Nanoparticles with potential to stabilize smectite clays in coal seam gas reservoirs

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Research aim

This projects aims to identify potential nanoparticle technologies to prevent swelling and spalling of smectite clays in coal seam gas well bores.

The key activities in this project include:

1. Screening clay stabilisers using visual and swellometer apparatus.
2. Detailed investigations of the surface interactions between nanoparticles and the clay minerals.
3. Evaluation of effectiveness of clay stabilisation under a flow of fresh water (or model reservoir fluid).

Screening of nanoparticles

- A visual swell test method was used to evaluate the effectiveness of six commercial nanoparticles (NP) to reduce swelling of bentonite clay powders. Initial screening of NPs was performed in distilled water.
- The metric of **swelling index (SI)** shows the change in height over the initial height of the clay.
- Fig. 1 shows the SI for bentonite treated with different concentrations of NPs. The red dashed line at SI=2.6 is for bentonite in distilled water (no NPs).
- We also observed silica NPs were effective in mitigating swelling across the widest pH range (3 to 13).

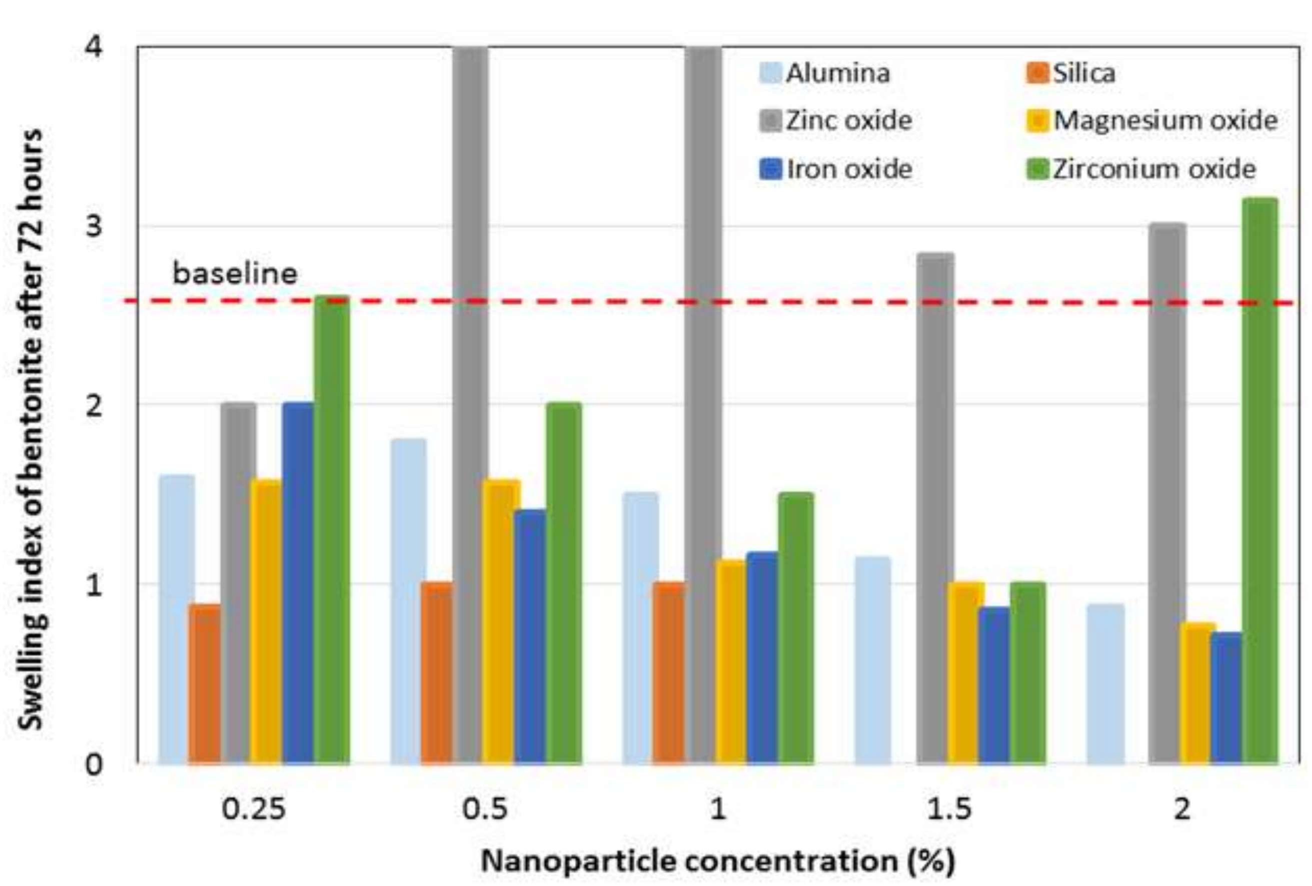
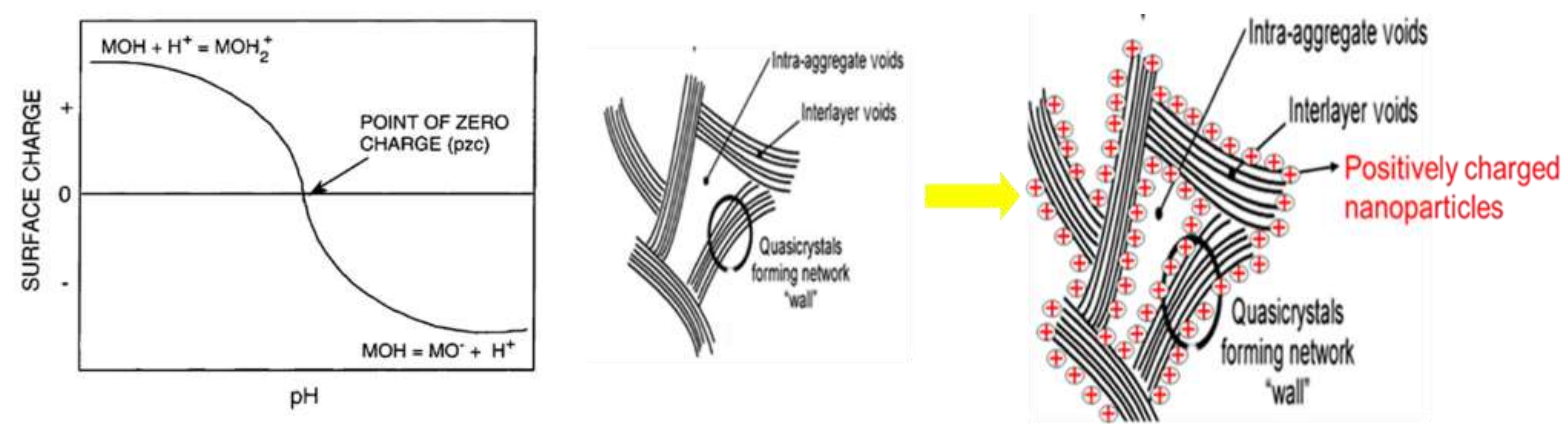


