# Kill•Spill project: Enhancement of biodegradation techniques

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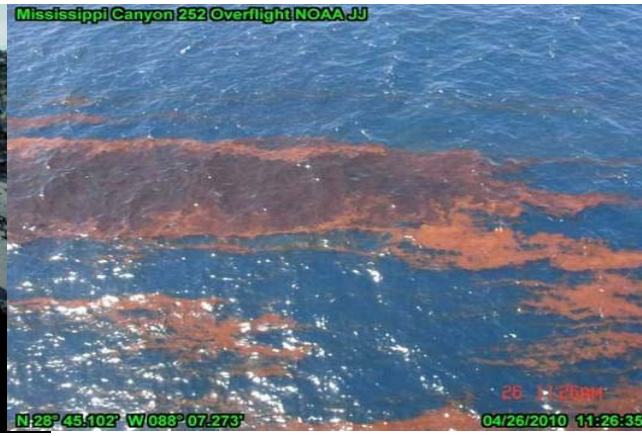
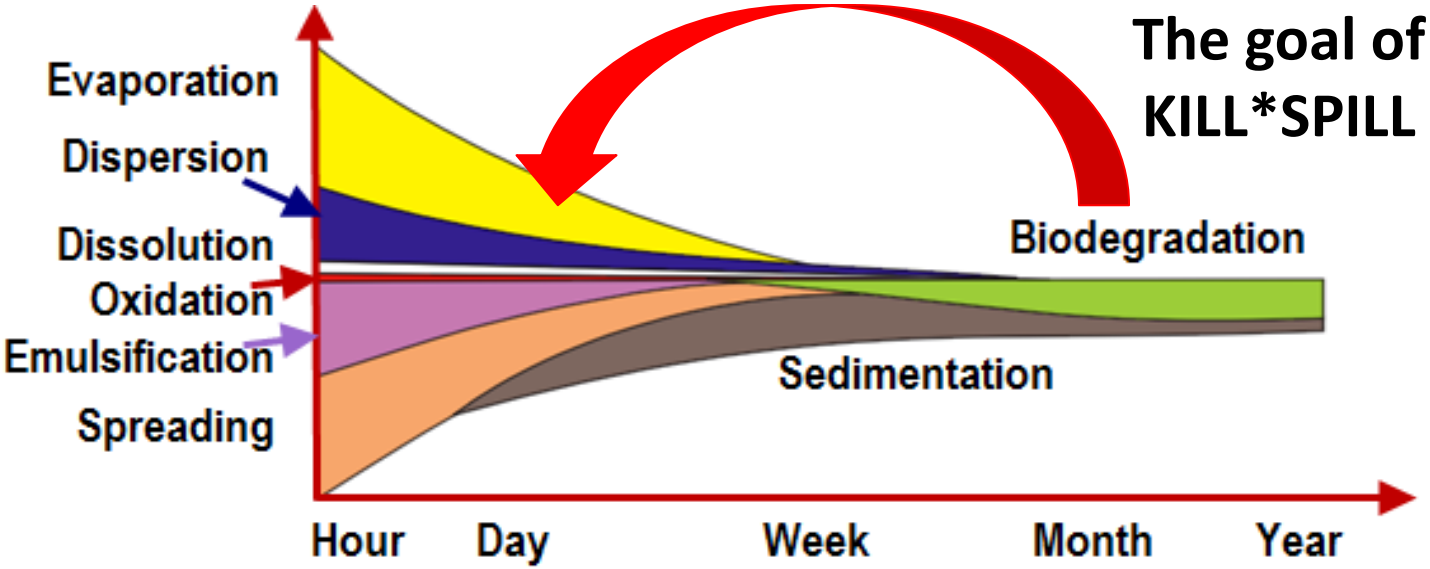
This project is supported by the European Union under the Food, Agriculture and Fisheries and Biotechnology theme of the 7th Framework Programme for Research and Technological Development under Grant Agreement no. 312139

