Providing a "quick wash" to oil contaminated wildlife using magnetic particle technology (MPT)

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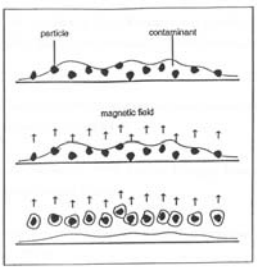
How can MPT be applied to environmental remediation and wildlife rehabilitation?

A very simple concept……



But the science is very challenging……

Development of the particles themselves – different materials, surface variation, size distributions, coatings etc….

Optimizing the particles with respect to different oils and substrates, such as rock surfaces, feathers, plumage, fur, live animals….

Development of the 'magnetic harvester' – field strength, on/off mechanism, design features etc…..

Development of methodologies and protocols for testing ….

Moving proof of principle 'lab work' to the field….

Waste disposal for different scenarios…..

Logistics and costs….

Potential spin-offs…..

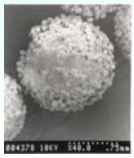
Particle development …..

Various particles continue to be explored and tested including -

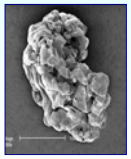
Iron particles coated with a hydrophobic oil-ab(d)sorbing material such as PVC or PE.

Different grades of finely divided iron powder with different surface characteristics.

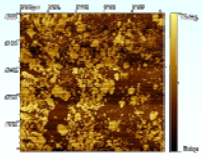
Iron particles with "nanoscale surface roughness" resulting in "super-hydrophobic" properties when coated with materials such as polydimethysiloxane (PDMS).



PVC coated iron pellet



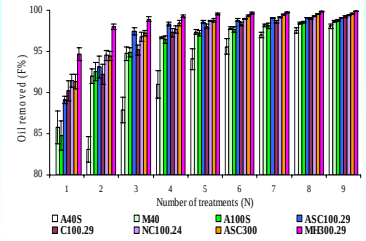
Different grades of iron powder



AFM imaging of iron particle surface

Optimizing the particles themselves…..

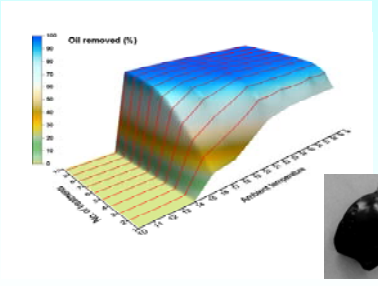
Comparative removal of oil from feathers for eight different grades of iron powder. MH300.29 ("spongy superfine") achieves 100% within experimental error.

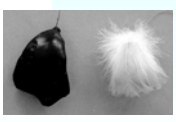


H. V. Dao, L.N. Ngeh, S.W. Bigger and J.D. Orbell, 2005, **"The achievement of 100% removal of oil from feathers employing magnetic particle technology"**, *J. Environ. Eng.*, Vol. 132, No. 5, 555-559.

Different oil types and ambient conditions…..

Removal of tarry/weathered contamination from feathers -





J.D. Orbell, H.V. Dao, L.N. Ngeh, S.W. Bigger, M. Healy, R. Jessop and P. Dann, 2005, **"Acute temperature dependency in the cleansing of tarry feathers utilizing magnetic particles"**, *Environ. Chemistry Letters*, 3(1), 25-27.

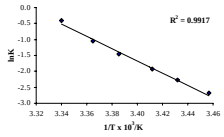
Why does this happen?

The transfer of oil from the surface of the tarry residue onto the iron particles represents competitive adsorption between two different surfaces:

Oil (tar) ➔ Oil (iron)

The experimental design allows the equilibrium constant for the process to be estimated at different temperatures and at different stages of removal.

This allows the Van't Hoff Equation, $\ln K = -\Delta H^{\circ}/RT + \Delta S^{\circ}/R$, to be applied.



Overall we can say that:

The process is *endothermic*. This favours transfer of oil onto the iron as the temperature increases.

