Moscow State University

Department of Chemistry

Use of IPC for Decontamination and Remediation of Soils Contaminated from Nuclear and Industrial Activities

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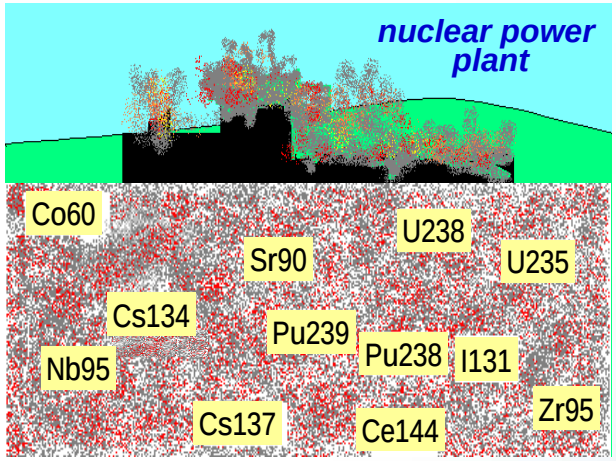
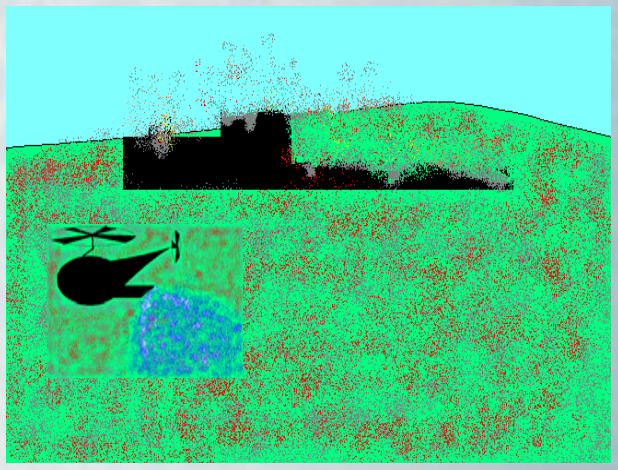
Topics

- creation of a new generation of polymeric binders based on IPC;
- use of novel polymeric binders for preventing water and wind erosion of contaminated soils;
- effect of developed IPC polymeric binders on ecology (plant vegetation);
- technology of IPC polymer binders application and environment decontamination.

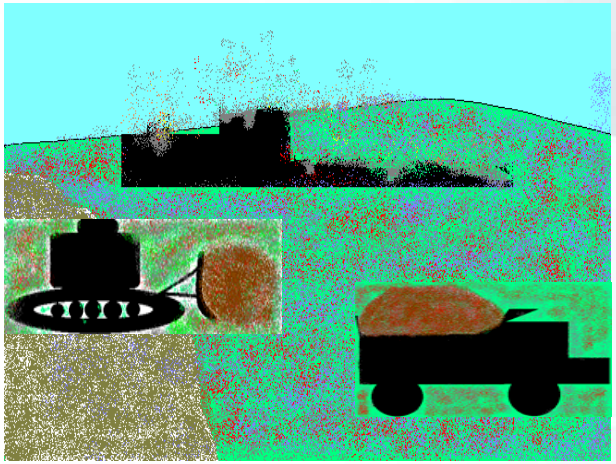
Soil contamination



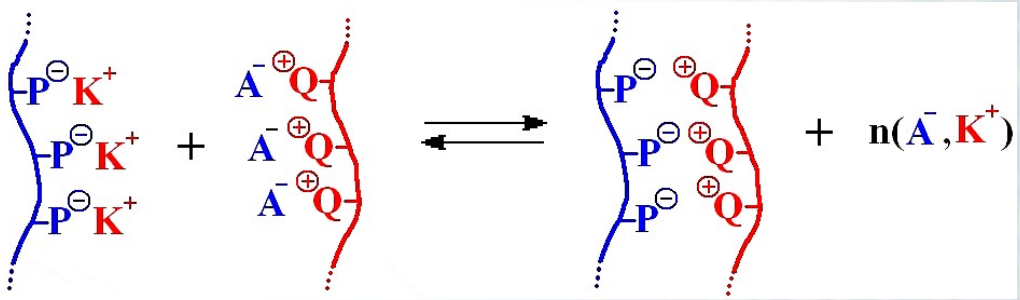
Radioactive dust suppression



Decontamination



The main idea of the project is the use of ecological friendly polymeric binders which form as a result of the interaction between oppositely charged polyelectrolytes (produced commercially).