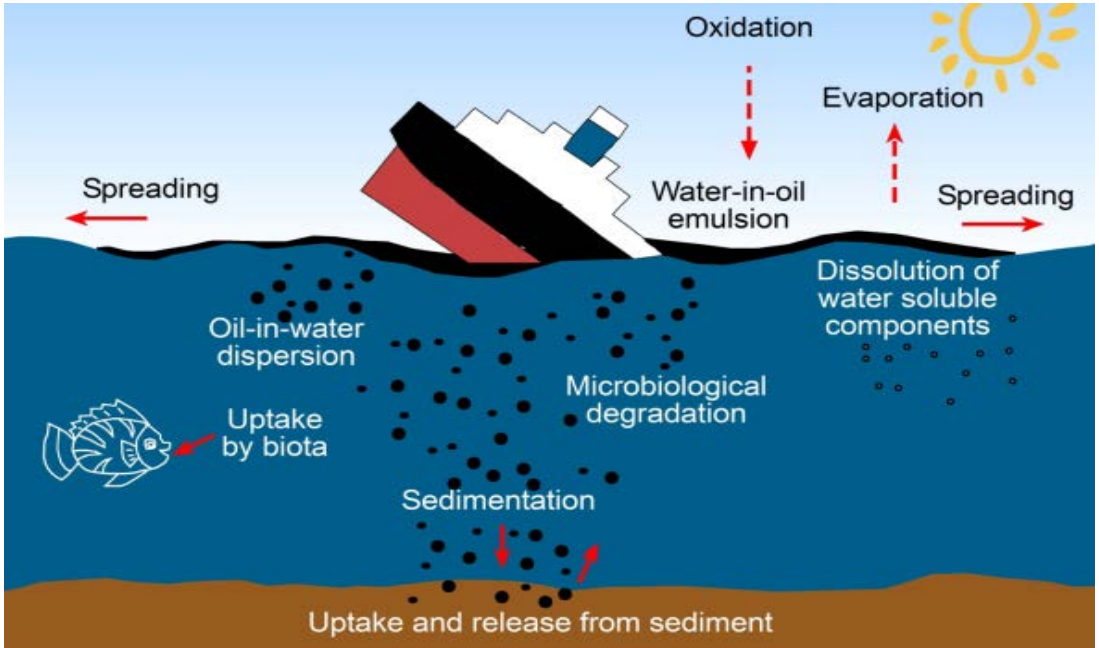
# Marine oil spills: Remain a serious environmental problem