Figure 1: Swelling index of bentonite treated with each of the nanoparticles in distilled water measured using a visual swelling test.

Potential Mechanisms

The NPs exhibit a net positive charge under certain conditions, and so can act similar to a simple cation such as Na^+ or K^+ used in a brine. This project will evaluate if the charged NPs can provide a longer lasting clay stabilisation than traditional brine treatments.

The isoelectric point of silica is around pH 2.5, below that it exhibits positive charge. In the presence Na^+ ions, negatively charged silica nanoparticles will coordinate with the Na+ ion and exhibit positive charge which could be responsible for clay swelling inhibition



Swelling in model formation water

A set of model formation waters were prepared to test the effectiveness of the NPs at conditions more like the formation water:

A1: TDS 2550 mg/L, Na 1000mg/L and pH 5 (buffered by HCl)

A2: TDS 2550 mg/L, Na 1000mg/L and pH 9 (buffered by NaOH)

B1: TDS 9000 mg/L, Na 3500mg/L and pH 5 (buffered by HCl)

B2: TDS 9000 mg/L, Na 3500mg/L and pH 9 (buffered by NaOH)

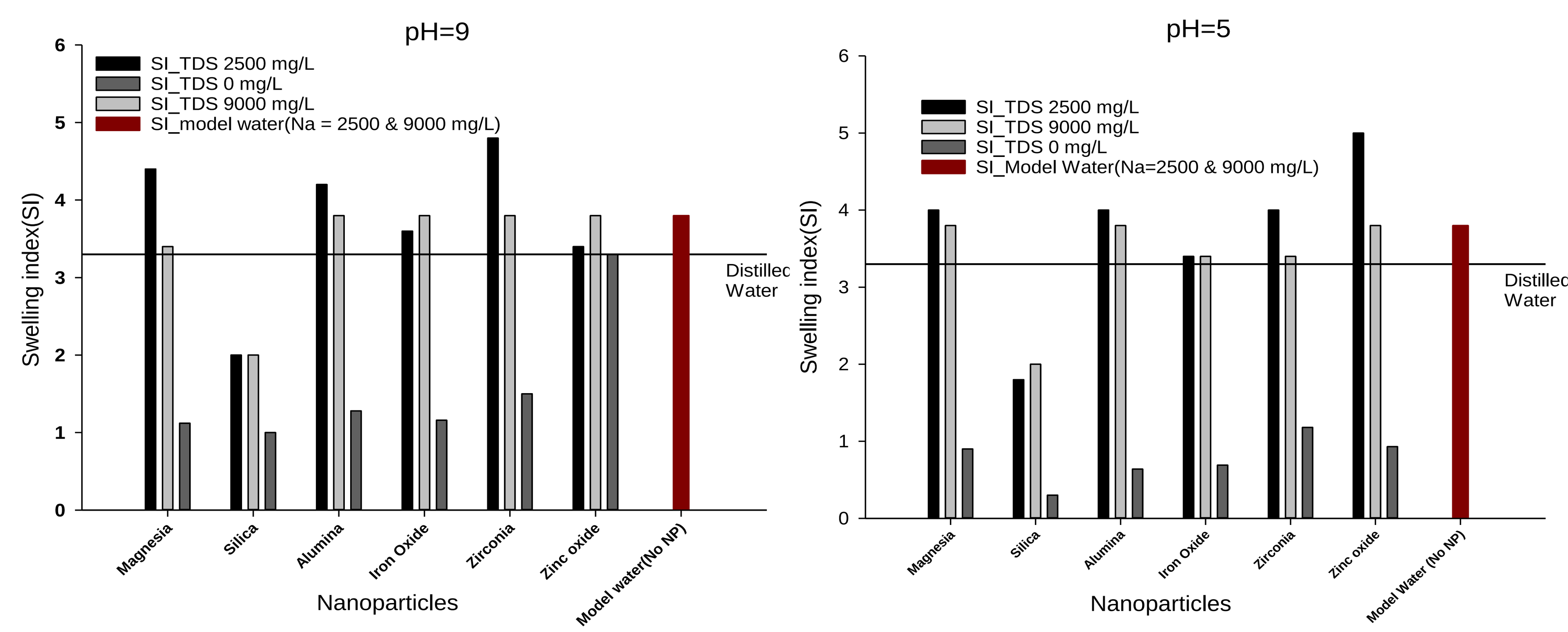


Figure 2: Comparison of swelling of bentonite treated with the six nanoparticles at different pH and TDS concentrations. The horizontal line in each figure represents the swelling index of bentonite measured in distilled water. Among all the nanoparticles silica nanoparticles showed potential to prevent clay swelling under formation water chemistry. The tests indicated that the presence of sodium ions in the formation water interfered with the ability of the nanoparticles to inhibit swelling of the bentonite clay.

