Soil and Groundwater Remediation using Reactive Nanoscale Iron Particles (RNIP)

NAKAMURAKISO.CO., LTD.

What is RNIP ?

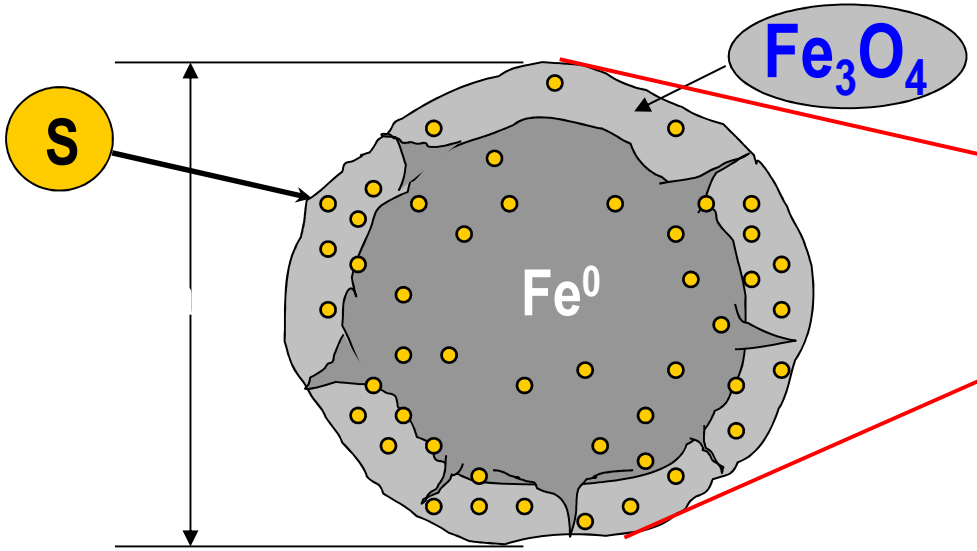


Fig. 1 Schematic RNIP structure

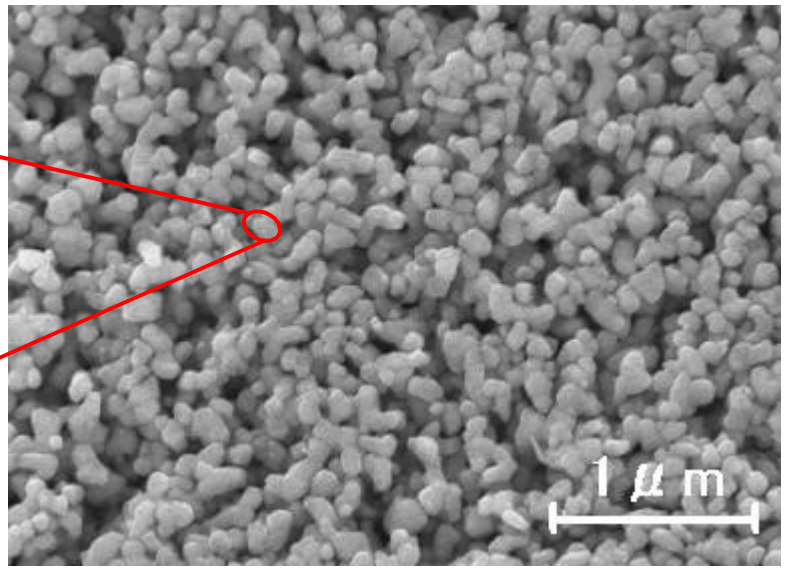


Fig. 2 SEM image of RNIP

RNIP consists of metallic iron core (α-Fe) and magnetite shell (Fe_3O_4).

- **Particle size; 70 nm**
- **Specific surface area; 30 m^2/g**

What is RNIP ?

- RNIP is processed in aqueous slurry.
  - Slurry Density; 1.25 g/ml
  - Solid concentration; 25 wt.%
  - Slurry Viscosity; 600～700 mPa･s

- Slurry of RNIP is diluted by several to one hundred times in use.