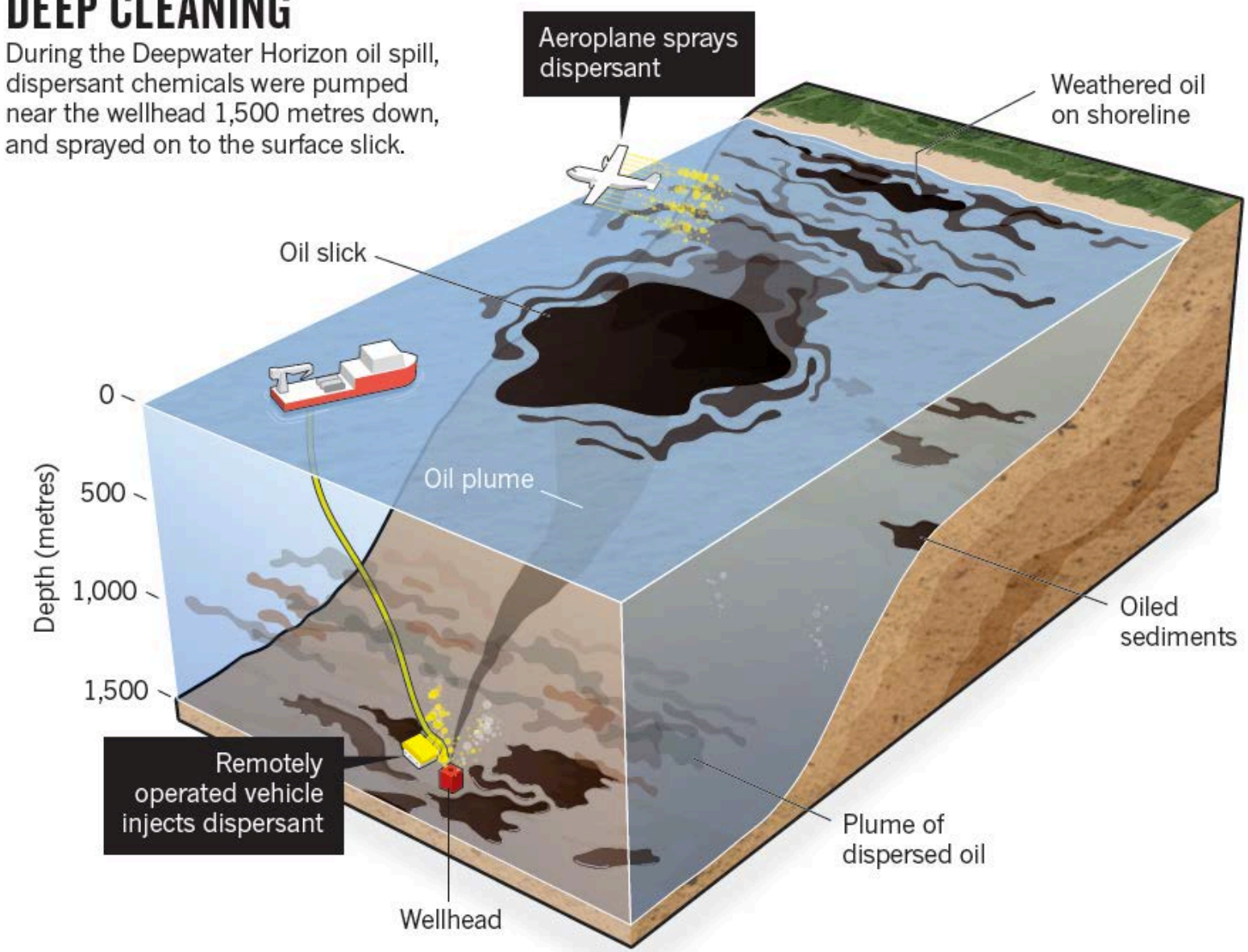

# Weathering processes & period of activation




**The goal of KILL*SPILL**



# Well blow-out / Deep sea releases



# FP-7 Topic Addressed

KBBE.2012.3.5-01

Innovative biotechnologies for tackling oil spill disasters (The Ocean of Tomorrow)

**Kill•Spill project:**

Total cost: 12,483,643.40 €

EU contribution: 8,996,599.00 €

with 27.38% to SMEs

# Project Partners

| KILL SPILL TEAM |
| --- |
| 1 TECHNICAL UNIVERSITY OF CRETE (TUC) - Greece |
| 2 FACHHOCHSCHULE NORDWESTSCHWEIZ (FHNW) - Switzerland |
| 3 ALMA MATER STUDIORUM-UNIVERSITA DI BOLOGNA (UNIBO) - Italy |
| 4 UNIVERSITY OF NEWCASTLE UPON TYNE (UNEW) - UK |
| 5 The Geological Survey of Denmark and Greenland (GEUS) - Denmark |
| 6 UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA (UNIRM) - Italy |
| 7 AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) - Spain |
| 8 UNIVERSITY OF ULSTER (Ulster) - UK |
| 9 CONSIGLIO NAZIONALE DELLE RICERCHE (CNR) - Italy |
| 10 UNIVERSITA DEGLI STUDI DI MILANO (UMIL) - Italy |
| 11 UNIVERSITEIT GENT (Ugent) - Belgium |
| 12 VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE (ICTP) - Czech Rep. |
| 13 Københavns Universitet (UCPH) - Denmark |
| 14 BANGOR UNIVERSITY (Bangor) - UK |
| 15 HELMHOLTZ ZENTRUM MUENCHEN DEUTSCHES FORSCHUNGSZENTRUM FUER GESUNDHEIT UND UMWELT GMBH (HMGU) - Germany |
| 16 MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM (MBA) - UK |
| 17 UNIVERSITE CATHOLIQUE DE LOUVAIN (UCL) - Belgium |

| KILL SPILL TEAM |
| --- |
| 18 NATIONAL UNIVERSITY OF IRELAND, GALWAY (NUIG) - Ireland |
| 19 BIOBASED EUROPE LIMITED (BBE) - UK |
| 20 BIOREM ENGINEERING BVBA (BIOREM) - Belgium |
| 21 GORTON CONSULTANCY LTD (GCL) - UK |
| 22 CREATIVE RESEARCH SOLUTIONS BVBA (CRS) - Belgium |
| 23 ENVIRONMENTAL PROTECTION ENGINEERING SA (EPE) - Greece |
| 24 MADEP SA (MADEP) - Switzerland |
| 25 HEIQ MATERIALS AG (HeiQ) - Switzerland |
| 26 MARITIM MILJO BEREDSKAP AS (MMB) - Norway |
| 27 INSTITUT ZA FIZIKALNO BIOLOGIJO D.O.O. (IFB) - Slovenia |
| 28 EcoTechSystems Srl (ECOTS) - Italy |
| 29 UK SPILL LIMITED (UKSpill) - UK |
| 30 VERMICON AKTIENGESELLSCHAFT (VER) - Germany |
| 31 ACTYGEA SRL (ACTY) - Italy |
| 32 OMYA DEVELOPMENT AG (OMYA) - Switzerland |
| 33 STATE UNIVERSITY OF NEW YORK AT BUFFALO (UB) - USA |

# Project Focus / Objectives

1. Review **State-of-the-Art** & identify technology gaps
2. Develop techniques (**biosensors & chemical indices)** to monitor hydrocarbon degraders & hydrocarbon degradation
3. Develop novel **bio-based dispersants**
4. Develop novel **bioremediation agents**
5. Develop **solutions for sediments**
6. Develop **multi-functional bioremediation** agents
7. Test their **toxicity**

