Interaction of long-lived radionuclides and microorganisms

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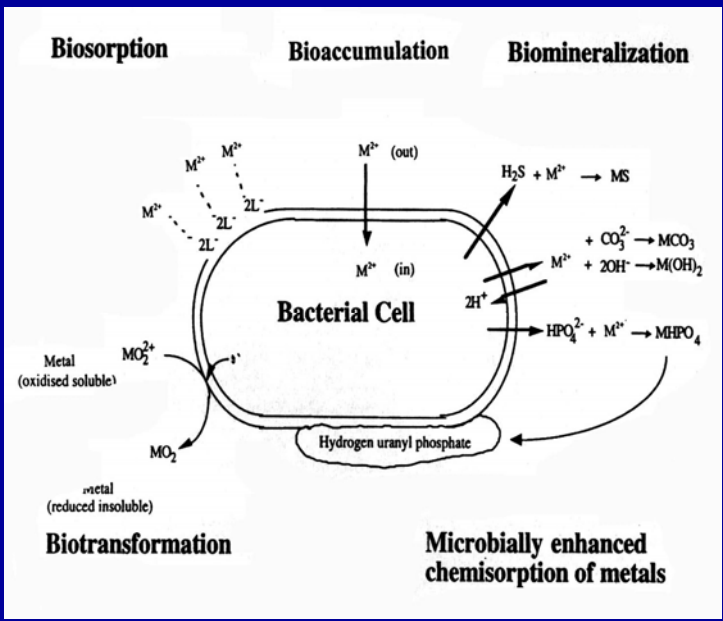
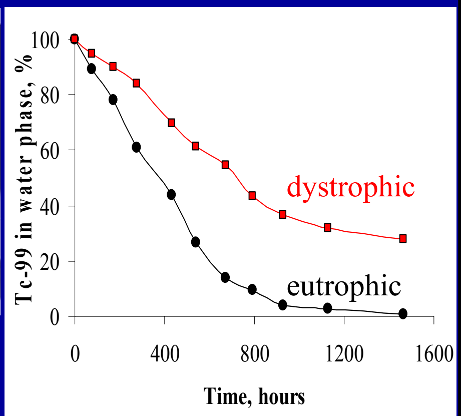
Principal types of interaction



Interaction of metals and microorganisms

Type of biomass	Mechanism
Living cells Cell suspension or extract	1. Adsorption or complexation on cell wall 2. Intracellular accumulation 3. Oxidation or reduction of metals 4. Transformation: methylation or demethylation 5. Inorganic ligand formation and metal precipitation 6. Metal binding with the exopolimers
Dead biomass	1. Adsorption or complexation on cell wall 2. Metal precipitation under enzyme action
Microbial products	1. Siderophores, thioneines 2. Polimers of cell wall – bacterial peptidoglican, chitin or chitosan from fungi 3. Melanins, humic acids 4. Pigments – quinone

Uptake of long-lived radionuclides by lake sediments of different trophic types

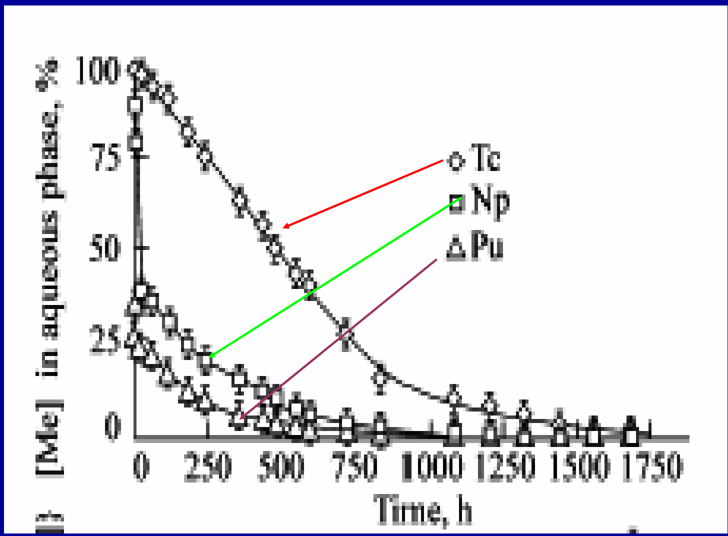


Solid phase – 0,023 mg/ml

1 – 4 months experiment.
2 – sterile controle (formalin or γ-irradiation)

