Magnetite nanoparticles and ferromagnetic bionanocomposites for crude oil removal from water

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21–24 June

AQUA

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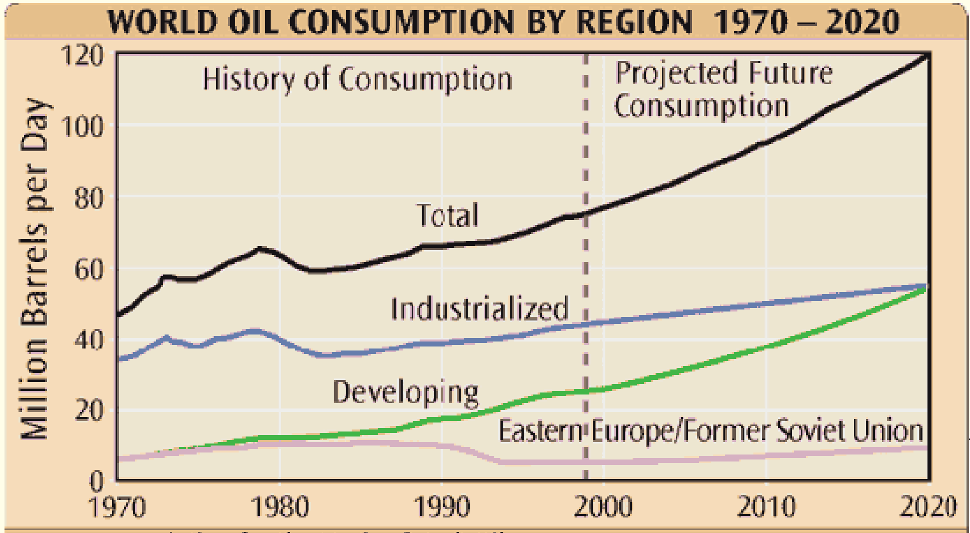
1933

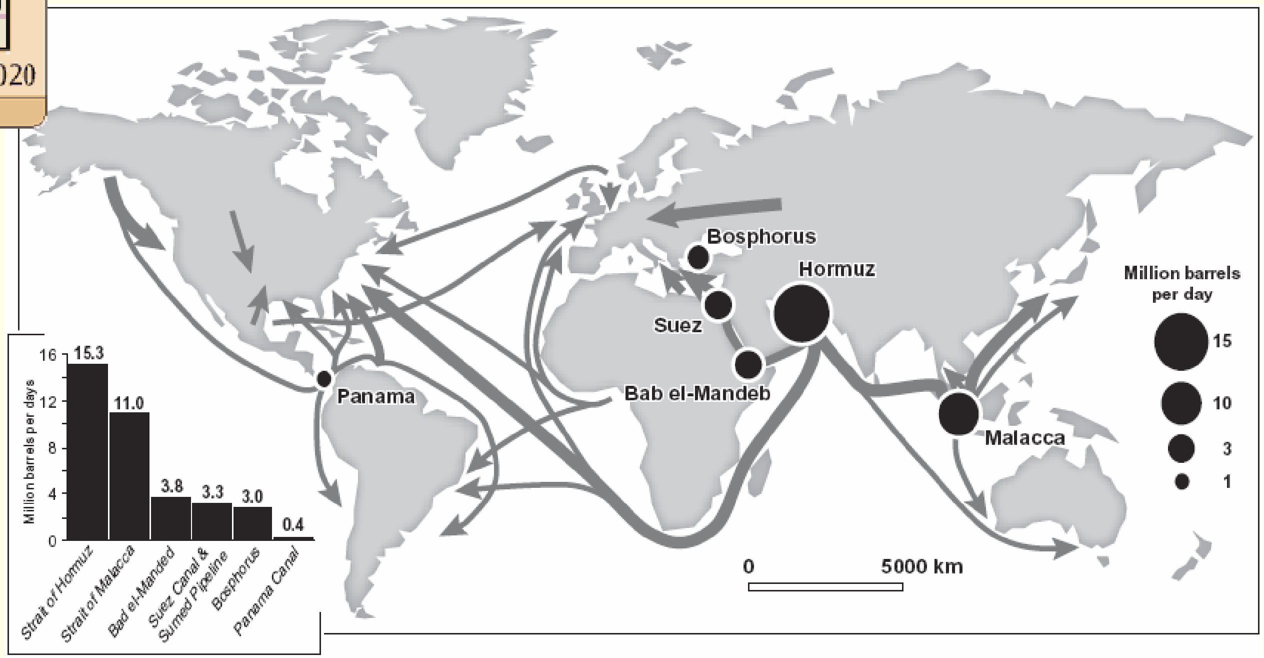
5th International Conference on Sustainable Solid Waste Management

Basis of our motivation



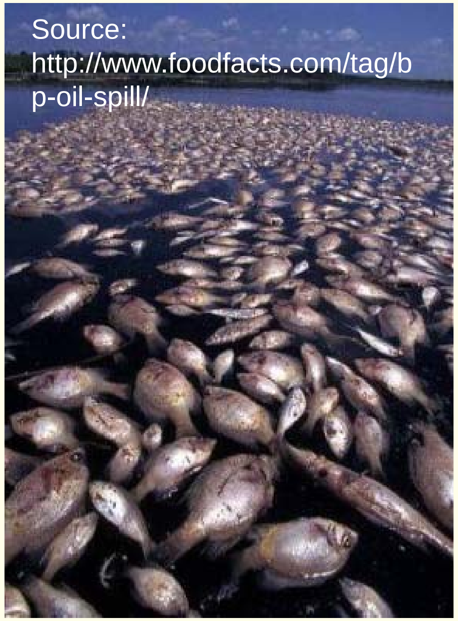
Source: Association for the Study of Peak Oil, www. asponews.org