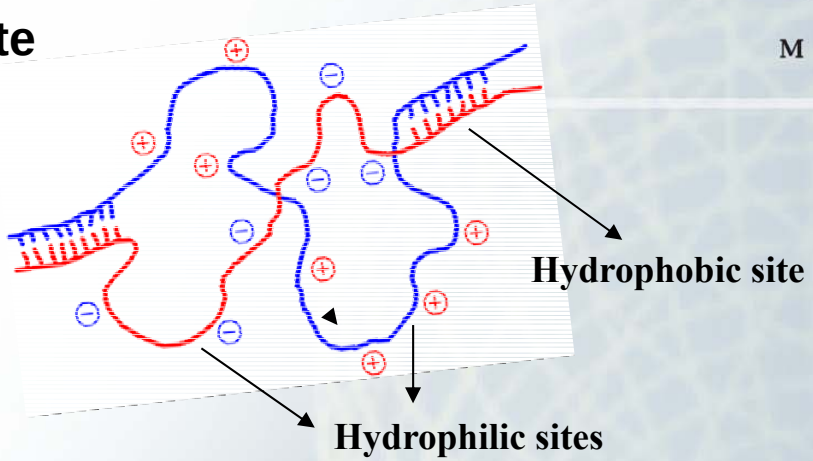
individual oppositely charged polyelectrolytes in aqueous solution

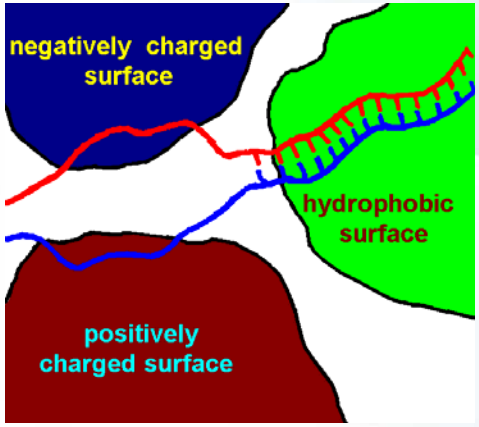
interpolyelectrolyte complex (IPC) in precipitate

IPC play a role of the binder of dispersions (soil, ground, sand, wastes etc.).
The concentration of simple salt controls the interpolyelectrolyte interaction.
One can easily and reversibly transfer the system from soluble state to insoluble one.

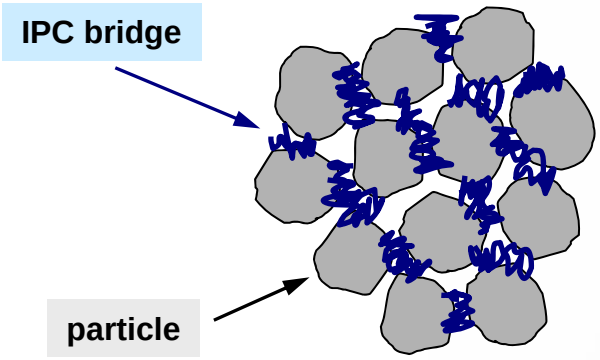
These considerations serve as the fundamental basis for the creation of binders compounds and the technology of their application.

Amphiphilic interpolyelectrolyte complex (IPC)



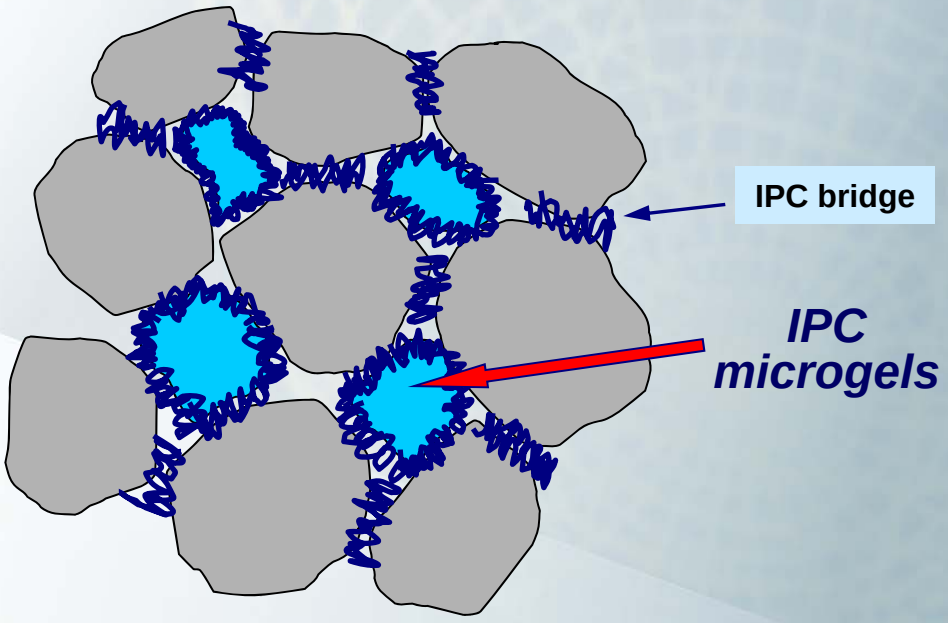


Being introduced in dispersion, IPC interacts with complementary areas on the surface of dispersed particles and glue them together



