Enhanced *in situ* biogas production from coal using semi conductive neutral red crystals

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Biologically produced combustible gas (biogas) has a large role to play in the future energy security of humankind. Coal deposits globally have great potential for methane generation via microbial biogasification. In our project we enhanced microbial methane formation from coal-associated groundwater through the application of the synthetic phenazine neutral red. The amendment was conducted in 80 m deep wells penetrating a coal seam in Australia in triplicate. The synthetic phenazine neutral red (2-amino-8-dimethylamino-3-methylphenazine) is a redox active compound that substantially increases methane production from anaerobic coal-fed cultures through the formation of self-assembling neutral-red crystal structures. Results show that the novel crystalline structure of neutral red acts as an organic semiconductor mediating electron transfer and enhancing the conversion of carbonaceous material to methane by rewiring the electron flow in favour of methanogenic populations. Neutral red is shown to deliver electrons directly to the heterodisulfide reductase of *Methanosarcina mazei*. *in situ* methanogenesis outperformed other proposed enhancement methods (nutrient or acetate addition). Furthermore, bacterial representatives of the coal-associated groundwater community related to *Rhizobium*, *Shewanella*, *Hydrogenophaga*, *Clostridium*, *Geosporobacter* and *Geobacter* species were stimulated whilst the growth of sulfate-reducing bacteria was inhibited favouring methane production.