The process is highly *entropy driven*.

J.D. Orbell, H.V. Dao, L.A. Maher, L.N. Ngeh, S.W. Bigger, M. Healy, R. Jessop and P. Dann, 2006, **" Removal of petroleum tar from bird feathers utilizing magnetic particles"**, *Environ. Chemistry Letters*, 4, 111-113.

Optimizing the magnetic harvester….

"Horses for courses"…….

The 'magnetic tester'– suitable for laboratory testing and proof of principle studies. Requires two hands to operate.

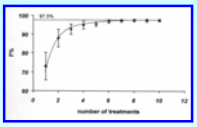
Trial electromagnetic device – insufficient magnetic field strength.

One-handed device powered by compressed air – too cumbersome for field work

The "magnetic wand" designed for a "quick clean (wash)". Strong localized magnetic field – non magnetic tip.

Different substrates…..

From feather clusters | **From rock surface** | **From Mammalian fur**



From plumage – whole bird models

Clean Little Penguin carcase

50% coverage of bunker oil

After 5 treatments

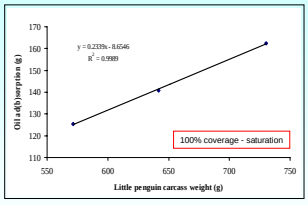
After 14 treatments

J.D. Orbell, H.V. Dao, J. Kapadia, L.N. Ngeh, S.W. Bigger, M, Healy, R, Jessop and P. Dann, 2007, **"An Investigation into the removal of oil from rock utilizing magnetic particle technology",** *Marine Pollution Bulletin*, 54, 1958 – 1961.

J.D. Orbell, L.N. Ngeh, S. W. Bigger, M. Zabinskas, M. Zheng, M. Healy, R. Jessop and P. Dann, 2004, **"Whole-Bird Models for the Magnetic Cleansing of Oiled Feathers"**, *Marine Pollution Bull.*, 48, 336-340.

Development of specific methodologies…..

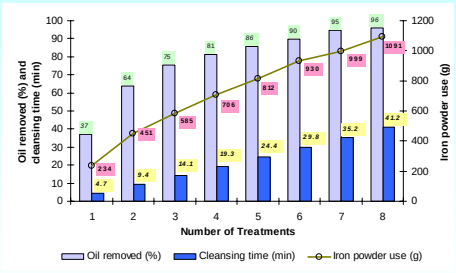
For example, determining the % coverage by mass for controlled experiments.



For example: for a bird with a body weight of 620 g the weight of oil required for saturation (100 % coverage) is (0.2339 x 620) – 8.6546 = 136 g. Therefore, 50% coverage by weight requires 136.4 x 0.5 = 68.2 g of oil to be applied.

Diesel required for 50% coverage

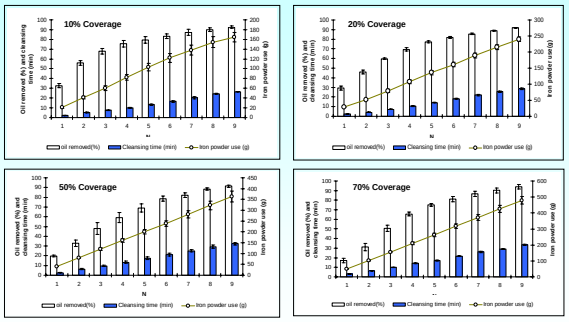
Systematic feasibility experiments - the potential for a "quick wash"



100% diesel coverage of Little Penguin plumage – a "worst case" scenario

J.D. Orbell, H.V. Dao, L.N. Ngeh and S.W. Bigger, (2008), **"An investigation into the feasibility of applying magnetic particle technology to the cleansing of oiled wildlife in the field"**. Report prepared for the Australian Maritime Safety Authority (National Plan Environment Working Group) and the Phillip Island Nature Park.