IPC:
effective glue for
nano-sized ***particles***

IPC microgels between oppositely charged weakly cross-linked microgel and linear polyelectrolyte: effective glue for **micro-sized** ***particles***



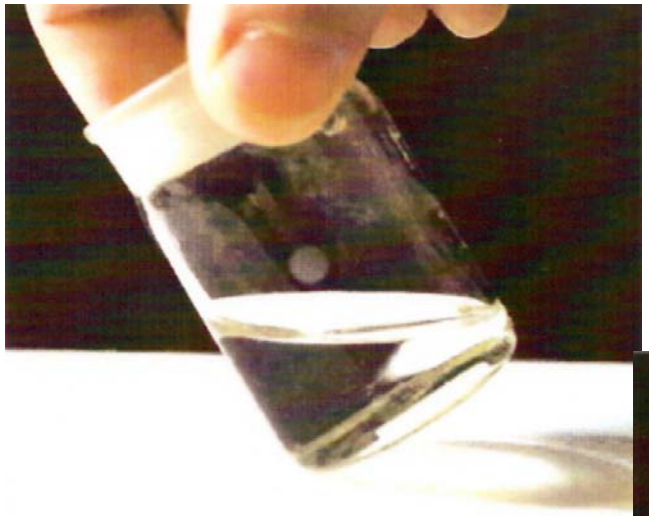
Typical IPC compound

The compound consists of hydrolyzed polyacrylonitrile (HPAN) and poly-N,N-diallyl-N,N-dimethylammonium chloride (PDADMAC)

HPAN – 1%wt.
PDADMAC -1%wt.
KNO_3 – 5% wt.
Water –the reminder

Consumption of compound is 10 t per 1 hectare (1 liter per 1 m^2)

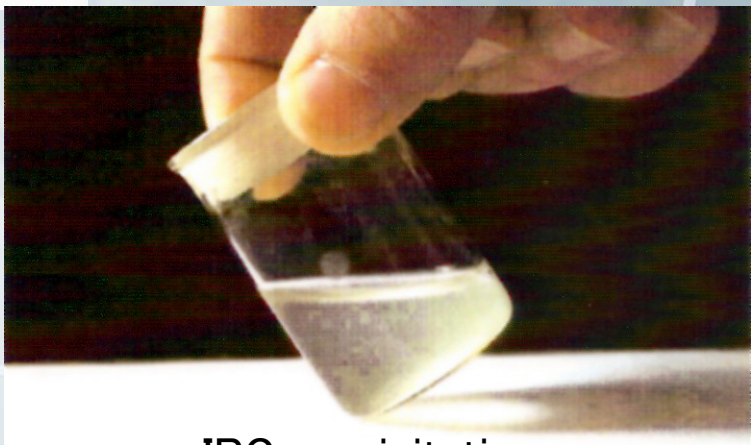
Illustration of technology of IPC binders application



Water–salt solution of polyelectrolytes mixture

Addition of pure water

Knowledge of this process is the key to create the technology of IPC binders application



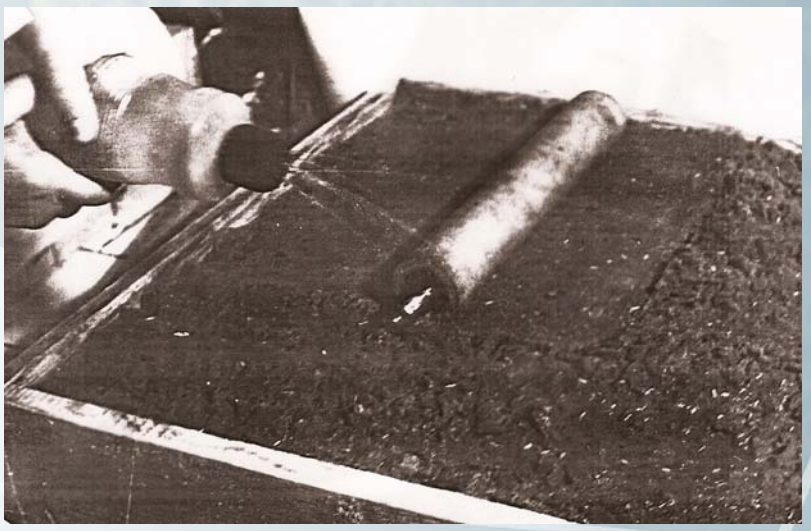
IPC precipitation

IPC compounds are applied on the topsoil, ground etc. using available machines

As a result of treatment topsoil becomes soaked with the compound.
After drying this layer is turned to 5–10 mm thick solid soil–polymeric crust.