Main oil routes in the world



Source: https://www.erudit.org

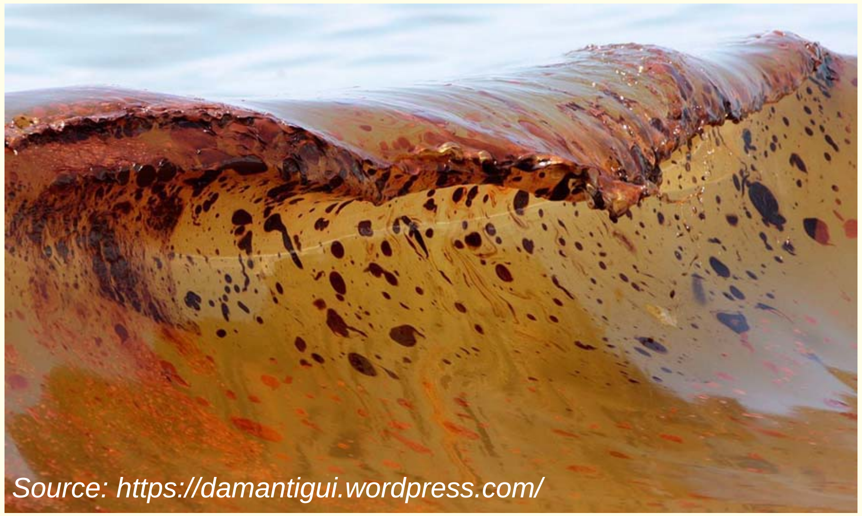
Source: http://www.theblackvault.com/document archive/oil-spills/#



Source: http://www.foodfacts.com/tag/bp-oil-spill/

Source: http://www.telegraph.co.uk

Source: https://www.dosomething.org/facts/11-facts-about-bp-oil-spill



Source: https://damantigui.wordpress.com/

Source: cccpublishing.com

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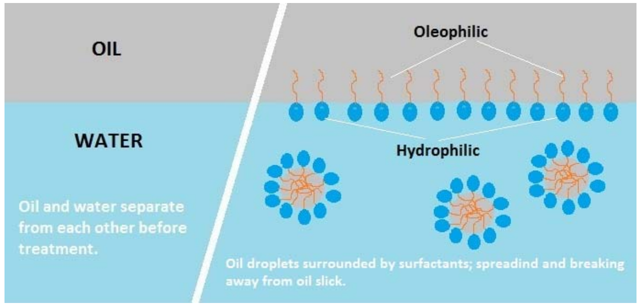
Source: http://response.restoration.noaa.gov

Gulf of Mexico oil spill in 2010 -- the worst environmental disaster in U.S. history -- to cost it $ 40 billion.

Recovery of Spilled Oils Today

Methods	Exemples	Limitations
Mechanicals	*booms, skimmers*	• Do not remove all oil
Chemicals	dispersants, surfactants and solidifiers	• Introduction of new substances in environment • Does not necessarily allow the oil to be removed
Biologicals	biodegradation	• Introduction of microorganisms and dispersants • It is necessary the prospection and the control of ideal conditions for each microorganisms • Do not permit the oil recovery



NEWS ALERT

French President Emmanuel Macron's party projected to win overwhelming majority in parliamentary election

Cleaning up oil spills with magnets and nanotechnology

By Tom Levitt, for CNN

Updated 1404 GMT (2204 HKT) September 21, 2012

Researchers hope the use of magnets will allow them to recover more oil and lead to an easier clean up operation.

Story highlights

Oil companies could soon be using an innovative new technique involving nanotechnology and magnets to help clean up offshore oil spills

FULL SCREEN

How to clean up oil spills

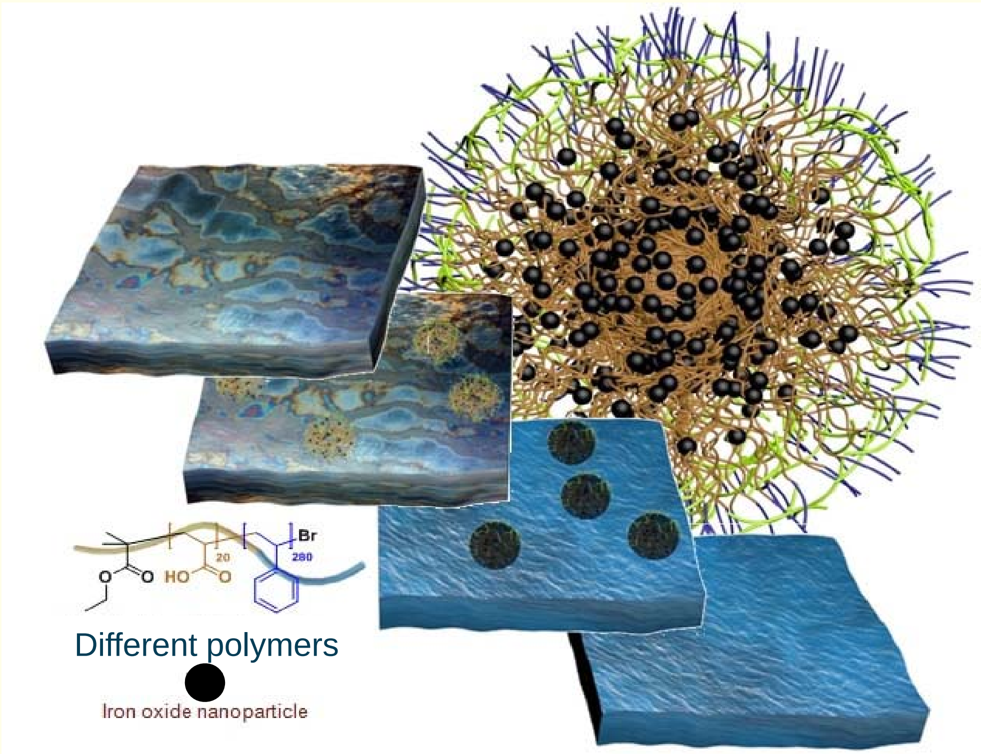
MIT researchers devise a surprisingly simple but effective method for magnetically separating oil and water.