# Technologies (products) to be Delivered

| No. | Technology | Application |
|---|---|---|
| 1 | "Kill•Spill Biosensor" (Biosensors for HC-monitoring) | On-site monitoring of oil degradation |
| 2 | "Kill•Spill FISH-Kit" (Cultivation-independent microbial diagnostic kits) | CARD-FISH diagnostic kit for on-site monitoring of microbial communities |
| 3 | "Kill•Spill FCM-Kit" (Cultivation-independent microbial diagnostic kits) | FISH + FCM diagnostic kit for on-site monitoring of microbial communities |
| 4 | "Kill•Spill Chip" (Microarray chip) | On-site monitoring of microbial communities |
| 5 | CHEMSIC | Monitoring of oil degradation |
| 6 | Polymer-based non-woven fabrics | Sorbent material (shoreline and near-shore) |
| 7 | Mineral-based powders | Sorbent material, accelerated bioremediation (oxic and anoxic environments) |
| 8 | Oxygen-releasing dispersants (OXYGEL™) | Dispersant, accelerated bioremediation (oxic and anoxic environments) |
| 9 | Porous granular sorbent (AEROBEADS™) | Sorbent (floating oil), accelerated bioremediation (oxic and anoxic environments) |
| 10 | Plant-based biosurfactant blends (SC1000™, SUPERSOLV™, EASYSOLV™) | Emulsification and mobilization of oil, sand washing, accelerated bioremediation |
| 11 | Microbial biosurfactants and emulsifiers | Emulsification and mobilization of oil, sand washing, accelerated bioremediation |
| 12 | Formulated HC-degrading MOs and consortia | In-situ bioaugmentation (incl. ABA), further technology development |
| 13 | High-pressure reactor | Lab-scale testing environment for deep-sea cases |
| 14 | Microdroplet reactor | Improvement/isolation of degrading MOs |

# Technologies (products) to be Delivered

| No. | Technology | Application |
|---|---|---|
| 15 | Low cost biostimulant formulations | Accelerated bioremediation, further technology development |
| 16 | "Kill•Spill Electr$O_2$" (Electrode-based oxygen supply) | In-situ sediment cleanup |
| 17 | "Kill•Spill snorkel" (Microbial electrochemical snorkel) | In-situ sediment cleanup |
| 18 | "Kill•Spill Robot" (Bio-electro-chemical roaming system) | In-situ sediment cleanup |
| 19 | Infauna accelerated degradation | In-situ sediment cleanup |
| 20 | "Kill•Spill Sed-Cleaner" (Modular system for enhanced biodegradation) | In-situ bioaugmentation and biostimulation for sediments |
| 21 | Sequestering sorbents | Sorbent material for oil sequestration in sediments |
| 22 | "Kill•Spill Deep-sea" (Multi-functional bioremediation agents) | Enhanced bioremediation of HC-"clouds" formed in deep-sea oil releases |
| 23 | "Kill•Spill Mesoporous" (Mesoporous silica (nano)particles) | Enhanced bioremediation though bioaugmentation and biostimulation on silica |
| 24 | "Kill•Spill SlowRelease" (Slow release microparticles) | Enhanced bioremediation though bioaugmentation and slow-release fertilizers in lipophilic carriers |
| 25 | "Kill•Spill All-in-One" ("All-in-One" multifunctional carrier) | First response measure for enhanced bioremediation and oil dispersion |
| 26 | "Kill•Spill MineralSorb" (Multifunctional sorbent materials) | Mineral based Sinking and agent (Oil transferred to sediments) and enhanced bioremediation |
| 27 | "Kill•Spill Bio-carriers " (Porous bio-carriers) | Biomaterials for immobilization of HC degraders and biostimulants for sea water & sediments |
| 28 | "Kill•Spill Bio-boom" (Improved biodegrading booms) | Oil barriers (booms) and with enhanced sorbent & bioremediation capabilities. |

# “Mandatory” Field Testing of Technologies

- Field tests of developed technologies during 3rd & 4th year:

1. At CNR-IAMC pilot testing facilities
2. **In Aegean Sea** (EPE)
3. **In North Sea/Norwegian Sea** (MMB)
4. At Sea DIAMOND wreck (EPE)
5. In Disko Bay / Greenland (GEUS)

<u>and at</u>

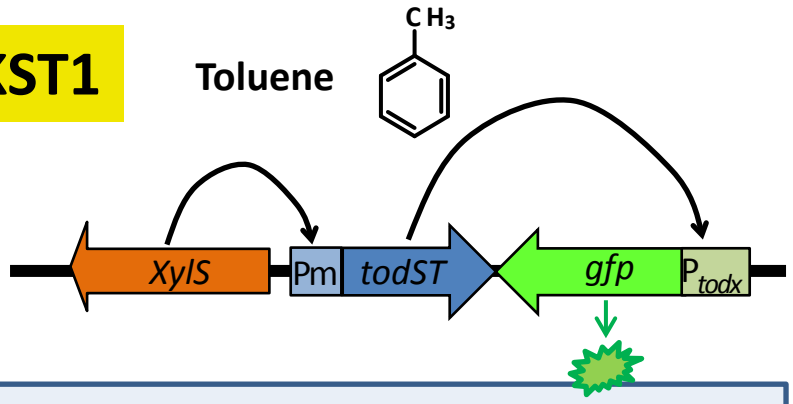
6. TUC landfarming mesocosms
7. At ship wreck (CNR-IAMC)