Protective crust is able to self-healing

Loosening of IPC treated soil



Plasticity of wet IPC - soil crust

Soil–IPC crust is plastic in the wet state and hard in the dry state. It prevents the water and wind erosion even at hurricane.

Rate of wind < 30 m/s

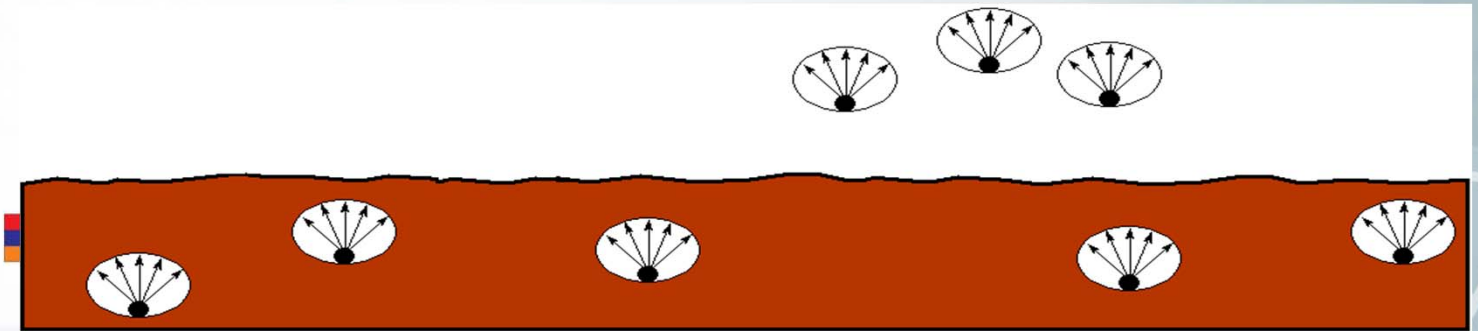
Rate of wind > 30 m/s

Soil - IPC crust has high resistance to wind erosion.

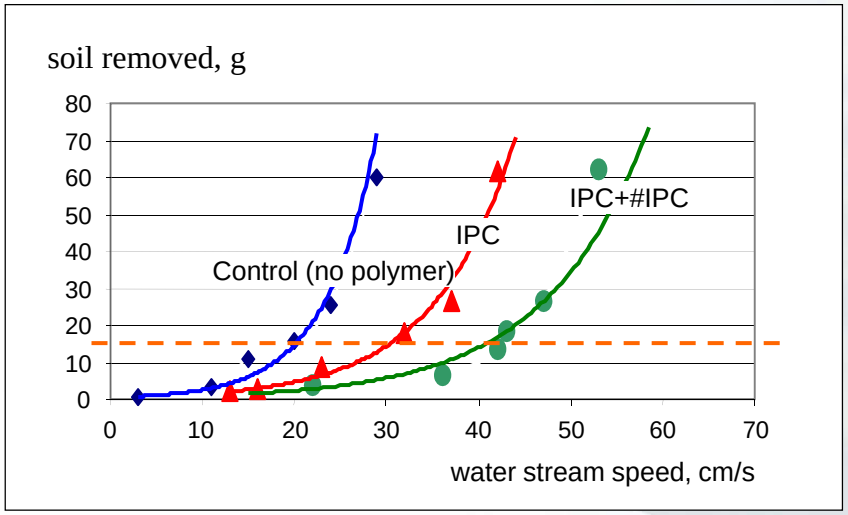
Suppression of radioactive dust spreading by using IPC

Specific radioactivity of aerosol in the air stream above soil specimen. Velocity of air stream was 10 m/s

Sample	The radioactivity, 10^{-6} Cu·m^{-3}	
	Before treatment	After treatment
1	4.9	0.1
2	37.5	3.2
3	97.6	6.5
4	56.4	1.3
5	179.3	4.1