  Dilution viscosity; <10 mPa･s

Fig. 3　Slurry of RNIP

What is RNIP ?

- We have produced RNIP slurry of 60 tons per month at our Higashi-hiroshima plant since 2017.

Fig. 4 Higashihiroshima plant

- **Site area**
  ca. 4,000㎡,
  built in October 2017
- **Production capacity**
  60 tons/month
  (Max 90 tons/month)

- Packaging product

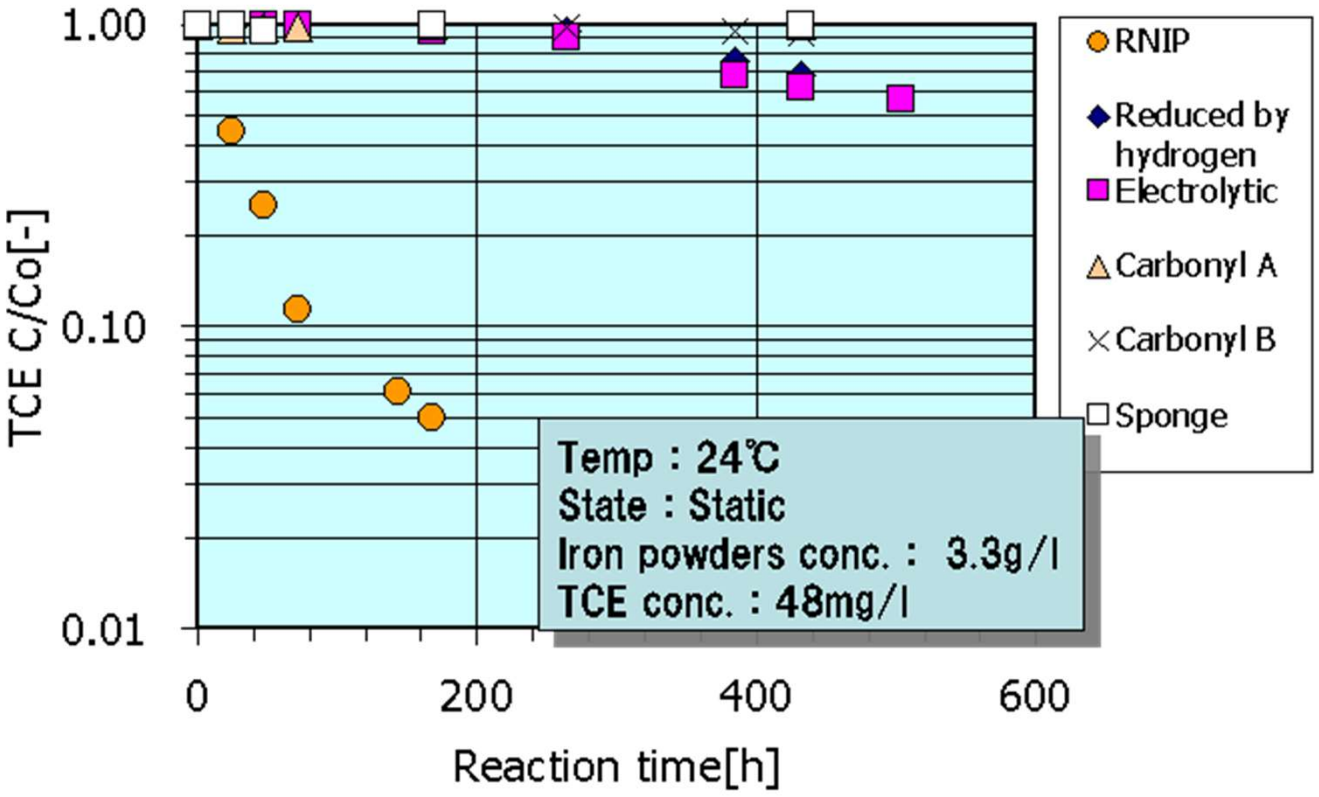
1m³
SUS container

200L
Drum can

20L
Plastic container

Characteristics of RNIP

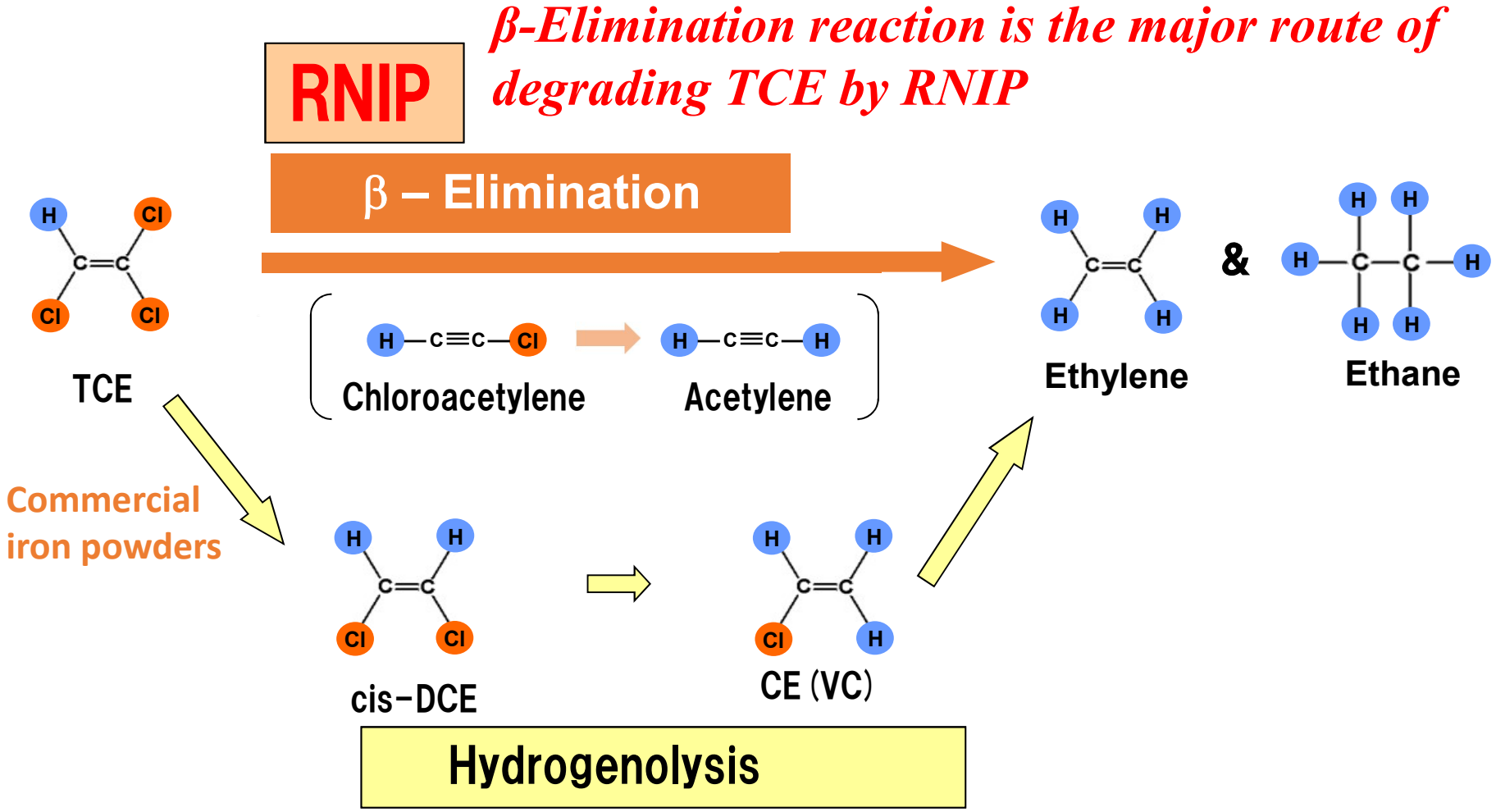
①TCE (Trichloroethylene) remediation performance