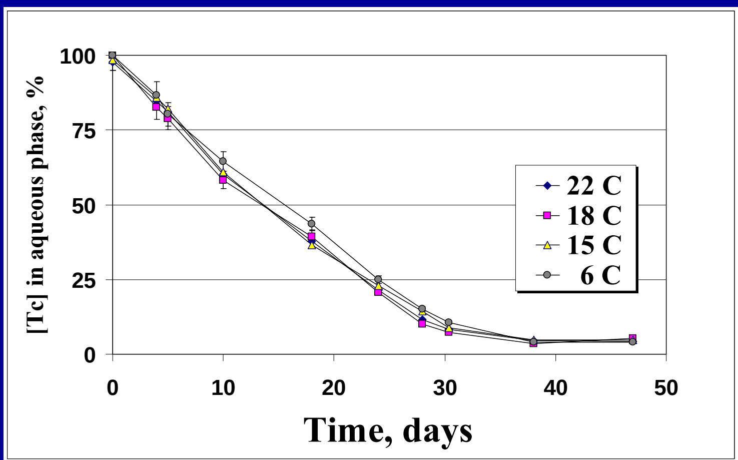
t=15° C,
$[Tc]_0=10^{-4}$M

Uptake of radionuclides by eutrophic sediments (lake Beloe, Moscow region)