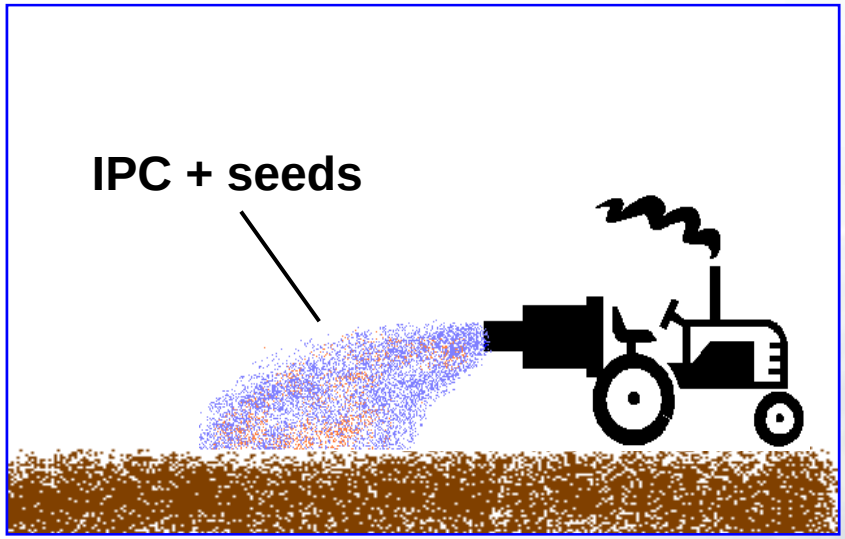


Water Erosion of IPC-Treated Soil

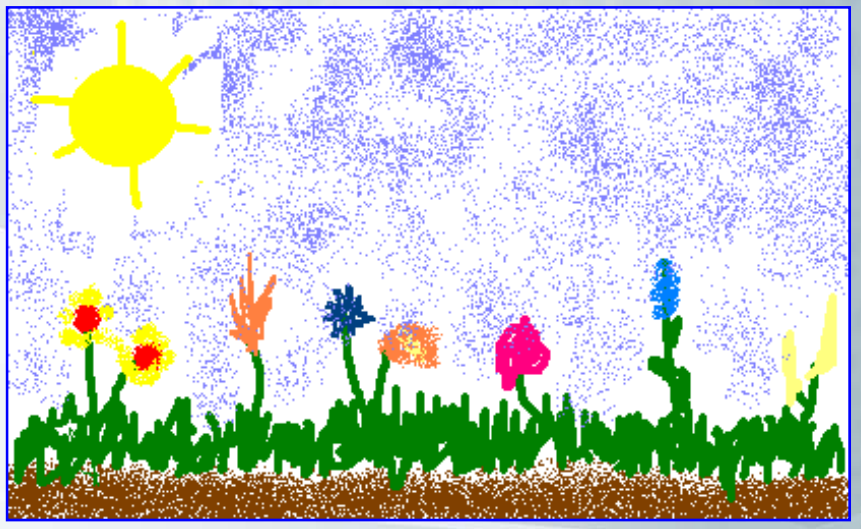


Equal removal of soil (15 g) is observed at 20 cm/s water stream speed for untreated soil (control), 30 cm/s for IPC-treated soil, and 40 cm/s for (IPC+#IPC)-treated soil

According to water resistance classification of soils, samples eroded by a 30 cm/s water stream are considered as the highly erosion-resistant



Remediation



Soil- IPC crust does not hamper the growth of grass, it stimulated their growth.

control components of IPC IPC

sudan grass

sudan grass mixed lawn grass

Polyelectrolytes and supporting salts used for IPC compound

N	IPC	C_{IPC}, wt.%	Salt (C, wt.%)
1	HPAN-PDADMAC	2.0	$NaC1/CaC1_2$ (1.8/0.4)
2	HPAN-PDADMAC	2.0	$KCl/MgC1_2$ (1.9/0.4)
3	HPAN-PDADMAC	2.0	$KNO_3/CaC1_2$ (2.70/0.42)
4	HPAN-PDADMAC	2.0	$NaC1/MgC1_2$ (1.8/0.4)
5	CMC-PDADMAC	1.65	$NaC1/CaC1_2$ (1.26/0.44)
6	CMC-PDADMAC	1.65	$KCl/CaC1_2$ (1.64/0.77)
7	CMC-PDADMAC	1.65	$KNO_3/CaC1_2$ (2.5/0.4)
8	CMC-PDADMAC	2.0	$KNO_3/MgC1_2$ (2.0/0.4)
9	CMC-PDADMAC	2.0	$NH_4NO_3/CaCl_2$ (1.6/0.3)

It is shown also that widely used inorganic fertilizers can be used as salts in IPC formulations.

IPC	NaCl	$NaCl/CaCl_2$	KNO_3	$KNO_3/CaCl_2$
HPAN-PDADMAC	3.0	1.80/0.40	5.0	2.70/0.42
CMC-PDADMAC	2.0	1.26/0.44	3.9	2.5/0.4

We found as well that salt concentration can be decreased via partial substitution of simple salts for salts of alkaline-earth metals.

Taking into consideration successful application of IPC compounds, primarily their high efficiency, availability and that they are inexpensive and ecologically friendly, we propose a series of approaches to make them more attractive:

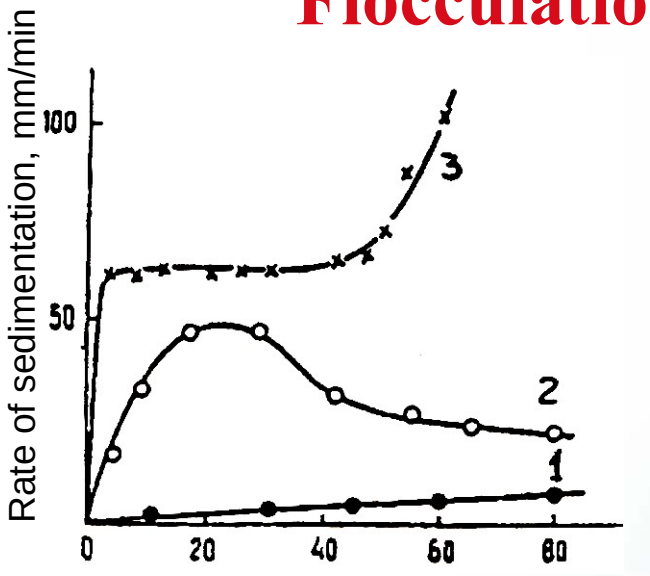
1. Widening the choice of polyelectrolytes with consideration for their commercial production in different regions and countries.
2. Widening the choice of salts via application of organic compounds and substances inherent in soil.
3. The elaboration of the technology for the creation of high concentrated or dry compounds which should be easy and rapidly dissolved in water.

Use of IPC compounds in processes of soil decontamination

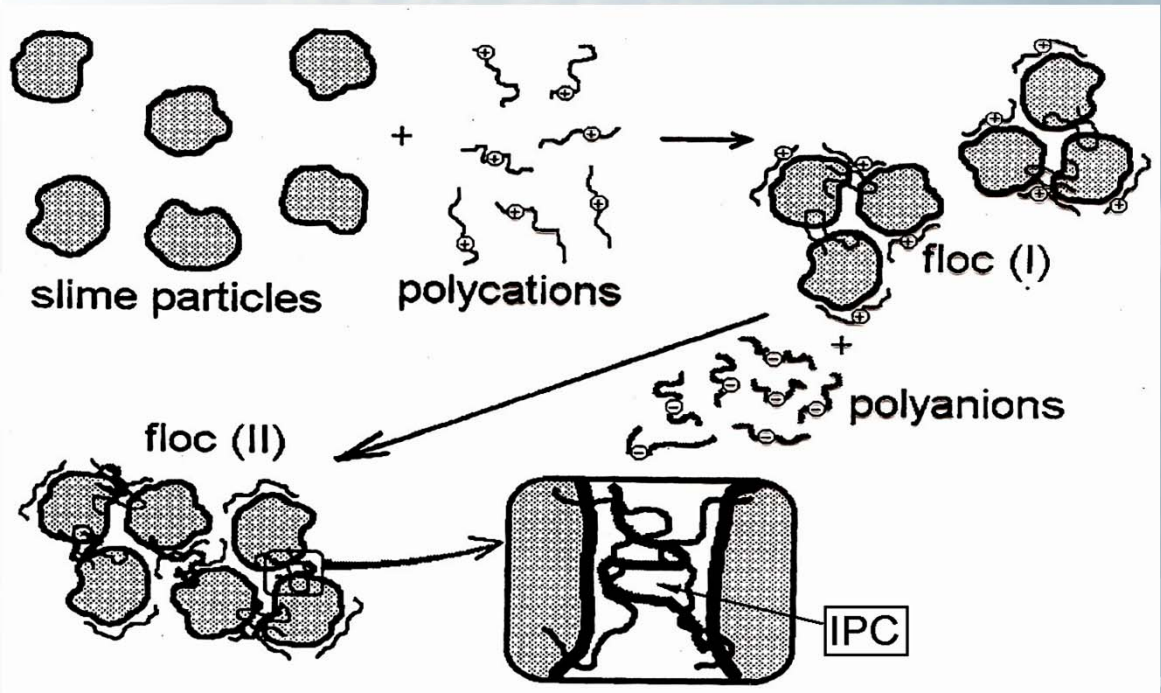
Decontamination should include gathering and compaction of contaminated soil-IPC crust. This can be done via mechanical separation of the protective crust using available machines. This procedure is not environmental hazard because the contaminations are present in the structured crust.

Key procedure of decontamination is the separation of highly contaminated part of collected soil (ground) using well known technique such as classifier. The main part of radionuclides is located in the highly disperse fraction, which ranges from 4 to 5 %-wt. Concentration and separation of this fraction can be achieved only via effective flocculation. This can be done successfully by using the same IPC compounds which were used as binders.