Larry Hardesty, MIT News Office
September 12, 2012

Press Inquiries

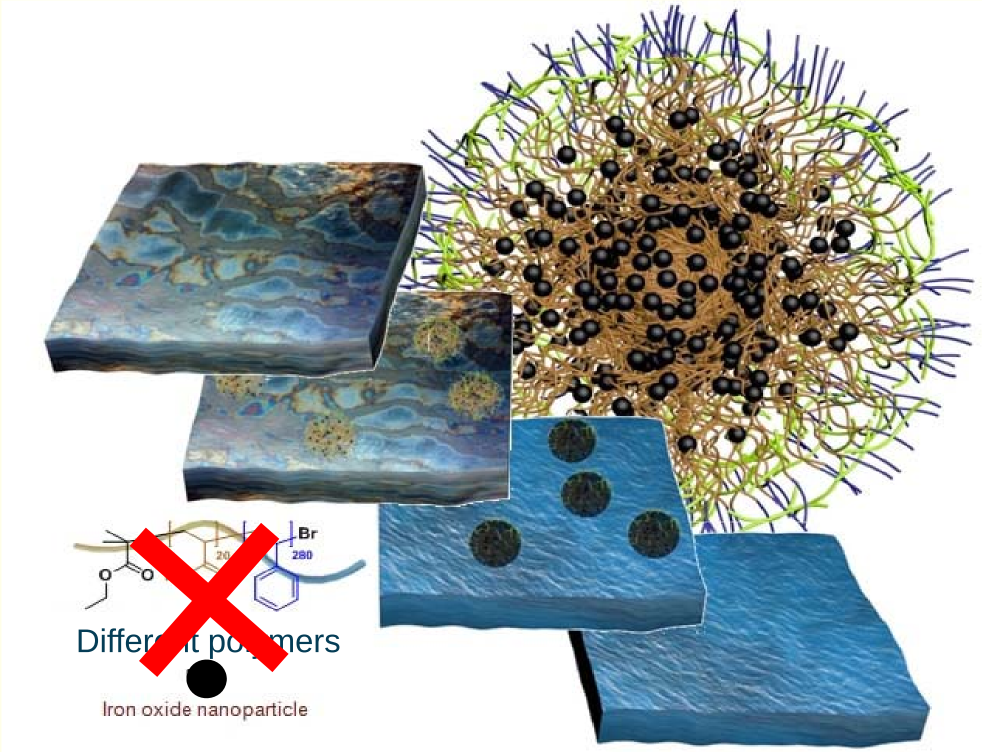
RELATED

Magnetic nanoparticles and composites: Biosorption



Source: http://www.science.tamu.edu

Magnetic nanoparticles and composites: Biosorption



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Biomasses:

Low cost

Inactive biological materials

Renewable sources

Residues

Hydrophobic surfaces

Development of new materials

(such as composites)

Synthesis

Magnetite nanoparticles

MNP

$$Fe^{2+}_{(aq)} + 2\ Fe^{3+}_{(aq)} + 8\ OH^{-}_{(aq)} \xrightarrow[\text{30 min}]{} Fe_3O_{4(s)} + 4H_2O_{(l)}$$

Addition of yeast biomass (YB)

YB-MNP

$$Fe_3O_{4(s)} + 4H_2O_{(l)} + YB_{(s)} \xrightarrow[\text{30 min, 80 °C}]{} YB - Fe_3O_{4(s)}$$

Yeast biomass (YB)

Magnetic nanoparticles (MNP)

Yeast Magnetic bionanocomposite (YB-MNP)

