Seawater Uranium Extraction
Technology Development
and
Cost Analysis

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OUTLINE

Uranium Resource in Seawater

Amidoxime Adsorbent

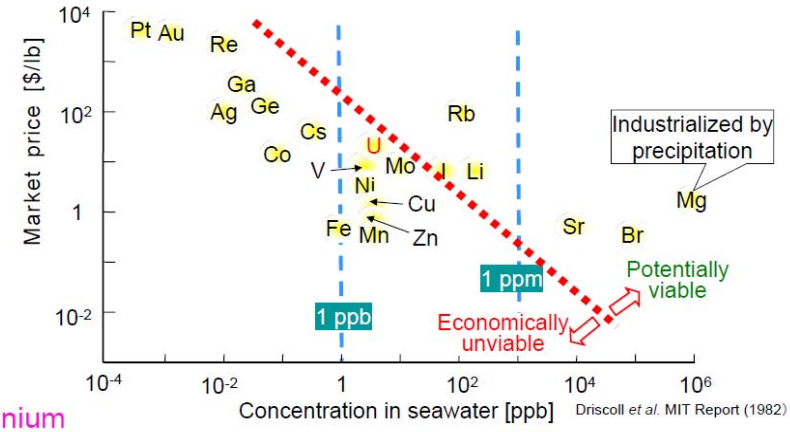
Marine Experiment of Adsorbent Fabric

R&D of Braid Adsorbent for Cost Reduction

Cost Analysis

Mineral resources in Seawater

Cost-effectiveness of minerals in seawater



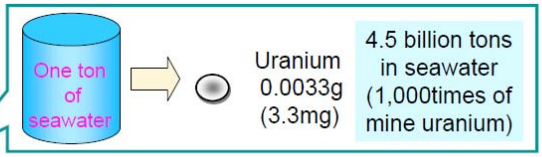
Driscoll *et al.* MIT Report (1982)

Uranium

- 3.3 ppb in seawater
- near boundary of cost-effectiveness

Commercialization of uranium collection from seawater:
How do we develop a cost-effective methods?

Uranium Resource in Seawater

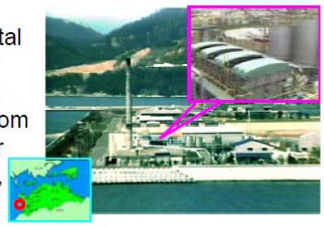


Resources with Japan current 5.2×10^6 t/y $\xrightarrow{\sim 0.2\%}$ Demand of Japan in a year 8×10^3 t/y

1960s
Uranium collection with Hydrous titanium oxide adsorbent

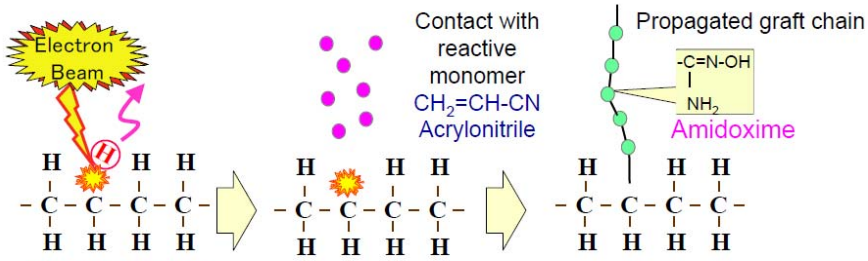
Atomic Energy Research Establishment near Harwell, United Kingdom

1973
Experimental Plant for Uranium collection from Seawater (Kagawa, Japan)



Radiation-induced Graft Polymerization

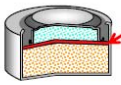
Imparting desired functional group into trunk polymer