Flocculation of slime species by IPC



Slime concentration 10 wt.%
Particle size 70 μ
1-HPAN
2-PDADMAC
3-IPC



Advantages of IPCs flocculants

- **high effectiveness at moderate MM of constituent polyelectrolytes (< 10^{-5});**

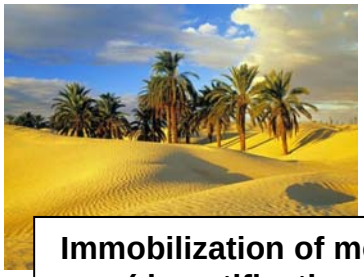
- **the lack of stabilization regime as a result of flocculants overdosing;**

- **high compactness of concentrated phase;**

- **possibility to regenerate IPCs flocculants which is re-usable.**

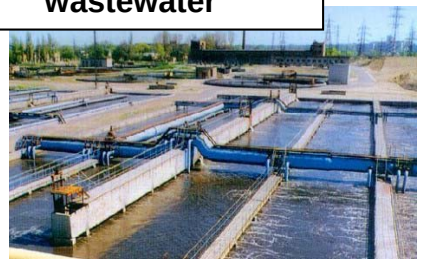
Other fields of IPC application

Construction of (temporary) roads and airfields

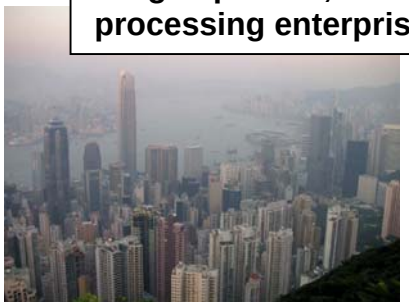


Immobilization of moving sands (desertification control)

Clearing of industrial wastewater



Dust catching control in megalopolises, mining and processing enterprises, etc.



Conservation of temporarily unused mining dumps

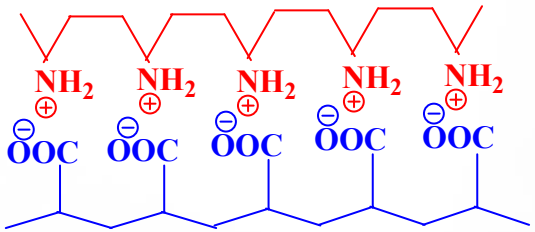
Construction of drainage systems

Treatment of slopes for soil-reclamation canals

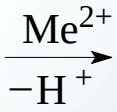
Protection of extended surfaces in emergency

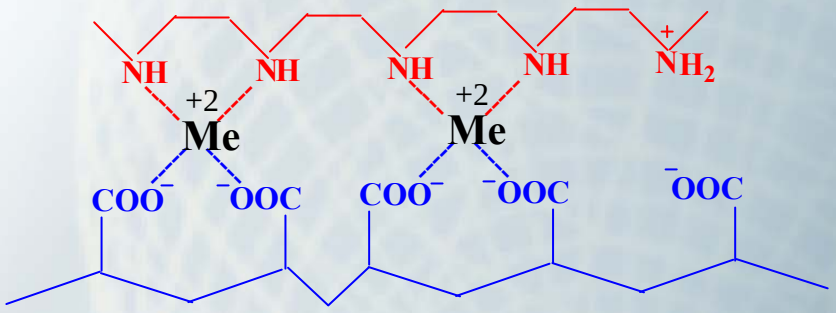
Treatment of road and railroad slopes

IPC can be used to sorb metal ions from their diluted aqueous solutions (10^{-5} –10^{-6} M)



IPC PAA-PEI





Triple IPC–metal complex (TPMC)

Main Results and Applications

The results demonstrate convincingly the wide potentialities of application of interpolyelectrolyte complexes (IPCs) as binders of different dispersed system in particular soils, ground, sand, tailings etc. Their application for the treatment of dispersions contaminated with radionuclides is especially effective to prevent spreading of contamination.

Especially important and promising is the application of the same IPC compound for the decontamination of contaminated dispersions and the remediation of soil.

IPC compound can be used as dewatering agents for silt and sludge.

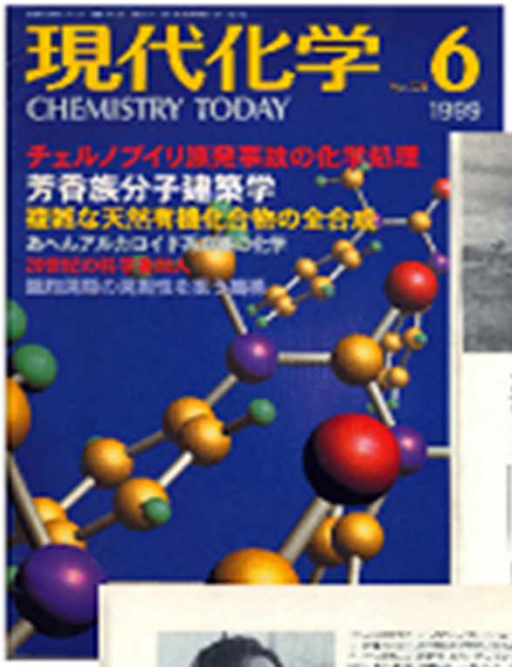
Proposal

1- We can help our Japanese colleagues to determine the type of IPC to be used according to its availability and efficiency.

2- We suggest to carry on site test to check the efficiency of our IPC method concerning the remediation due to Cs spread.

3- We can help to set up a local laboratory and work out all the technology with our Japanese colleagues.