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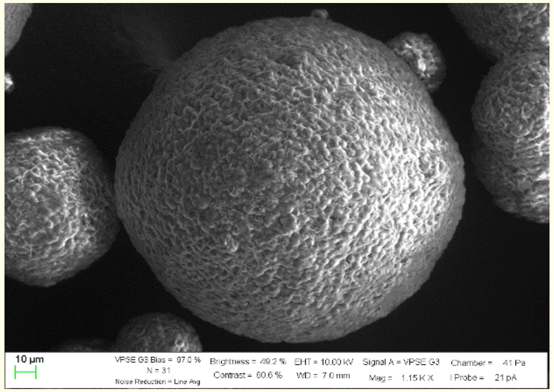
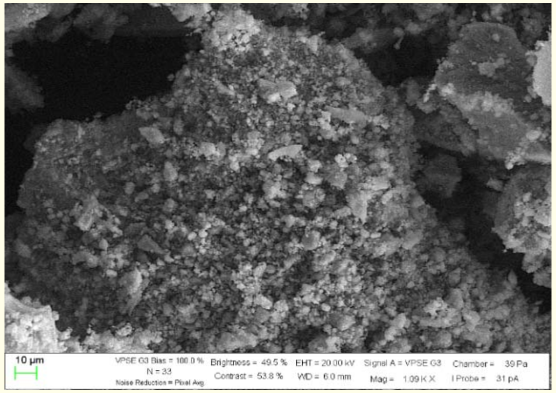
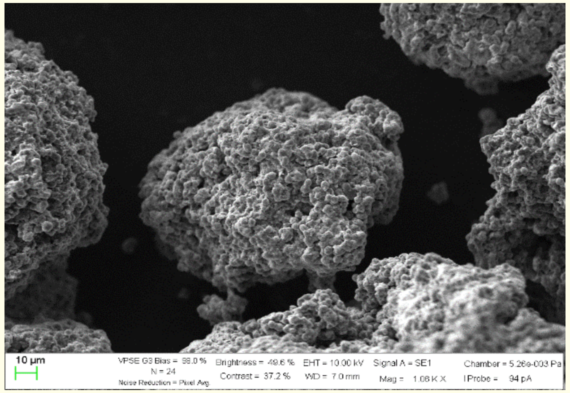
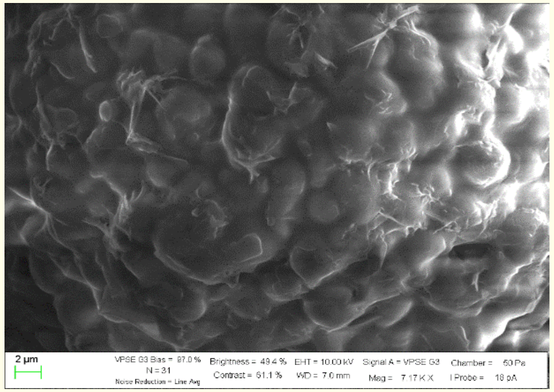
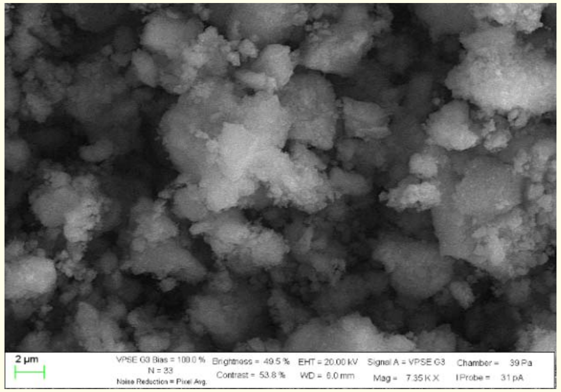
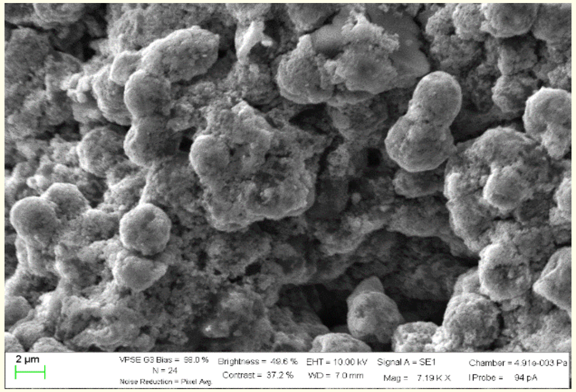
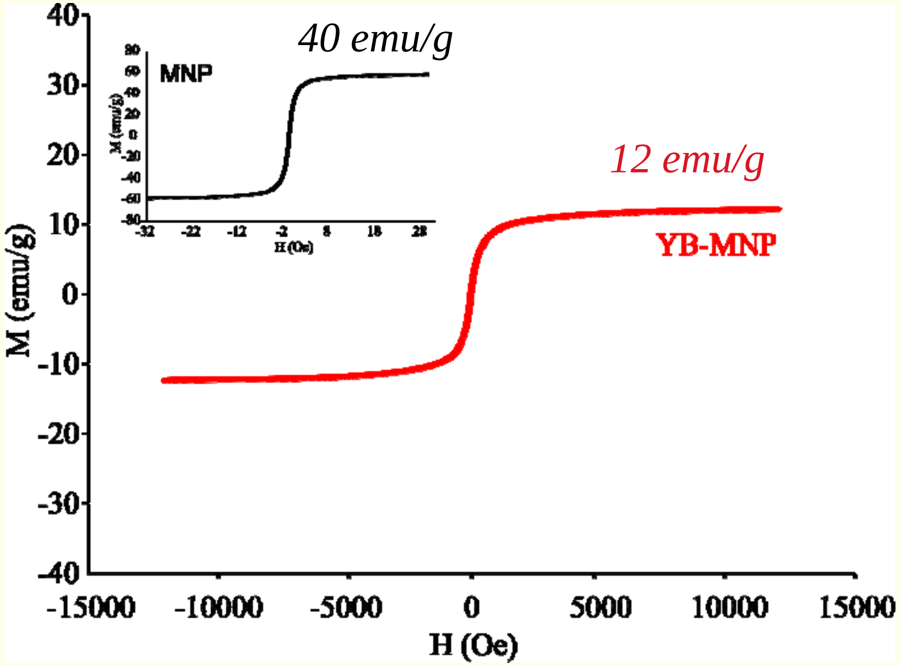
Characterization

scanning electron microscope (SEM)

	YB	MNP	YB-MNP	
magnified 1000X				
magnified 7000X				
Elemental Analyses	N = 6.14%	N = 0.40%	N = 3.8%	
	C = 41.0%	C = 3.5%	C = 29.7%	
	H = 6.21%	H = 1.0%	H = 4.3%	

