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

nuclear power plant

Co60
Sr90
Cs134
Nb95
Cs137
Pu239
Pu238
I131
Zr95

Cs137
U238
U235

Co60
Sr90
Cs134
Nb95
Cs137
Ce144
Zr95

Cs134
Pu239
Pu238
I131
Zr95

Co60
Sr90
Cs134
Nb95
Cs137
Ce144
Zr95

Cs134
Pu239
Pu238
I131
Zr95

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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).

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 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.
KNO₃ – 5% wt.
Water – the reminder

Consumption of compound is 10 t per 1 hectare (1 liter per 1 m²)
Water–salt solution of polyelectrolytes mixture

Addition of pure water

IPC precipitation

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

<table>
<thead>
<tr>
<th>Sample</th>
<th>The radioactivity, $10^{-6}$ Cu $\cdot$ m$^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment</td>
</tr>
<tr>
<td>1</td>
<td>4.9</td>
</tr>
<tr>
<td>2</td>
<td>37.5</td>
</tr>
<tr>
<td>3</td>
<td>97.6</td>
</tr>
<tr>
<td>4</td>
<td>56.4</td>
</tr>
<tr>
<td>5</td>
<td>179.3</td>
</tr>
</tbody>
</table>
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

IPC + seeds
Soil- IPC crust does not hamper the growth of grass, it stimulated their growth.
<table>
<thead>
<tr>
<th>N</th>
<th>IPC</th>
<th>$C_{IPC}$, wt.%</th>
<th>Salt (C, wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HPAN-PDADMAC</td>
<td>2.0</td>
<td>NaCl/CaCl$_2$ (1.8/0.4)</td>
</tr>
<tr>
<td>2</td>
<td>HPAN-PDADMAC</td>
<td>2.0</td>
<td>KCl/MgCl$_2$ (1.9/0.4)</td>
</tr>
<tr>
<td>3</td>
<td>HPAN-PDADMAC</td>
<td>2.0</td>
<td>KNO$_3$/CaCl$_2$ (2.70/0.42)</td>
</tr>
<tr>
<td>4</td>
<td>HPAN-PDADMAC</td>
<td>2.0</td>
<td>NaCl/MgCl$_2$ (1.8/0.4)</td>
</tr>
<tr>
<td>5</td>
<td>CMC-PDADMAC</td>
<td>1.65</td>
<td>NaCl/CaCl$_2$ (1.26/0.44)</td>
</tr>
<tr>
<td>6</td>
<td>CMC-PDADMAC</td>
<td>1.65</td>
<td>KCl/CaCl$_2$ (1.64/0.77)</td>
</tr>
<tr>
<td>7</td>
<td>CMC-PDADMAC</td>
<td>1.65</td>
<td>KNO$_3$/CaCl$_2$ (2.5/0.4)</td>
</tr>
<tr>
<td>8</td>
<td>CMC-PDADMAC</td>
<td>2.0</td>
<td>KNO$_3$/MgCl$_2$ (2.0/0.4)</td>
</tr>
<tr>
<td>9</td>
<td>CMC-PDADMAC</td>
<td>2.0</td>
<td>NH$_4$NO$_3$/CaCl$_2$ (1.6/0.3)</td>
</tr>
</tbody>
</table>

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

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 reusable.
Other fields of IPC application

- Immobilization of moving sands (desertification control)
- Treatment of slopes for soil-reclamation canals
- Conservation of temporarily unused mining dumps
- Treatment of road and railroad slopes
- Protection of extended surfaces in emergency
- Clearing of industrial wastewater
- Construction of (temporary) roads and airfields
- Construction of drainage systems
- Dust catching control in megalopolises, mining and processing enterprises, etc.
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 (IPC\textsubscript{s}) 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\textsubscript{c} compound for the decontamination of contaminated dispersions and the remediation of soil.

IPC\textsubscript{c} 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
Thank you!
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

<table>
<thead>
<tr>
<th>Polyanions</th>
<th>Polycations</th>
</tr>
</thead>
<tbody>
<tr>
<td>PANa</td>
<td>PEVPB</td>
</tr>
<tr>
<td>HPAN</td>
<td>PDADMAC</td>
</tr>
<tr>
<td>PMANa</td>
<td>PDMAEMA</td>
</tr>
<tr>
<td>PSSNa</td>
<td>PEI</td>
</tr>
<tr>
<td>CMC-Na</td>
<td>CHITOSANE</td>
</tr>
<tr>
<td>PPhNa</td>
<td></td>
</tr>
</tbody>
</table>