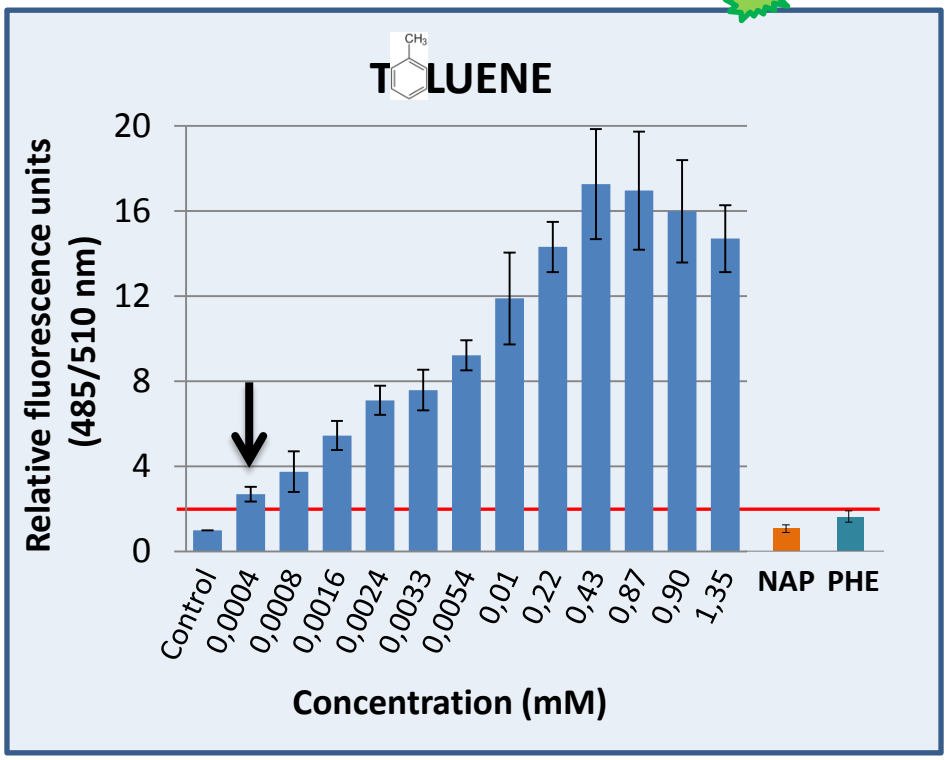
# pKST-1 in *Alcanivorax borkumensis* SK2