Characterization

Magnetization



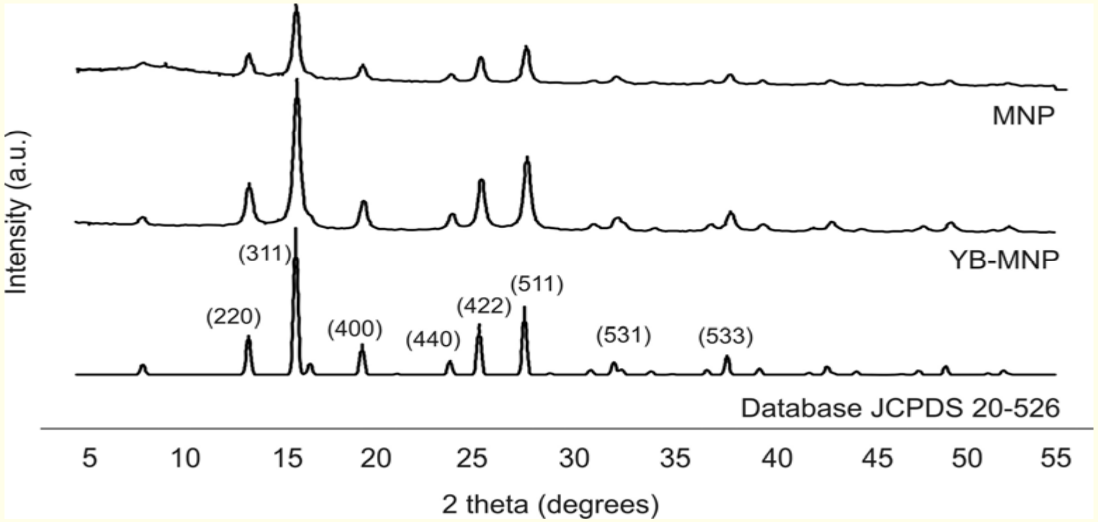
zeta potential

YB = -9.39 ± 0.86 mV (negatively charged)

YB-MNP = -13.9 ± 0.5 mV (negatively charged)

MNP = +20.3 ± 0.4 mV (positively charged)

- **Superparamagnetism: Strong magnetic response with low magnetic fields**
- **Easy removing by a magnetic field**
- **Fe_3O_4 nanoparticles are environmental friendly, naturally present**



X-ray powder diffractograms from representative MNP; YB-MNP and MNP from Database JCPDS 20-526 nanoparticles displaying the Bragg peak reflections of magnetite.

Oils removing

New Motor Oil (NMO) d = 0.8983 kg/m^3

Mixed Used Motor Oil (MUMO) d = 0.9046 kg/m^3

Petroleum 28 °API (P28API) d = 1.0366 kg/m^3

Fractional Factorial Design (two-layers procedure)

Experimental design varying four parameters: material, contact time, temperature and mass.

Condition	Material	Contact time	Temperature	Mass
C1	-1	-1	-1	-1
C2	+1	-1	-1	+1
C3	-1	+1	-1	+1
C4	+1	+1	-1	-1
C5	-1	-1	+1	+1
C6	+1	-1	+1	-1
C7	-1	+1	+1	-1
C8	+1	+1	+1	+1