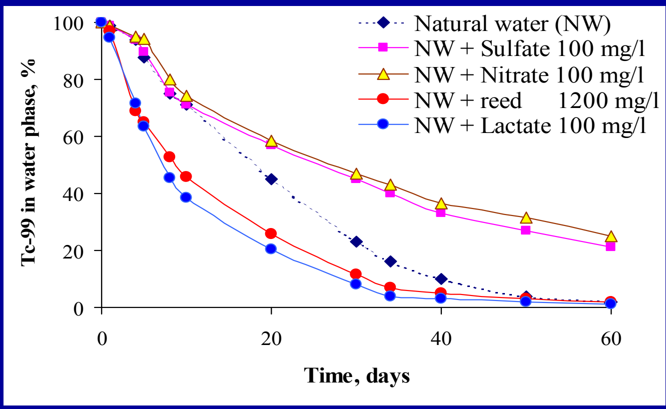


$[Tc]_0 = [Np]_0 = [Pu]_0 = 10^{-5}$ M

Temperature influence on Tc-uptake by eutrophic sediment



Substrate impact on the ^{99}Tc uptake by eutrophic sediment

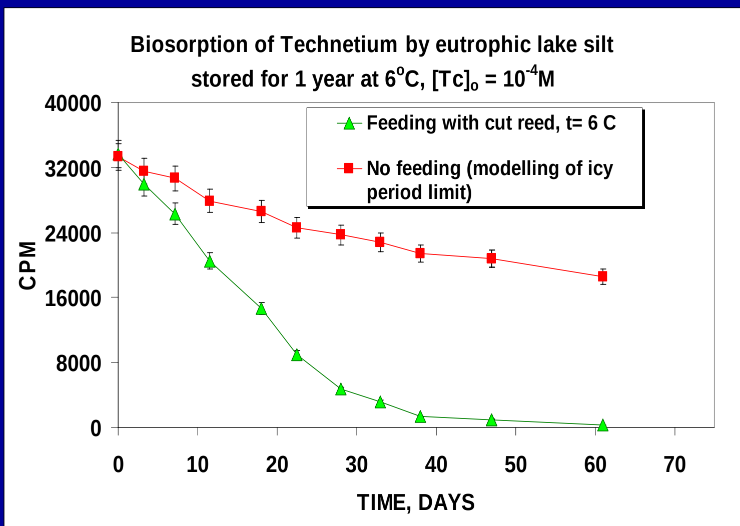


Uptake rate of ^{99}Tc

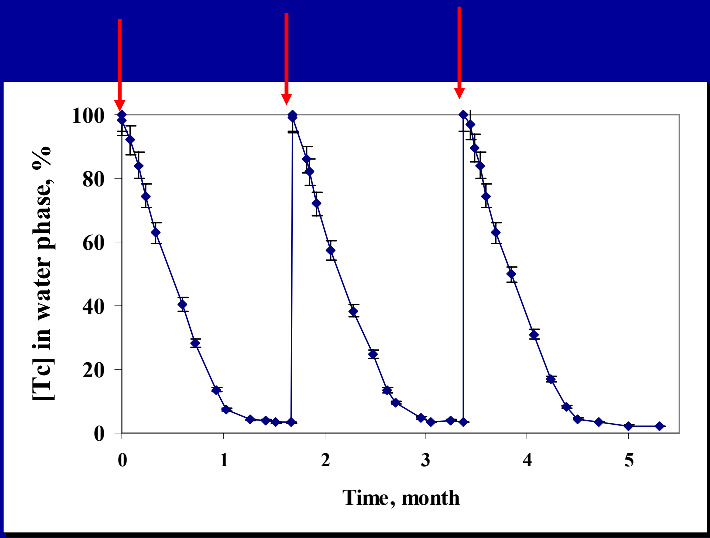
* Edition of e-acceptor (sulfate, nitrate) ⇓

* Edition of e-donor (lactate, reed) ⇑

Substrate impact on the 99Tc uptake by eutrophic sediment (2)

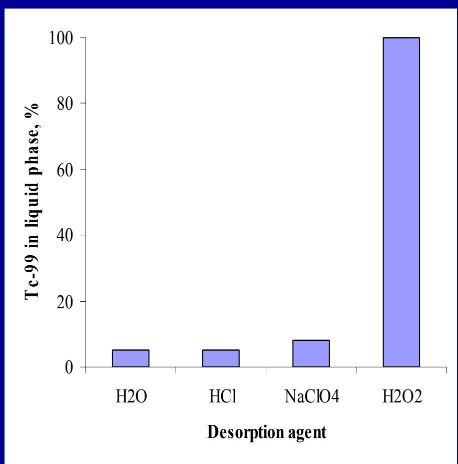


Multiple addition and uptake of Tc-99 by eutrophic sediments



t = 18°C, $[Tc]_o = 10^{-4}$M

Desorption of ^{99}Tc from eutrophic sediments



Desorption factor:

- ❖ H_2O - 0.05
- ❖ HCl - 0.05
- ❖ $NaClO_4$ - 0.08
- ❖ H_2O_2 - 0.99

Tc-reduction by microorganisms

TcO_4^- + e-donor → TcO_2

Soluble → Solid

Bacterial reduction of TcO_4^-

- *Desulfovibrio desulfuricans*
- *Desulfovibrio gigas*
- *Moraxella, Planococcus*
- *Shewanella putrifaciens*
- *Geobacter metallireducens*
- *Escherichia coli*
- *Pseudomonas vanadiumreductans*
- *P. isachenkovii*
- *Thermoterrabacterium ferrireducens*
- *Tepidibacter thalassicus*
- *Pyrobaculum islandicum*

} pH 7

- *Acidithiobacillus ferrooxidans*
- *Acidithiobacillus thiooxidans*

} pH 2-3

- *Halomonas sp.* — pH 9-10

Reduction of $^{99}Tc\ O_4^-$ by suspension of sulfate-reducing bacteria

TABLE 1. Effect of electron donor on Tc reduction and removal by resting cells of *D. desulfuricans*[a]

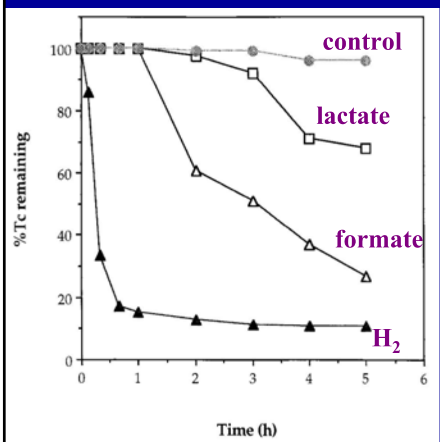
Electron donor	CR
Hydrogen	12,850
Formate	11,648
Pyruvate	6,393
Lactate	2,940
Ethanol	1,093
Succinate	363
Glycerol	336
Acetate	197
Methanol	101

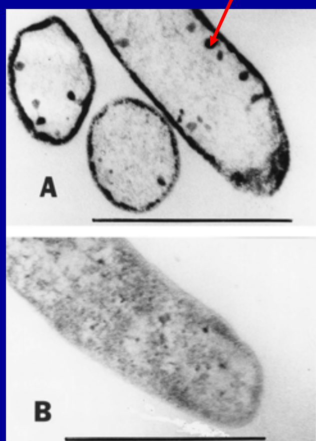
[a] Results are expressed as the CR, calculated after 24 h of incubation at 30°C.