- **Dechlorination reaction rates of iron particles can be expressed as a pseudo first order reaction.**
- **The reaction rate of RNIP is much greater than that of commercial iron powders by 100 times.**

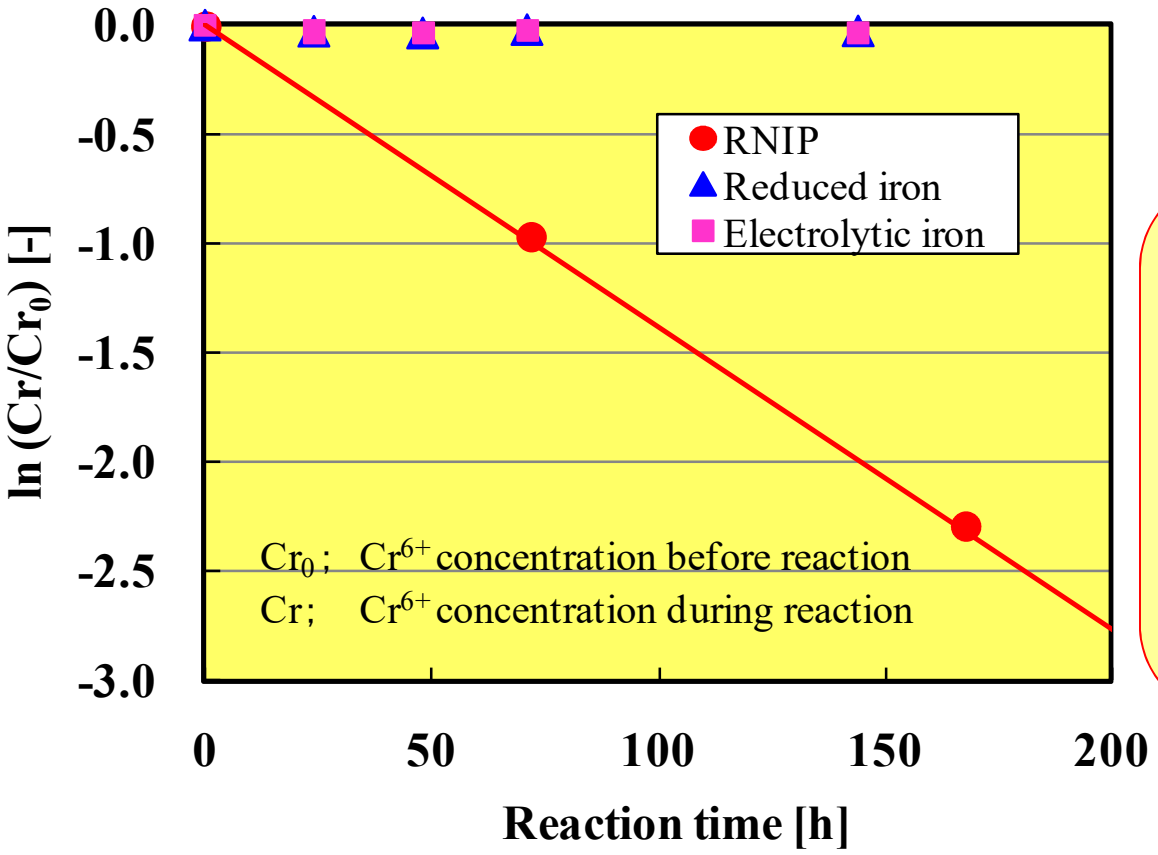
Fig. 5 TCE Decomposition rate by RNIP compared with another iron materials

