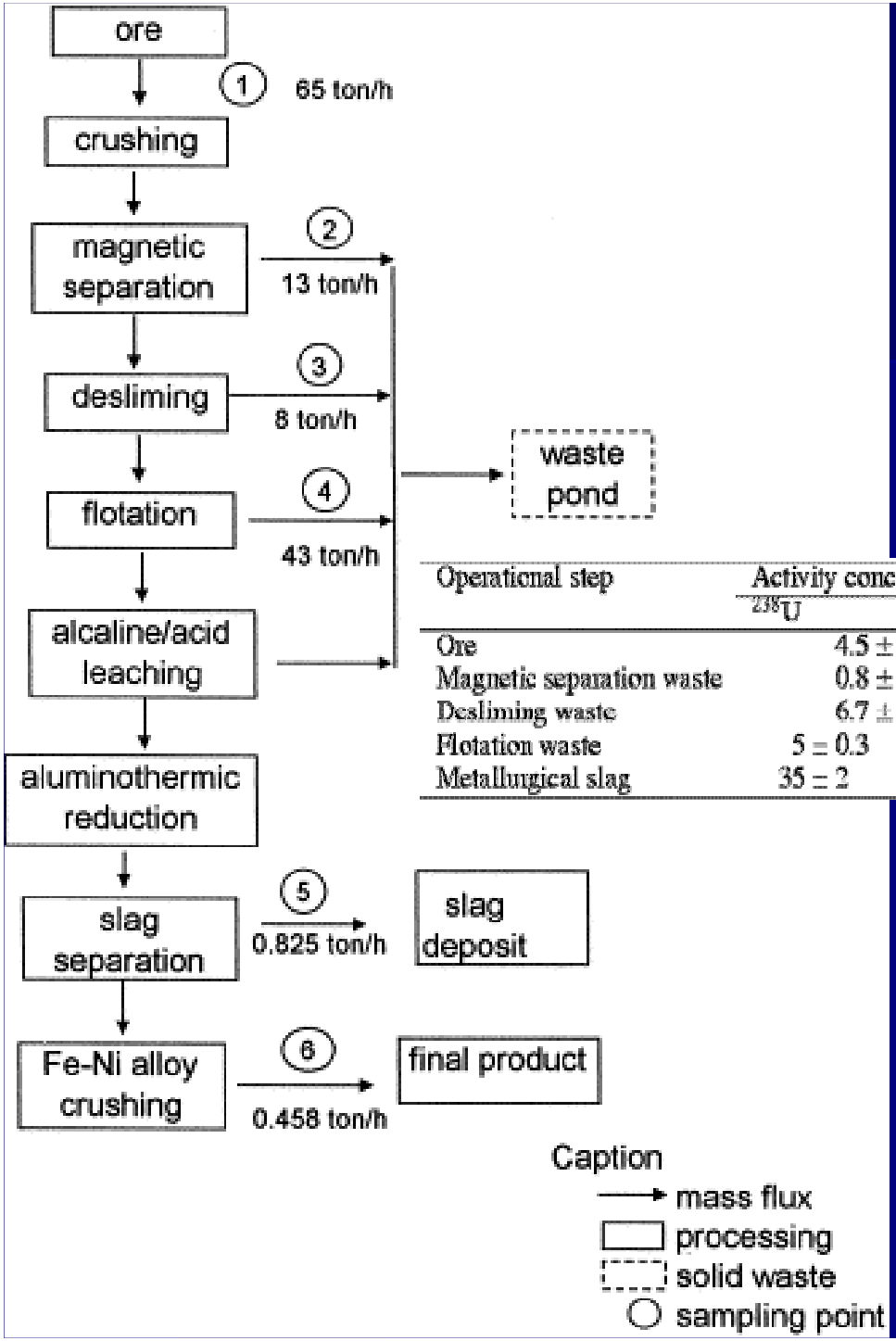
A- Bauxite profile of Pitinga region, field photograph of B- Oxisol, C- Loose material, D- detail of the nodules and pisoliths, E and F - portions with ferruginous nodules and pisolith, G- massive bauxite

Pitinga Project (cont.)

- The production capacity would be 240t/y. The mining group will supply INB with uranium by-products from its mine;
- INB will use its technology to refine the uranium and will take on operational costs such as transport, while the Pintinga project owner would invest US$5.2mn to install a commercial treatment unit.

Buena Project

- The Physical Ore Treatment Unit in Buena, owned by INB-Indústrias Nucleares do Brasil, located in the district of São Francisco de Itabapoana/RJ, has the capacity to produce 5 thousand tons/month of heavy minerals concentrate.
- The unit of secondary treatment produced in 2001, 6,129 tons of ilmenite, 9,090 tons of zirconite, 591 tons of rutile, but no monazite (RE).
- The byproduct ilmeno-monazite obtained at the secondary treatment unit was stockpiled for future processing at the Monazite Chemical Treatment Unit, at Pocos de Caldas Novas/MG.
- This Unit is ready for operation and is just awaiting the necessary environmental licenses. Its nominal capacity will be 1,560 tons/year of latanium chloride solution and 360 tons/year of cerium hydroxide.
- Also in the Buena Unit's The solvent extraction pilot plant at the Buena's Unit remains closed down.



Flowchart of the operational process of a niobium industry in Brazil

Operational step	Activity concentration (kBq/kg)				
	^{238}U	^{226}Ra	^{210}Pb	^{232}Th	^{228}Ra
Ore	4.5 ± 0.3	3.4 ± 0.3	8 ± 1	0.9 ± 0.09	2 ± 0.3
Magnetic separation waste	0.8 ± 0.06	0.9 ± 0.1	1.7 ± 0.3	0.3 ± 0.03	0.3 ± 0.1
Desliming waste	6.7 ± 0.1	6.9 ± 0.4	6.2 ± 0.9	1.7 ± 0.2	3 ± 0.4
Flotation waste	5 ± 0.3	3.4 ± 0.3	7.5 ± 1	1 ± 0.1	1.8 ± 0.3
Metallurgical slag	35 ± 2	5 ± 0.3	0.4 ± 0.1	17 ± 2	6.4 ± 0.9

- Approximately 150 t ^{238}U could be potentially recovered yearly from the floatation waste

General Issues

- INB is a state-owned company
- Nuclear material is monopoly of the State
- Recovery of Uranium from Unconventional sources requires legal arrangements. Partnerships have to be built
- This is a challenge for regulators – Santa Quiteria Project: CNEN regulates the milling process

Conclusion

- With the present and planned production Brazil will be able to sustain its internal consumption 3 Angra NPP's + 4 (most probable scenario);
- Different opinions prevail in the Government about exportation;
- Exports of uranium concentrate do not seem to be the preferred option
- No probable scenario for privatization of uranium production
- Unconventional resources do not seem that will be exploited in addition to Santa Quiteria