4.- We can adopt soil-washing technology for local soil types, develop and construct plant for soil decontamination with capacity 1-5 t/h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東海で実験、成功

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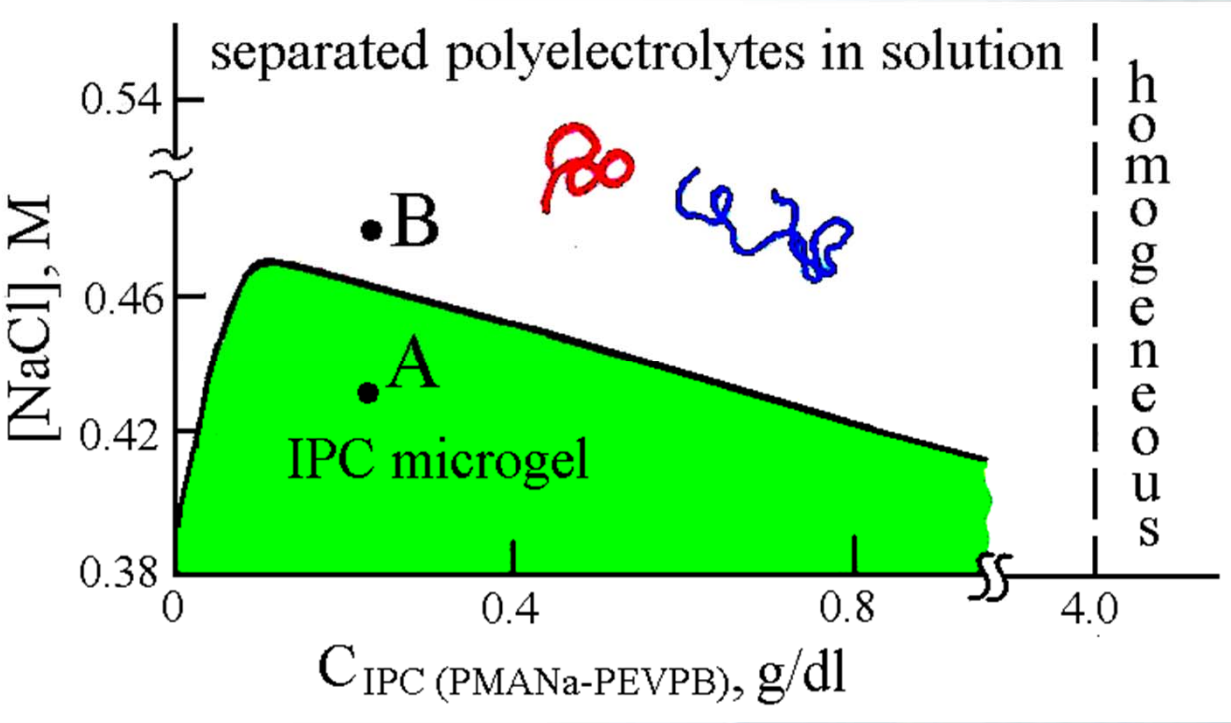
Typical phase diagram for IPC water–salt solution

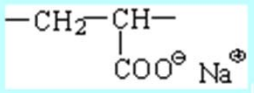


If one move from the point B to A via diluting IPC solution with pure water the system transforms into the microgel.

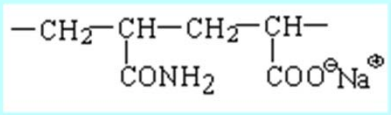
Polyanions and Polycations applied as binders

Polyanions

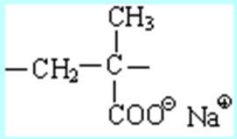
PANa



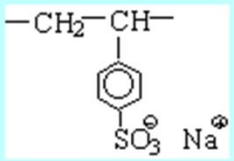
HPAN



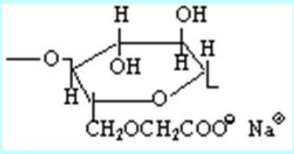
PMANa



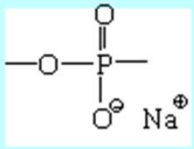
PSSNa



CMC-Na

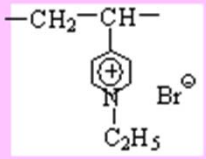


PPhNa

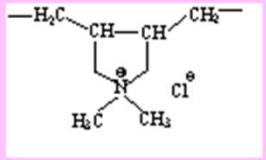


Polycations

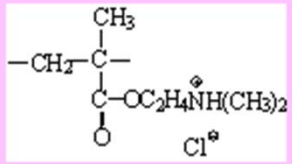
PEVPB



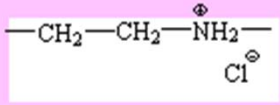
PDADMAC



PDMAEMA



PEI



CHITOSANE