Polyethylene
High mechanical strength

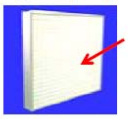
Uranium adsorbent

Industrial applications of graft polymerization



Electro conductive diaphragm membrane

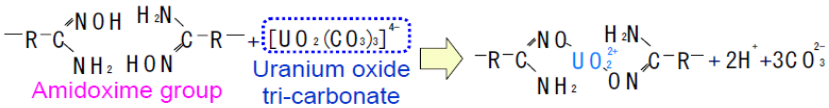
Button shaped buttery



NH_3 gas adsorbent for semiconductor factory

Air purification filter

Characteristic of Amidoxime Adsorbent

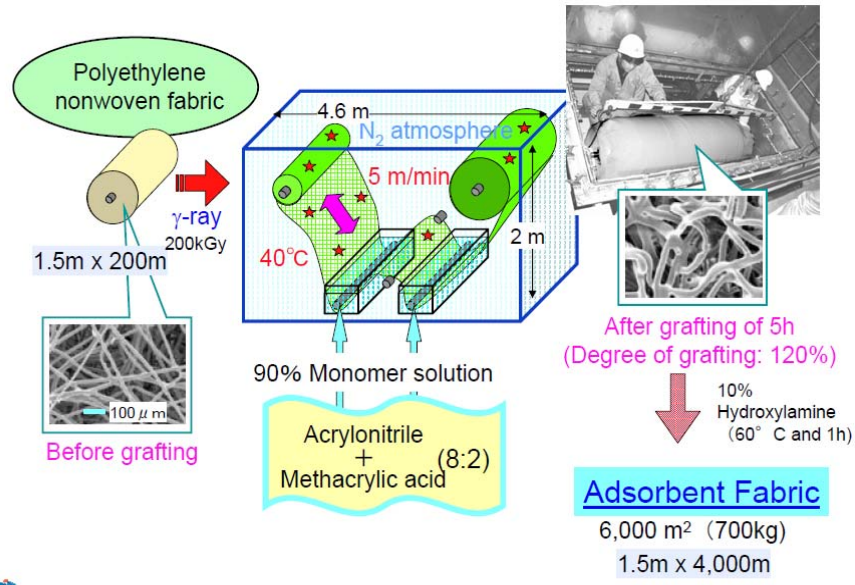


Selectivity of amidoxime adsorbent

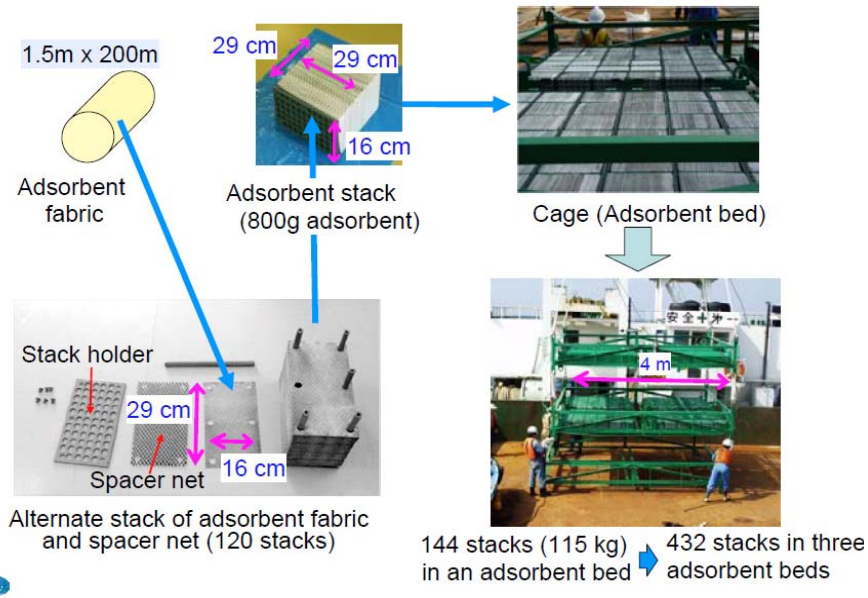
Elements	Concentration in seawater[a] [μg/L]	Concentration in adsorbent[b] [μg/g-ad]	Distribution coefficient (b/1000a)
Na	1.08×10^7	618.5	0.057
K	3.80×10^5	45.9	0.12
Al	2	86.94	4.35×10^3
Pb	0.03	108.82	3.62×10^6
Ti	1	1.49	1.49×10^3
Fe	2	414.44	2.07×10^5
Co	0.05	23.57	4.71×10^5
Ni	1.7	78.17	4.60×10^4
U	3.2	63.72	1.99×10^4

Adsorption conditions:0.2g adsorbent 25℃、3L/min seawater, and 7 days.