Desulfovibrio desulfuricans

Kinetic of $^{99}Tc\ O_4^-$ reduction by *D.desulfuricans*

Tc

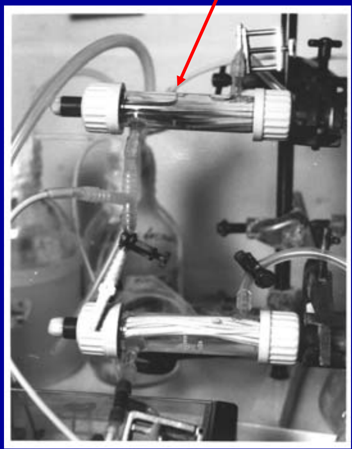


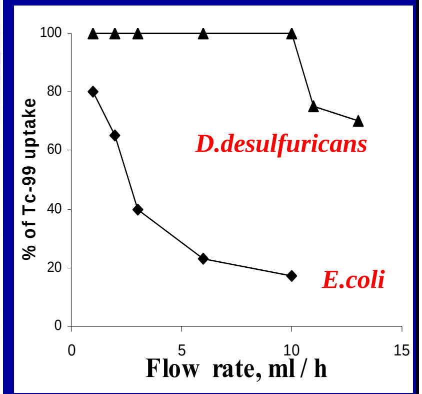


TcO_4^- Nitrate reductase → $TcO_2\downarrow$

Reduction of ^{99}Tc O4- by sulfate-reducing bacteria

TcO_2

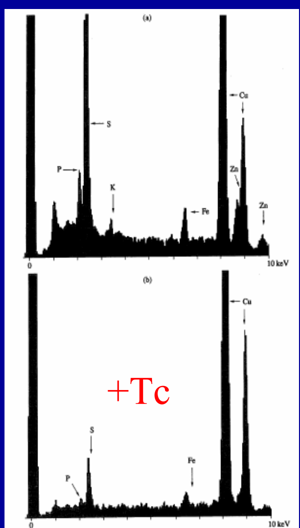




pH=7, $[TcO_4^-]_0$ = 25 mg/L

Desulfovibrio desulfuricans

Impact of pertechnetate on metabolism of aciditiobacilli



Acidithiobacillus ferrooxidans

Technetium concentration, mg/l	Concentration of Fe^{3+} formed, mg/l	Protein concentration at the end of the experiment, µg/ml
0	2500–2800	75
50	275–285	35
100	200; 400	30; 45
250	50–60	15
500	0	10
750	0	10