Characteristics of RNIP



Characteristics of RNIP

②Heavy metals containment performance

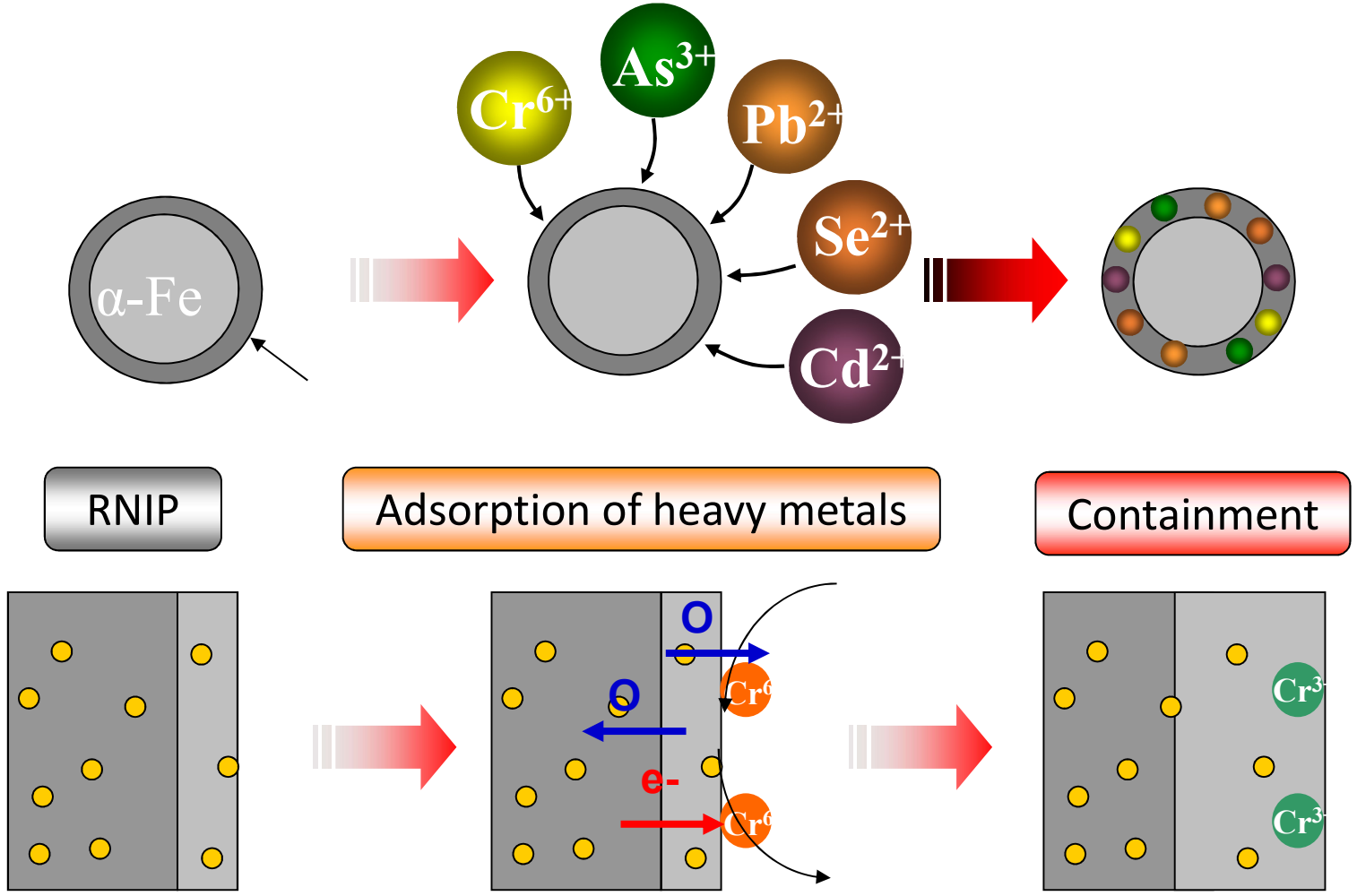


- **RNIP removed Chromium (VI) from model contaminated groundwater rapidly. This reaction shows pseudo first order reaction.**
- **Commercial iron powders have little containment performance.**

Fig. 6 Reaction rates of removal of Cr^{6+} by RNIP compared with commercial iron powders

Characteristics of RNIP

Reaction schematic of removal of heavy metals by RNIP



Characteristics of RNIP

③High mobility performance for in-situ remediation

Mobility test with saturated soil

RNIP diffuses easily into the deep spots of contaminated soil because of very fine particles.