Example visual swell test

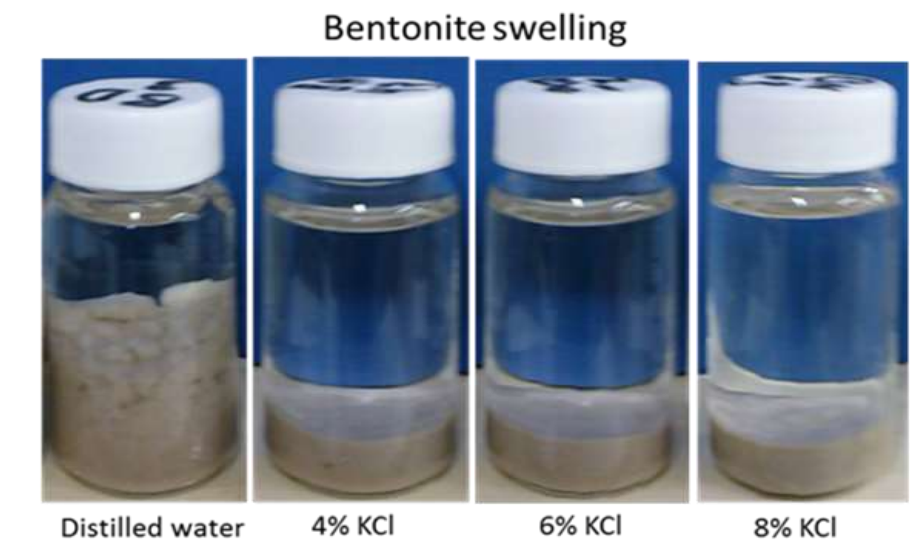


Figure 3: Example of visual swell tests performed with 2g of bentonite powder in 20 mL of distilled water or KCl brines. Swelling indexes for the brines were 0.94 in 4% KCl, 0.46 in 6% KCl and 0.20 in 8% KCl.

Summary and recommendations

- In distilled water five of the six nanoparticles exhibited some potential to control clay swelling. Zinc oxide nanoparticles did not prevent clay swelling in distilled water.
- In the presence of salt (NaCl) and at pH of some typical formation water for CSG reservoirs, the silica NPs show the most promising clay stabilisation potential.
- Screening experiments highlighted two controlling factors that must be investigated further:
  1. pH and the isoelectric point of the nanoparticles, and
  2. Dispersion of the nanoparticles in the treatment fluid.

Future work

1. Refinement of the clay swelling measurement techniques to (a) understand interaction of NPs and clay, and (b) allow translation of results from powdered clay to consolidated rock samples.
2. Development of a mechanistic model to describe how nanoparticles may stabilise clay swelling.
3. Investigation of charge behaviour of nanoparticles (i.e. zetapotential and isoelectric point measurements).
4. Functionalisation or coating of nanoparticles to improve effectiveness and aid dispersion in aqueous solutions.

Acknowledgement

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