KILL•SPILL Biosensor

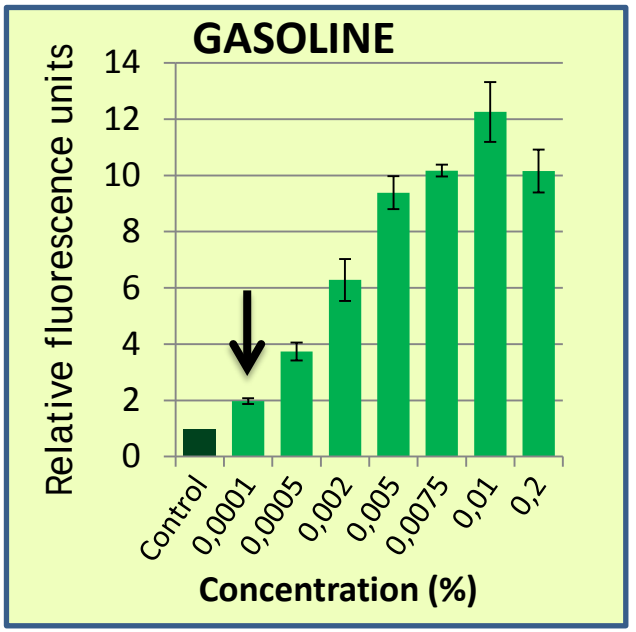
**pKST1**

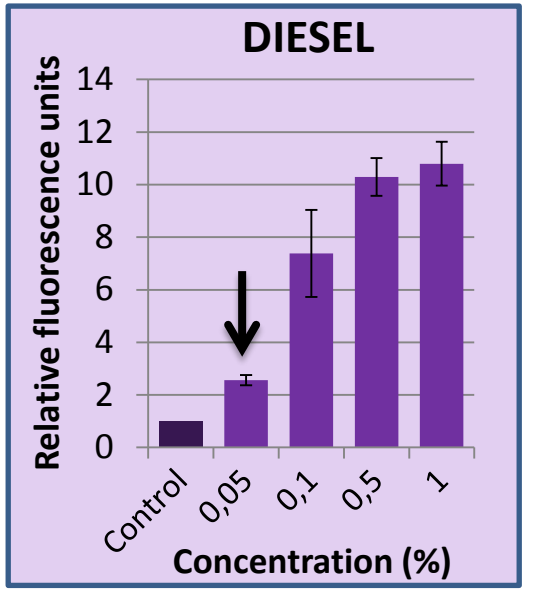
Toluene




↓ Indicates the detection limit of this biosensor



# PAH biosensor (pKSPA-1)

KILL•SPILL Biosensor

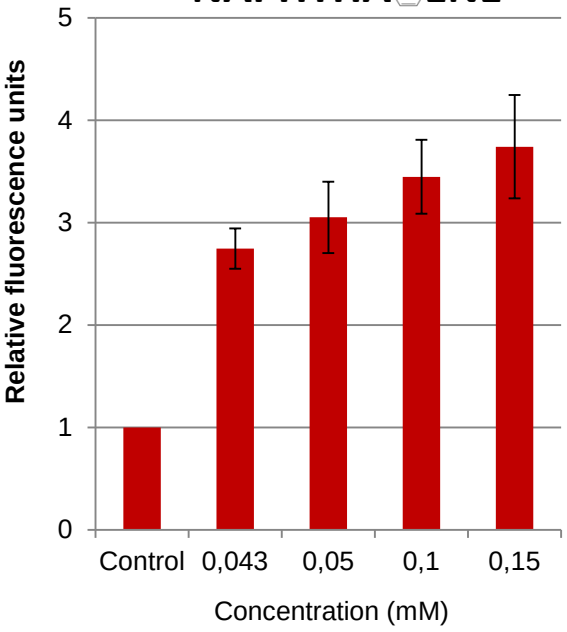
CSIC
Consejo Superior de Investigaciones Científicas

***Novosphingobium* sp. HR1a**

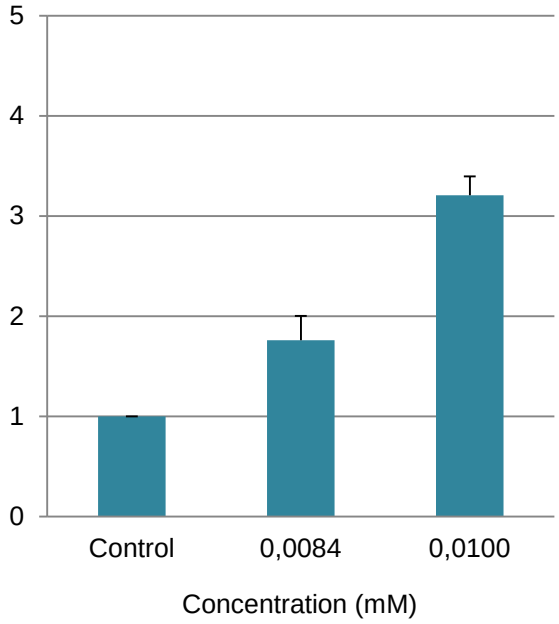

**pSEVA637 (Gm$^R$)**

**No induction with BTEX**

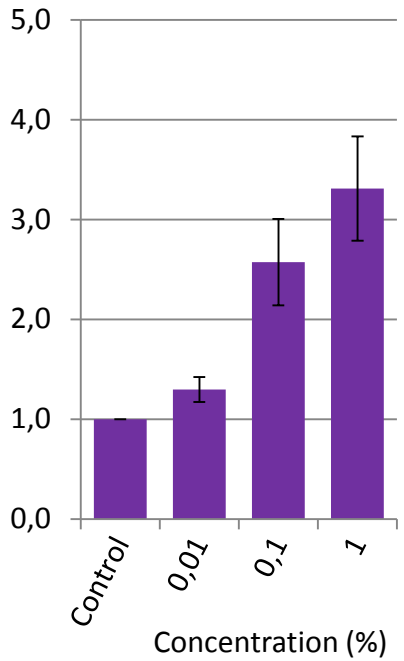
**NAPHTHALENE**



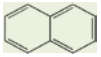

**PHENANTHENE**



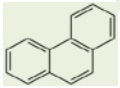

**DIESEL**



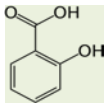

**Detection limits**



Naphthalene: **40 µM** Fuel: **0.1%**



Phenanthrene: **8.5 µM**




Salycylic acid: **0.1 µM**

Experiments done in marine media

**No induction with Gasoline**

KILL SPILL

KILL•SPILL chip microarray

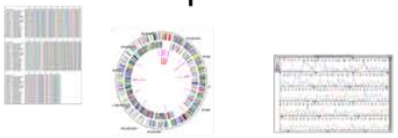
# On-site monitoring of microbial communities