Characteristics of RNIP

④Harmless materials

Elution test of RNIP

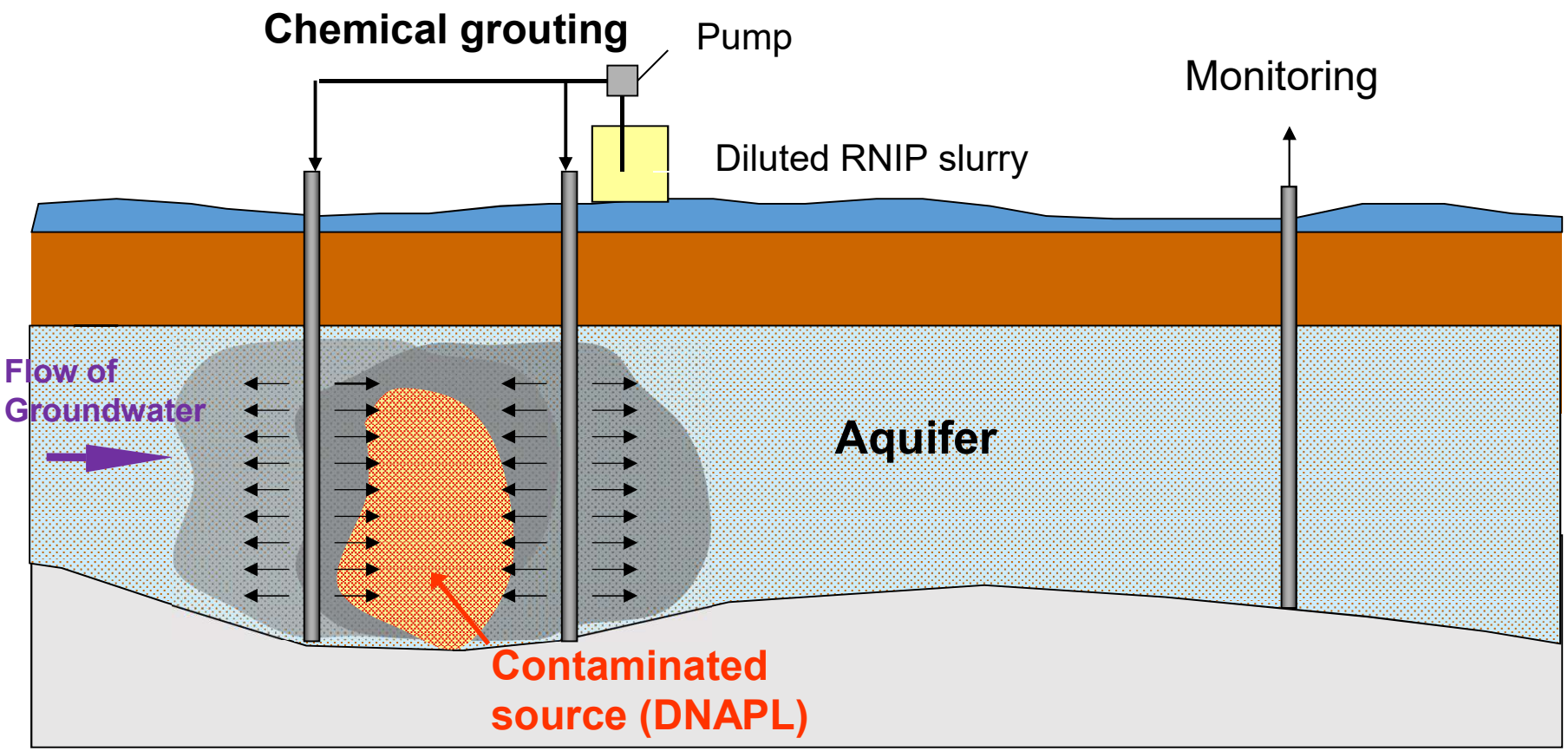
Element	Elution Value of RNIP	Japanese Regulation
Cd [mg/l]	＜ 0.001	≦ 0.01
Total-CN [mg/l]	Not detected	Not detected
Pb [mg/l]	＜ 0.005	≦ 0.01
Cr6+ [mg/l]	＜ 0.04	≦ 0.05
As [mg/l]	＜ 0.001	≦ 0.01
Total-Hg [mg/l]	＜ 0.0005	≦ 0.0005
Se [mg/l]	＜ 0.002	≦ 0.01
F [mg/l]	＜ 0.5	≦ 0.8
B [mg/l]	＜ 0.1	≦ 1
Total-Cr [mg/l]	＜ 0.1	-
Mn [mg/l]	＜ 0.1	-