Material -1 = YB-MNP

Material +1 = MNP

Mass -1 = 50 mg

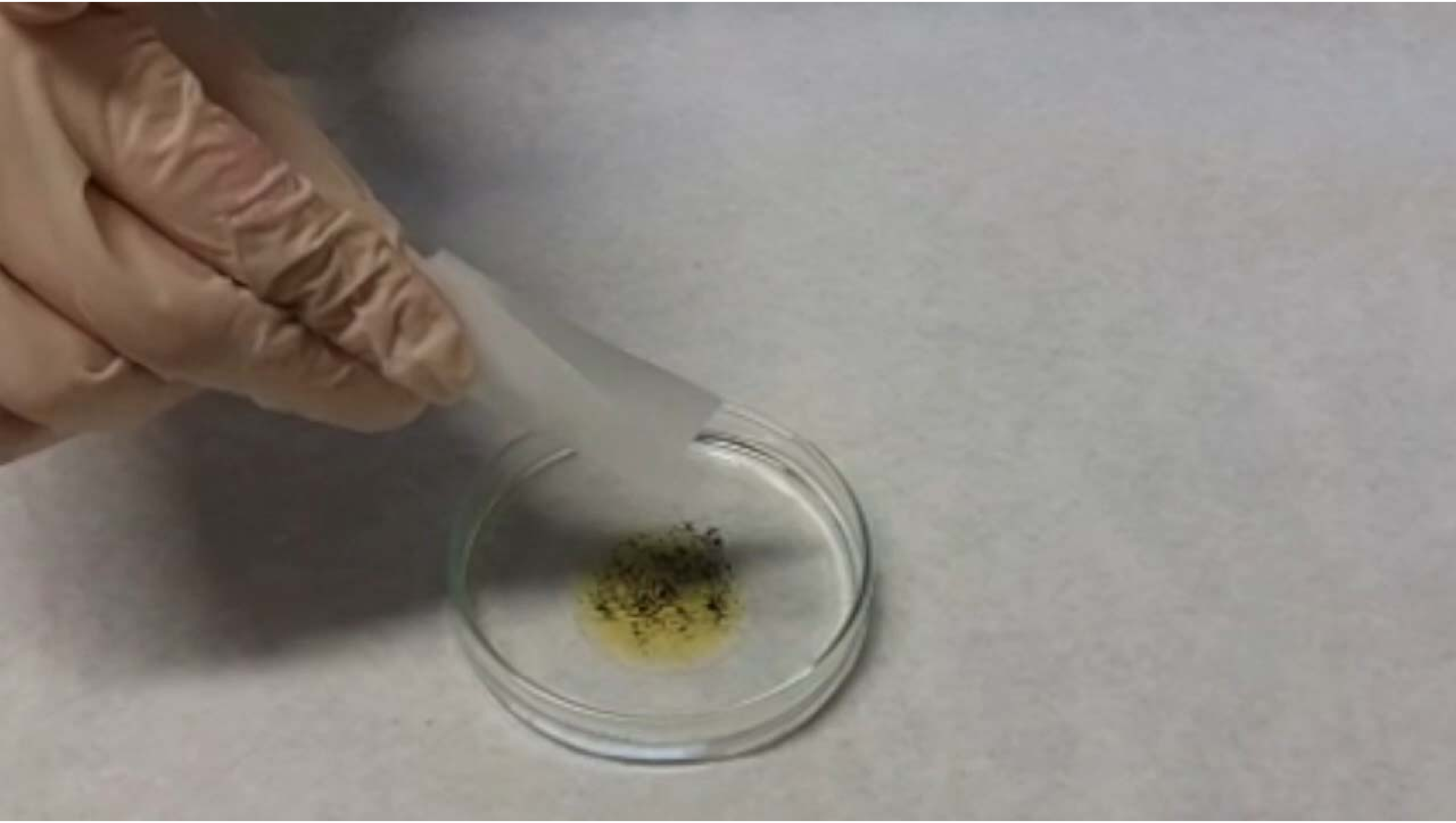
Mass +1 = 70 mg

Contact time -1 = 2 min

Contact time +1 = 30 min

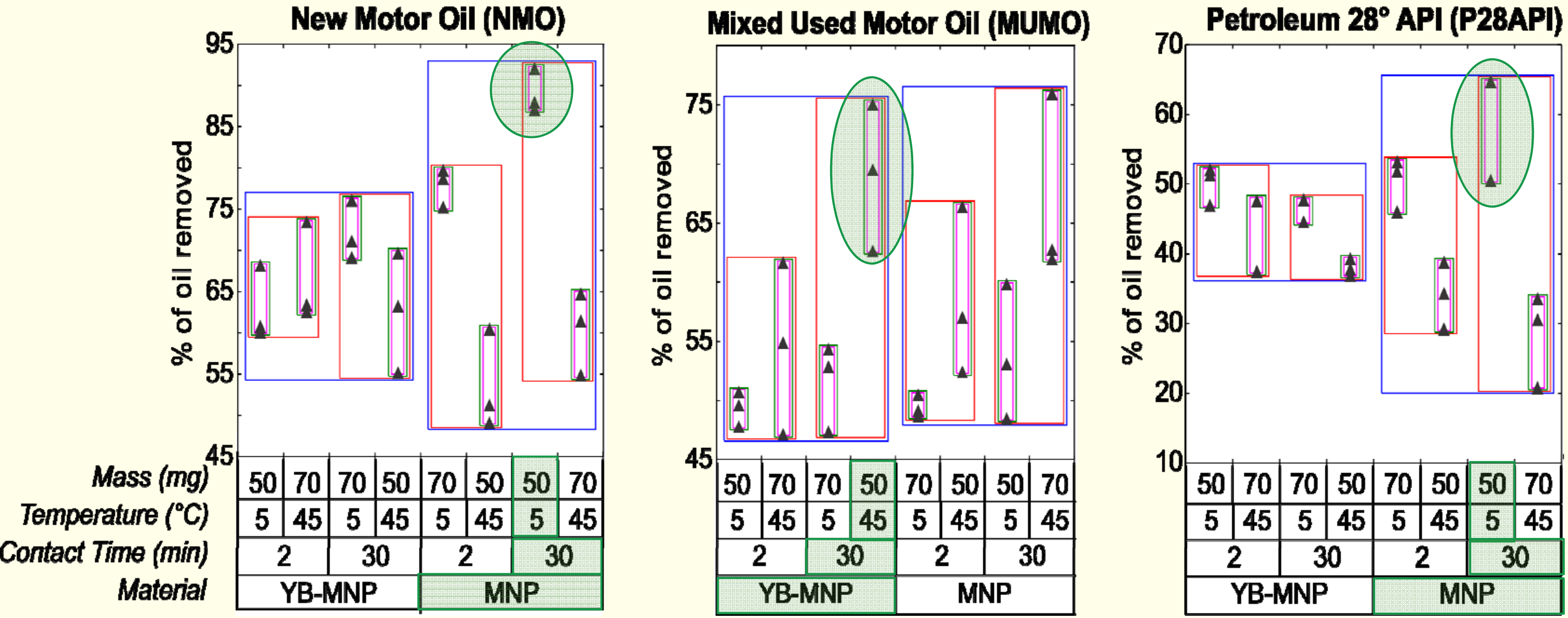
Temperature -1 = 5 °C

Temperature +1 = 45 °C



Results

D-Optimals

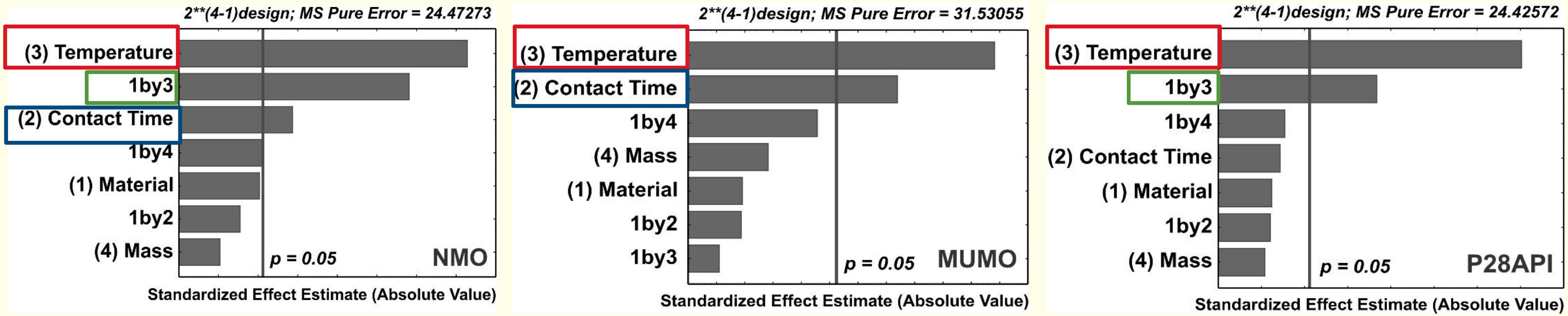


3.5 ± 0.1 kg oil/kg MNP

2.8 ± 0.3 kg oil/kg YB-MNP

2.2 ± 0.3 kg oil/kg MNP

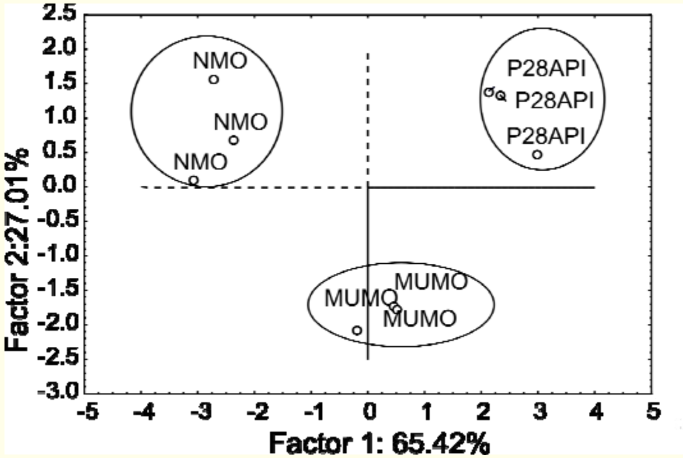
Results



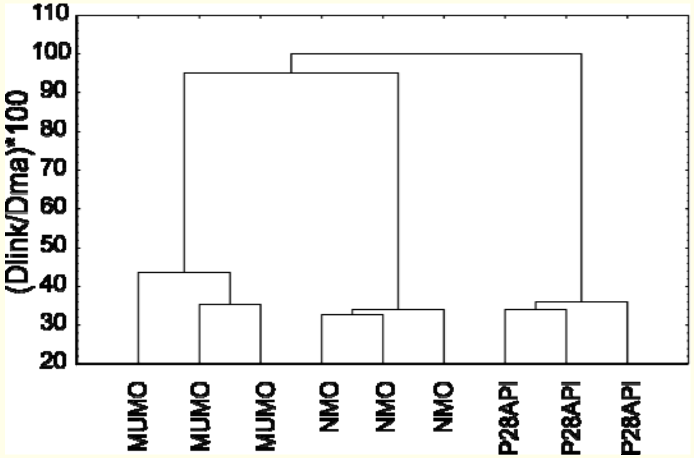
Pareto's graphics for removing of different oils by magnetic materials YB-MNP (yeast magnetic bionanocomposite) and MNP (magnetite nanoparticles).

New Motor Oil (NMO)
Mixed Used Motor Oil (MUMO)
Petroleum 28 °API (P28API)

Principal Components Analyses