## Kill Spill chip: analysis pipeline

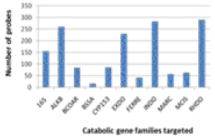
PRIFYSGOL BANGOR UNIVERSITY

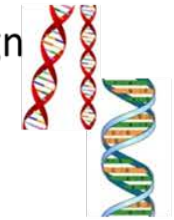
### Design of Chip

Sequences analysis



Probe design





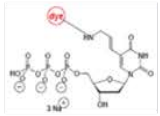
Printing of chip probes

### Preparation of Environmental samples

DNA extraction

DNA amplification

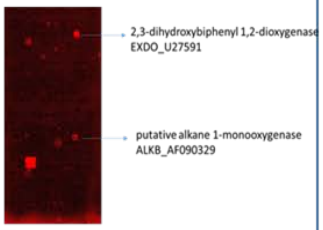
DNA Labelling

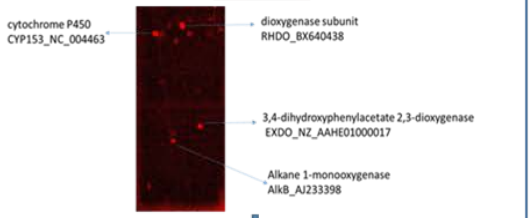


Hybridization

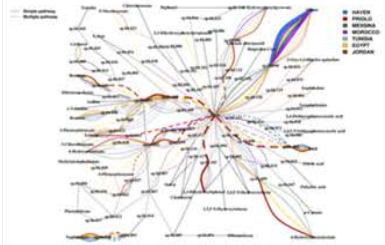
### Data processing

Scanning and image analysis




Data analysis and network reconstruction

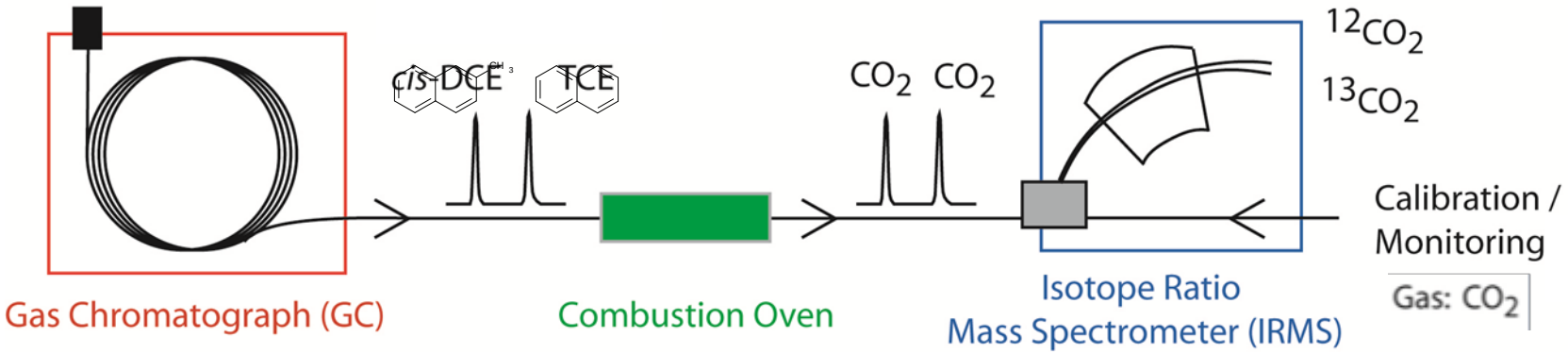


Development of **molecular tools for the rapid detection of microbial degradation** of oil compounds in the marine environment

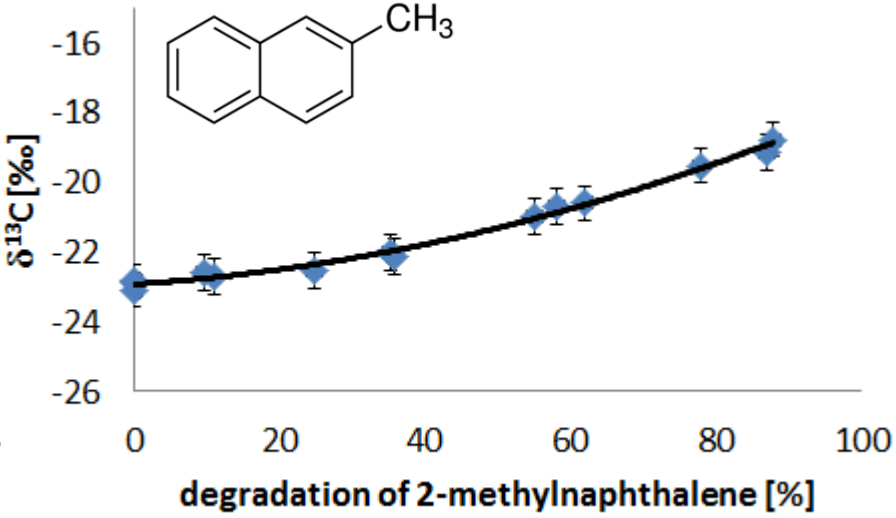
KILL•SPILL monitoring

HelmholtzZentrum münchen
German Research Center for Environmental Health

# Compound Specific Isotope Analysis: Identification of in-situ Degradation of **P**olycyclic **A**romatic **H**ydrocarbon**s**