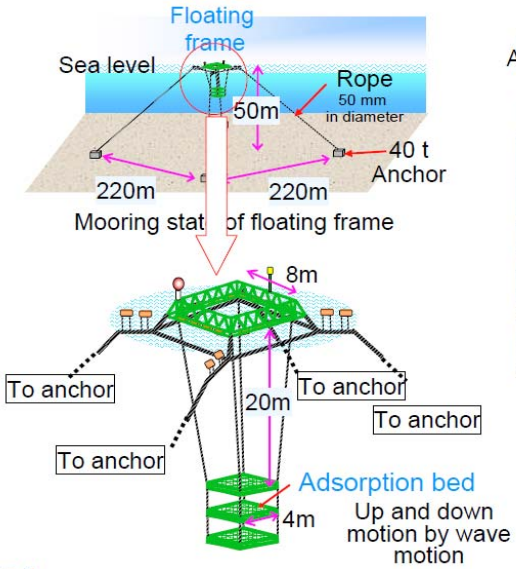
Mass Production of Adsorbent Fabric

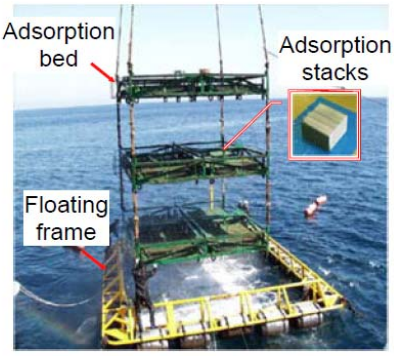


Adsorbent Fabric Stacks & Cages



Marine Experiment Offshore of Sekinehama





Drawing up of adsorption bed packed with adsorbent stacks at northern sea in Japan

(350 kg in three adsorbent beds)

Extracted Uranium

Adsorption stacks → Fractional Elution of Uranium by dilute acid → Purification Solvent extraction → Uranium (Yellow cake)

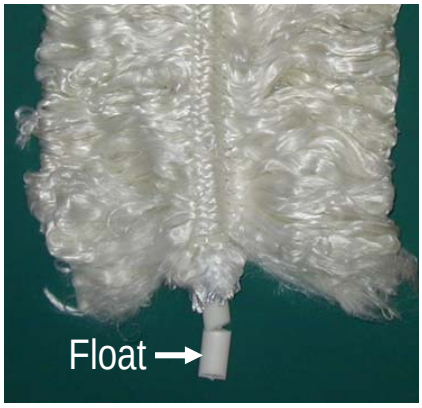
Submersion period	Submersion days	Seawater temperature [° C]	Number of stacks	Adsorbed uranium [g]
1999 29 Sep.-20 Oct.	21	19 - 21	144	66
2000 8 Jun.-28 Jun.	20	12 - 13	144	47
28 Jun.-8 Aug.	40	13 - 22	144	66
8 Aug.-7 Sep.	29	20 - 24	144	101
7 Sep.-28 Sep	21	24 - 22	144	76
28 Sep.-19 Oct.	21	20 - 18	144	77
2001 15 Jun.-17 Jul.	32	13 - 18	216	95
18 Jul.-20 Aug.	32	18 - 20	216	119
15 Jun.-20 Aug.	65	13 - 20	72	48
20 Aug.-21 Sep.	31	20 - 19	216	118
18 Jul.-21 Sep	63	18 - 19	144	150
15 Jun.- 21 Sep.	96	13 - 19	72	120
				1083