pH 2.5

Reduction of TcO_4^- under anaerobic condition, pH 2.5, incubation 7 d

TcO_4- + S^0 → $TcO_{2\ complex\text{-}colloid}$

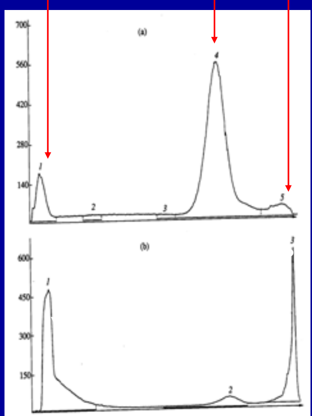
Acidithiobacillus ferrooxidans

№	Final radioactivity of solution, %
Control	100
1	43
2	39

Chromatographic separation of Tc-99 after incubation with *A.ferrooxidans*

Tc $^{5+}$ Tc^{7+} Tc^{4+}

pH 2.5



Bacterial spent medium

Colloid

TcO_4^- → $TcO_{2\ colloid}$

Reduction of TcO_4^- by haloalkaliphilic bacteria genus *Halomonas*

pH = 10,

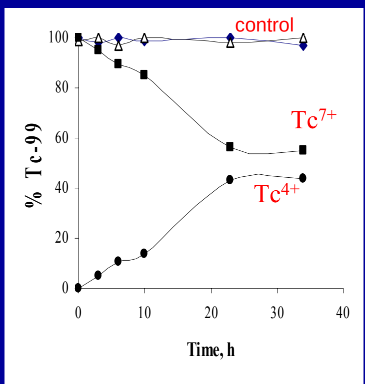
$[Tc]_o$ = 0.25 mM

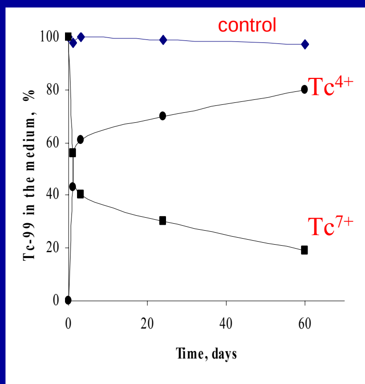
1 - control

2,3 - *Halomonas*

Kinetic of bacterial reduction of TcO_4^- under alkaline conditions

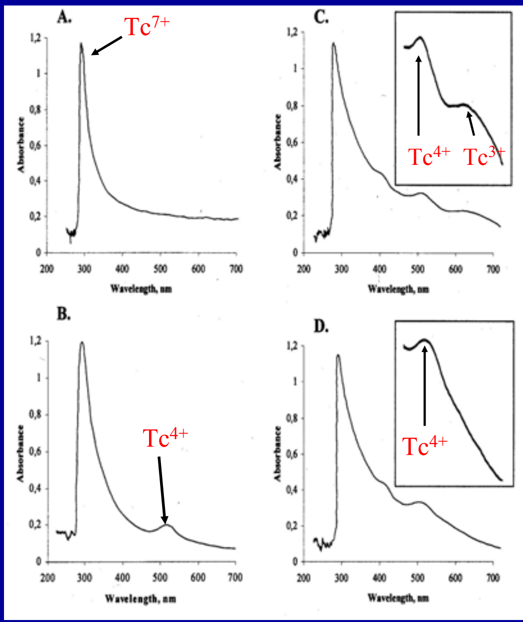
pH 9,8-10, carbonate/bicarbonate medium, salinity 1 M,
Halomonas strain Mono, acetate 10 мM, TcO_4^- = 0.25mM





$Tc^{VII}O_4^-$ —Nitrate-reductase→ $Tc^{(IV)}_{complex}$

Spectrophotometric analysis of bacterial spent medium under alkaline conditions



Anaerobic conditions

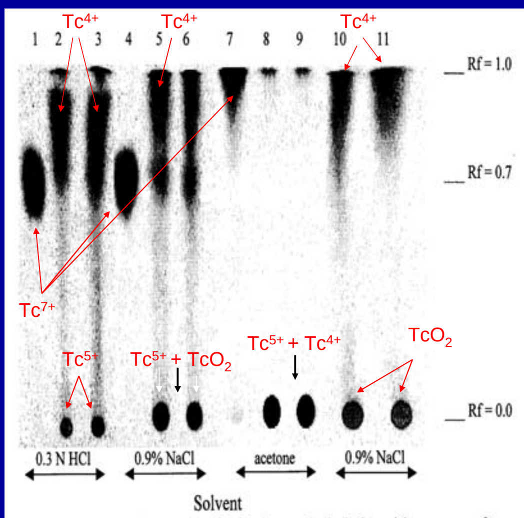
pH 9,8-10,

salinity 1 M, *Halomonas* strain Mono

Acetate 10 mM,

$TcO_4^- = 0.25$ mM

Chromatographic separation of different forms of Tc



$TcO(OH)_2$ (aq)
$TcO(OH)_3^-$
$Tc(OH)_2CO_3$
$Tc^{IV}O(OH)_3(CO_3)^-$

Anaerobic conditions, pH 9,8-10, salinity 1 M,

Halomonas strain Mono, Acetate 10 mM, $TcO_4^- = 0.25$ mM

Influence of e-donors on pertechnetate reduction under alkaline conditions

Substrate	Technetium in the supernatant (%) Tc(VII)	Tc(IV)	Tc(V)
Formate	65.0	32	3
Acetate	67.0	28.9	4
Lactate	68.0	28	3
Methanol	69.0	29	2
Ethanol	68.8	28.8	2.4
Control without bacteria	100.0	0	0
Control without e-donor	100.0	0	0

Anaerobic conditions, pH 9,8-10, e-donors – 10 мM
salinity 1 M, suspension of strain Mono (0,035 mg/mL), TcO_4^- = 0.25mM

Conclusion – bacterial reduction of TcO_4^-

	Final reduced form	
pH 2-3	TcO_2 –colloid	!!! SOLUBLE
pH 7	TcO_2	Solid
pH 8-11	$Tc^{IV}O(OH)_3(CO_3)^-$	!!! SOLUBLE

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