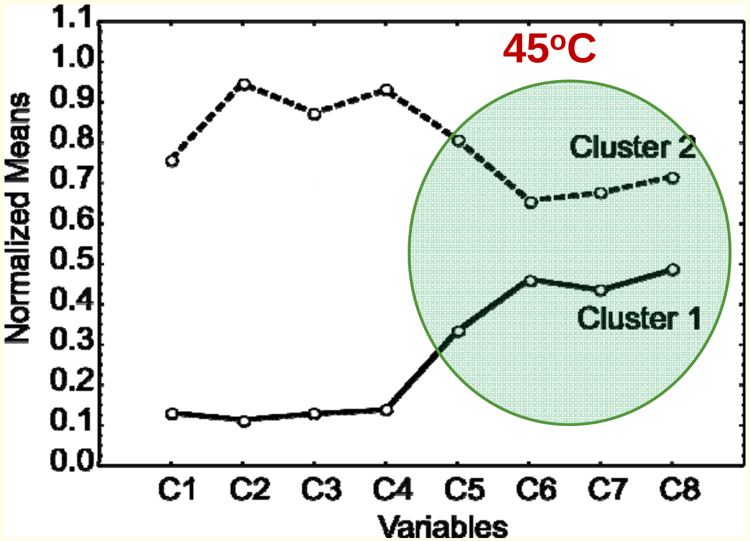
Hierarchical Components Analyses



Graphics for de complete data set of oils removal from water by the different evaluated magnetic materials.

New Motor Oil (NMO)
Mixed Used Motor Oil (MUMO)
Petroleum 28 °API (P28API)

Graph of cluster (K-Means) for the different conditions of fractional factorial design employed f\or oils removal.



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Results

Table 1. Regression analyses for oils uptakes by magnetic materials YB-MNP (bionanocomposite of yeast biomass) and MNP (magnetite nanoparticles). Material: -1 (YB-MNP) and +1 (MNP); Contact Time: -1 (2 min) and +1 (30 min); Temperature: -1 (5 °C) and +1 (45 °C); Mass: -1 (0.05 g) and +1 (0.07 g).