Content test of RNIP

Element	Content Value of RNIP	Japanese Regulation
Cd [mg/kg]	＜ 2	≦ 150
Total-CN [mg/kg]	＜ 5	≦ 50
Pb [mg/kg]	＜ 5	≦ 150
Cr6+ [mg/kg]	＜ 5	≦ 250
As [mg/kg]	＜ 1	≦ 150
Total-Hg [mg/kg]	＜ 1	≦ 15
Se [mgkg]	＜ 1	≦ 150
F [mgkg]	＜ 20	≦ 4000
B [mg/kg]	＜ 20	≦ 4000

- **RNIP is no toxicity and quite safety.**
- **It does not cause a secondary environmental pollution using RNIP.**

In-situ Remediation process by RNIP with Grouting Method



- This process is very easy and simple.
- It is not necessary to use special or large-scaled equipments.

Site Remediation example in Japan

Old machine factory site

- The remediation site was adjacent to a road and encompassed a volume of 136m^3.
- The groundwater table at the site fluctuated between 2 to 4 meters below ground surface.
- The site soils consist of silty sand and gravel with coefficent permeability of 10^{-3}~10^{-4} cm/s.
- The maximum TCE concentration in soil was about 0.2 mg/L.

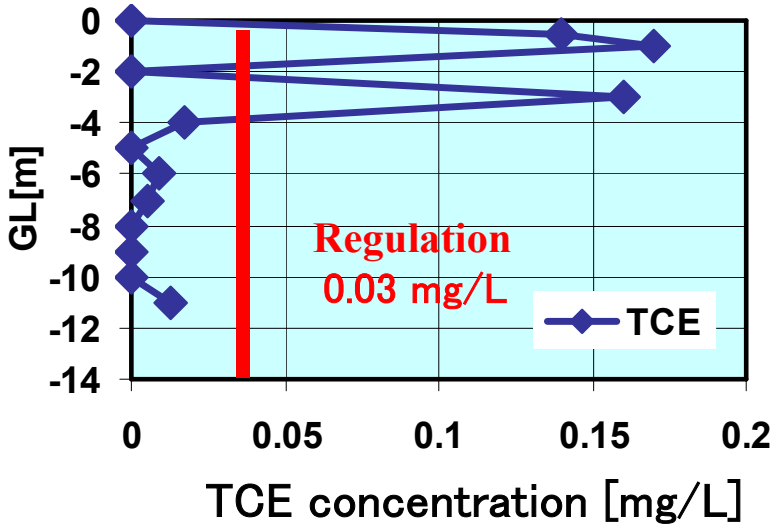
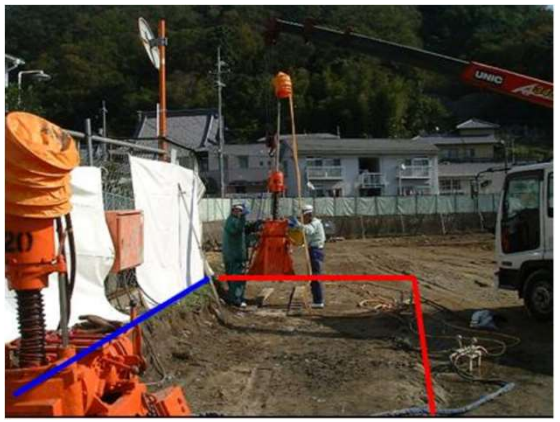