Purified yellow cake made of uranium from seawater

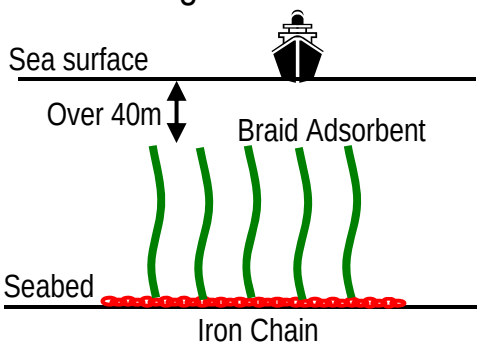
The factors which affect the uranium adsorption were the temperature of seawater and the average height of significant wave.

R&D of Braid Adsorbent for Cost Reduction

Braid Adsorbent



Mooring System of Braid Adsorbent Standing on the Seabed



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Advantage of Standing Mooring of Braid Adsorbent

- Braid Type, so
  - Light & economy
  - Shellfishes don't stick on
- Standing on the Seabed, so
  - Ships aren't disturbed
  - No damage by Typhoons
  - Seaweeds don't grow on
- Built-in Float, so
  - No dragging in strong current
- Attached to Chain, so
  - Easy to withdraw one after another

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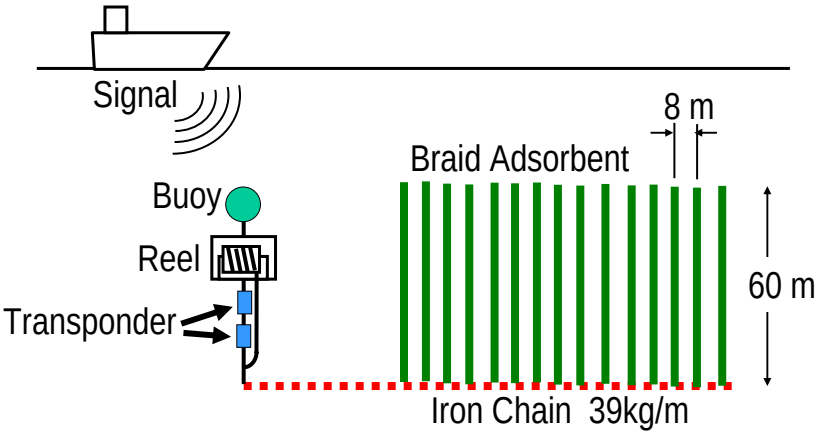
Shellfishes don't Stick on Braid Adsorbent

Many shellfishes stick on a rope.

Withdrawal System

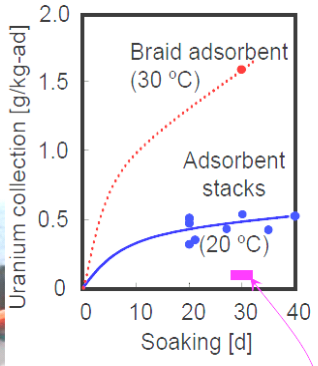


Marine Experiment of Braid Absorbent in Okinawa

Offing of Okinawa

Preparation in wharf

Recovery operation of adsorbent



- 10 °C enhanced 1.5 times
- Efficient constant with seawater: 2 times

Hydrous titanium oxide adsorbent

Specifications for Cost Estimation of U Collection from Seawater

- Scale of U collection : 1200 t /y [as metal U]
  (1milion kW 6 Atomic power generator、1/6 Japan Demands)
- Braid Adsorbents: 60 days' soaking and 6 times/y

Cost estimation on achieved data

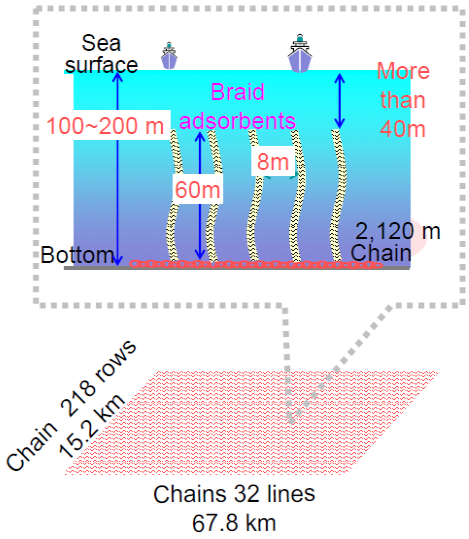
- Performance : 2 g-U/kg-ad
- Durability : 6 times