% coverage experiments (diesel)



Magnetic tester; iron powder grade MH300.29; no pre-conditioner

J.D. Orbell, H.V. Dao, L.N. Ngeh, S.W. Bigger, M. Healy, R. Jessop and P. Dann, 2006, **"Magnetic cleansing of weathered/tarry oiled feathers - the role of pre-conditioners"**, *Marine Pollution Bulletin*, 52, 1591-1594.

"In the field" scenario – some *conservative* numbers

Based on 100 birds for 1 (blue) treatment and 2 (red) treatments

Number of birds = 100 (100)

Average coverage = 50% (50%)

Treatments per bird = 1 (2)

Average time for treatment(s) = 2.5 min (5 min)

Average mass of powder per bird = 35 g (68 g)

Average % oil removal = 25% (40%)

Average mass of oil removed per bird = 17 g (27 g)

Number of 2-person teams = 2 (2)

Total person hours required = 4.2 hrs (8.4 hrs)

Total time per 2-person team = 2.1 hrs (4.2 hrs)

Number of birds per 2-person team = 50 (50)

Total mass of powder = 3.5 kg (6.8 kg)

Total mass of oil removed = 1.7 kg (2.7 kg)

Total mass of waste = 5.2 kg (9.5 kg)

Mass of powder per 2-person team = 1.75 kg (3.4 kg)

Mass of oil per 2-person team = 0.85 kg (1.35 kg)

Mass of waste per 2-person team = 2.6 kg (4.75 kg)

"Holding bay" scenario – some *conservative* numbers

Based on 1000 birds for 1 (blue) treatment and 2 (red) treatments

Number of birds = 1000 (1000)

Average coverage = 50% (50%)

Treatments per bird = 1 (2)

Average time per treatment(s) = 2.5 min (5 min)

Average mass of powder per bird = 35 g (68 g)

Average % oil removal = 25% (40%)

Average mass of oil removed per bird = 17 g (27 g)

Number of 2-person teams = 10 (10)

Total person hours required = 42 hrs (84 hrs)

Total time per 2-person team = 4.2 hrs (8.4 hrs)

Number of birds per 2-person team = 100 (100)

Total mass of powder = 35 kg (68 kg)

Total mass of oil removed = 17 kg (27 kg)

Total mass of waste = 52 kg (95 kg)

Mass of powder per 2- person team = 3.5 kg (6.8 kg)

Mass of oil per 2-person team = 1.7 kg (2.7 kg)

Mass of waste per 2-person team = 5.2 kg (9.5 kg)

Some estimated costs for both scenarios

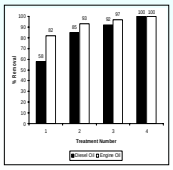
100 Birds/2 Teams3	One treatment	Two treatments
Iron powder at $5.50/kg	3.5 kg x 5.5 = $19	6.8 kg x 5.5 = $37
Waste disposal at $8/kg	5.2 kg x 8 = $42	9.5 kg x 8 = $76
Personnel at $25 per hour	2.1 hrs x 4 x 25 = $210	4.2 hrs x 4 x 25 = $420
Total	$271	$533
Cost per bird	**$2.71**	**$5.33**

1000 Birds/10 Teams	One treatment	Two treatments
Iron powder at $5.50/kg	35 kg x 5.5 = $193	68 kg x 5.5 = $374
Waste disposal at $8/kg	52 kg x 8 = $416	95 kg x 8 = $770
Personnel at $25 per hour	4.2 hrs x 20 x 25 = $2100	8.4 hrs x 20 x 25 = $4,200
Total	$2,709	$5,344
Cost per bird	**$2.71**	**$5.34**

Latest estimate of equipment with "wand" = $600/team team

Developing equipment, techniques and logistical data for a quick wash – utilizing the "wand"……..

Non-magnetic tip allows oil laden particles to be readily disposed of.



The Animal Rehabilitation Technology (ART) Group

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