Fig. 7 TCE concentration profile

Site Remediation example in Japan

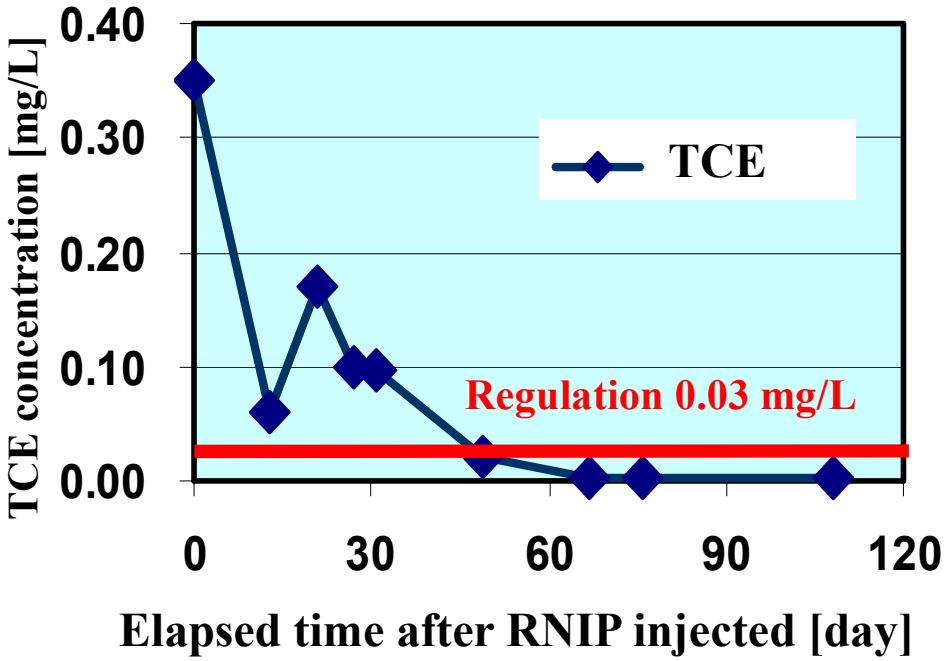
Test condition and result



<Condition>

- The injected RNIP concentration was 5 kg/m^3 soil.

<Result>



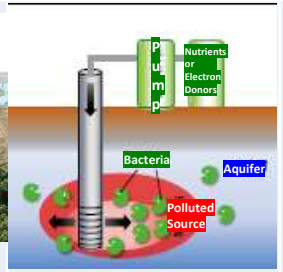
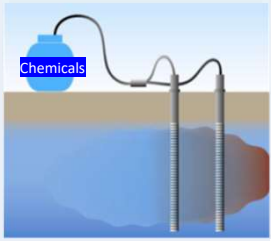
➢The remediation was finished in 56 days

Fig. 8 TCE concentration behavior after RNIP injection

Summary

- RNIP consists of metallic iron core (α-Fe) and magnetite shell (Fe_3O_4) and has an average size of 70 nm.
- The VOC remediation performance of RNIP is much greater than that of commercial iron powders by 100 times.
- RNIP also has a high performance for containing heavy metals such a Chromium (VI) .
- RNIP has a high mobility performance and is suited for in-site rapid remediation using the chemical grouting method.
- RNIP is no toxicity and quite safety. Therefore, it does not cause a secondary environmental pollution using RNIP.
- It is an issue in the future to improve the further decomposition performance of RNIP for persistent organic compounds such as dioxins.

Our Soil & Groundwater Remediation

	Excavation & Removal	In Situ Remediation			
		Injection of RNIP	Mixing of RNIP or Iron	Bio Remediation	Chemical Oxidation
Schematic Figure or Picture					
Target Contaminants	VOC Heavy Metals	VOC Heavy Metals	VOC	VOC・Oil Cyanide	VOC Cyanide
Certainty	◎	○	△	△	○
Environmental Benign	△	◎	○	△	△
Work Period	◎	◎	△	△	◎
Cost	△	◎	◎	◎	◎

Acknowledgement

Thank You for Your Kind Attention

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