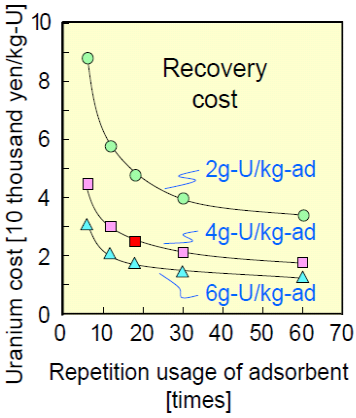
} total : 6×10^5 t adsorbents

Varying conditions

・Performance	2, 4, 6 g-U/kg-ad
・Durability	6,12,18,30,60 times

Estimated Cost for 1200 ton Uranium in a Year



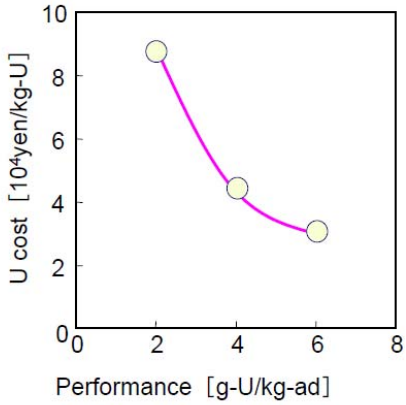


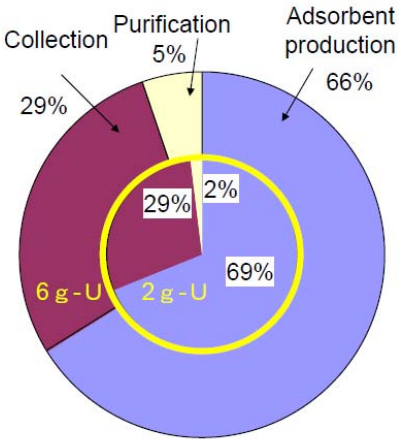
- Weekly spot price \$41/lb-U_3O_8 at June, 2010 is 12,000 yen/kg-U.
- Promising collection cost is 25,000 yen/kg-U. This price is twice of spot price.

Improvement of Adsorption Performance

2g-U/kg-ad ⇨ 6g-U/kg-ad

6 times repetition



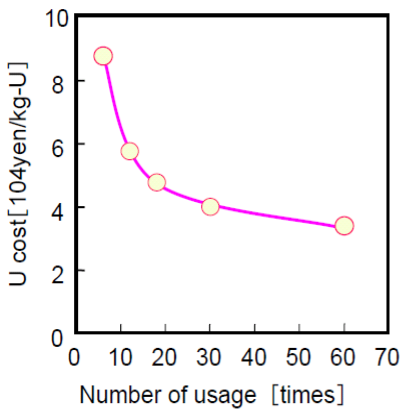


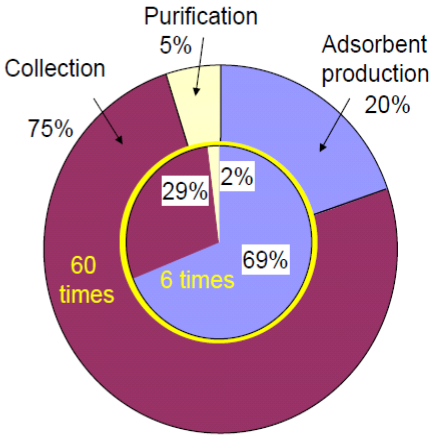
Cost reduction in production equipment and collection system

Improvement of Durability in Repetition Usage

6 times use ⇨ 60 times use

2g-U/kg-ad





Cost reduction of Production equipment