	Parameter				Experimental	Applied Regression Model				
Oil	**Material**	**Mass (mg)**	**Temperature (°C)**	**Contact time (min)**	**Maximum Experimental Mean (%) (just like D-Optimal)**	**D-Optimals**	**Multiple regression**	**MARS (Multivariate Adaptive Regression Splines)**	**Neural Networks**	**Models Mean**
NMO	+1	-1	-1	+1	89.0 ± 2.6	89.0 (0.0) $r^2 = 0.87$	79.5 (10.7) $r^2 = 0.54$	62.8 (29.4) $r^2 = 0.87$	89.7 (0.8) $r^2 = 0.94$	80.3 ± 31.3**
MUMO	-1	-1	+1	+1	69.1 ± 6.2	69.1 (0.0) $r^2 = 0.70$	66.5 (3.8) $r^2 = 0.65$	69.1 (0.0) $r^2 = 0.71$	68.8 (0.4) $r^2 = 0.86$	68.4 ± 3.8**
P28API	+1	-1	-1	+1	55.3 ± 8.2	55.7 (0.7) $r^2 = 0.82$	48.8 (11.8) $r^2 = 0.62$	38.1 (31.1) $r^2 = 0.82$	57.5 (4.0) $r^2 = 0.90$	50.0 ± 33.5**
Mean NMO + MUMO + P28API					71.1 ± 9.8*	71.3 ±0.7**	64.9 ± 16.4**	56.7 ± 42.8**	72.0 ± 4.1**	

*Standard Error, **Propagated Error

New Motor Oil (NMO), Mixed Used Motor Oil (MUMO), Petroleum 28 °API (P28API)

Our conclusions

- Temperature was the most significant parameter for improve oils removal capacities. However, contact time and magnetic material are also important.
- Greater contact time and smaller masses of magnetic materials improve oil removing.
- The oil characteristics affect its removal from water by this proposed method.
- The cluster analysis showed that the temperature increasing turns the behavior of the other oils similar to MUMO (from C5, temperature = 45°C).
- The theoretical models satisfactorily fitted experimental data, denoting the capacity of explanation of the observed phenomena.
- Bionanocomposite reduces de cost with reagents to produce magnetite nanoparticles maintaining the desired magnetic characteristic.

We are grateful to

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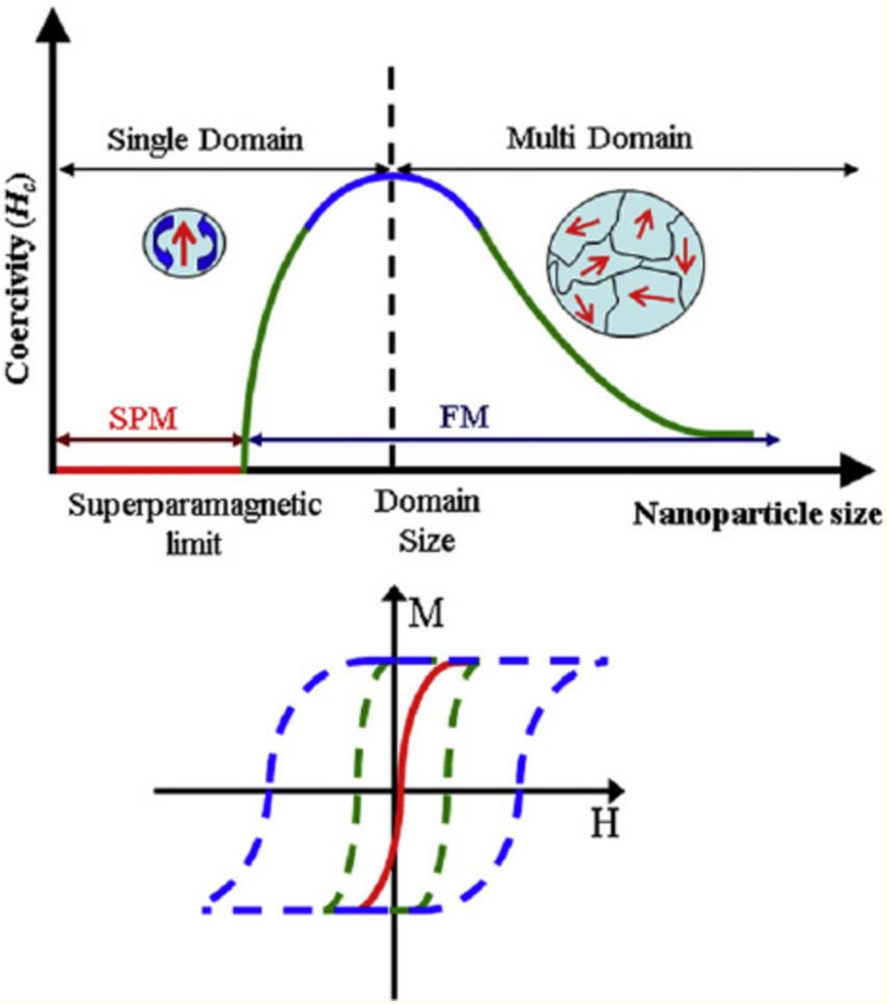

The qualitative behavior of the size-dependent coercivity of magnetic particles. The magnetic behavior of superparamagnetic (SPM) nanoparticles is demonstrated by the solid line, while ferromagnetic (FM) particles are presented by dashed lines. Here H denotes the applied magnetic field strength and M is the measured magnetization. Superparamagnetism occurs in particles with sizes smaller than the superparamagnetic limit.

ÓLEOS				
Tipo de Óleo	SAE 90	25W-60	SAE 50	20W-50
	Óleo Original	LUBRAX	LUBRAX	LUBRAX
Marca		Petrobras	Petrobras	Petrobras
GRAU SAE	90	25W-60	SAE 50	20W-50
GL		-	-	-
Densidade a 20/4oC		0,8983	0,8997	0,8846
Ponto de Fulgor (VA) (°C)		240	272	240
Ponto de Fluidez (°C)		-21	-6	-24
Viscosidade a 40°C (cSt)	180	267,7	226,2	183,7
Viscosidade a 100°C (cSt)	13,5 - 24,0	25,18	19,4	20,8
Índice de Viscosidade		121	97	134