- ✓ **Degradation is associated with an enrichment of $^{13}C$ in the remaining contaminant pool → increasing $\delta^{13}C$**
- ✓ **Differentiation between degradation and physical processes (isotope insensitive) like sorption and dilution.**



KILL•SPILL geneCARD-FISH assay

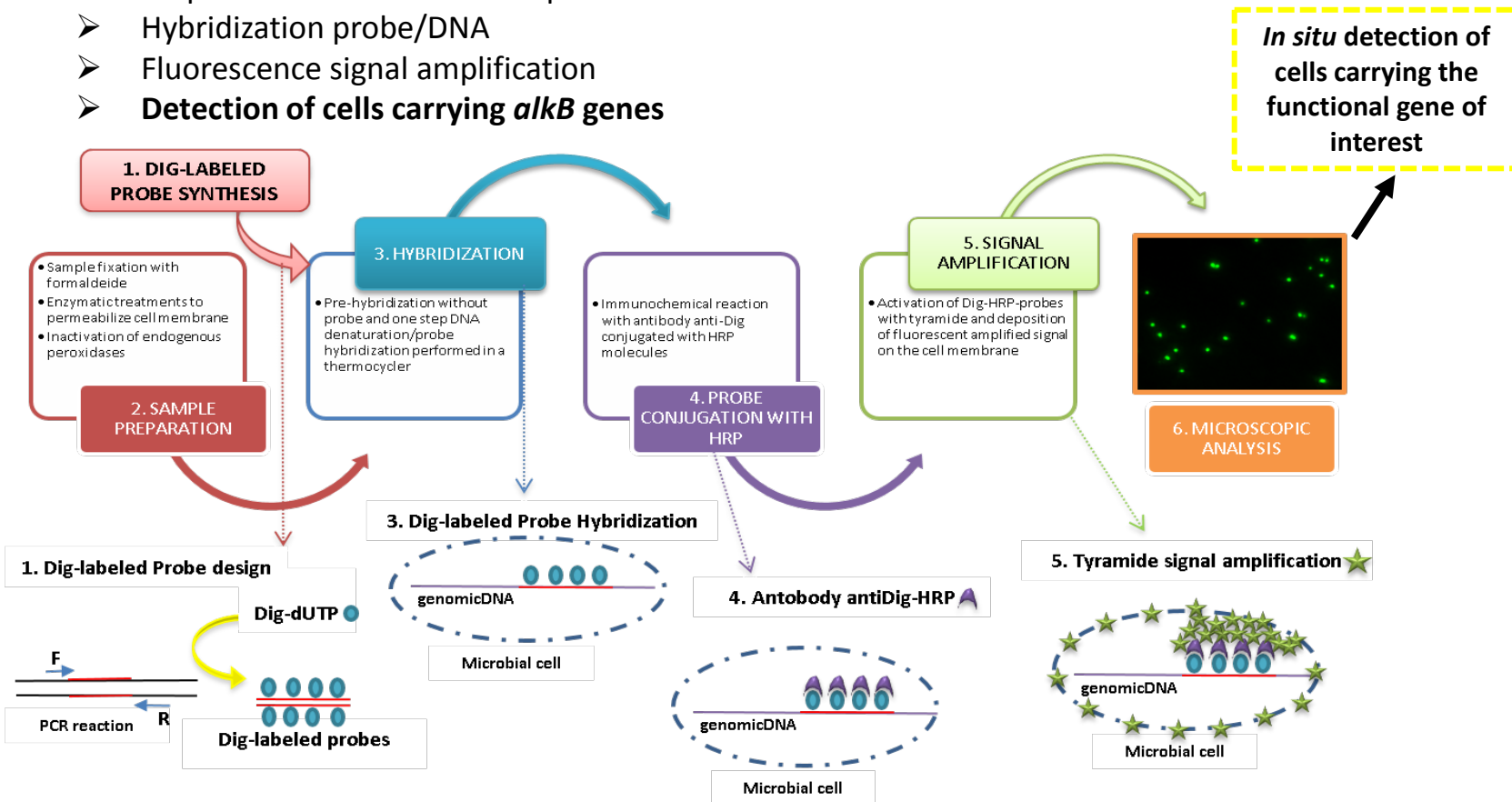
# geneCARD-FISH assay: detection of *alkB* genes involved in the hydrocarbons degradation

## A NOVEL BIOMONITORING TOOL:

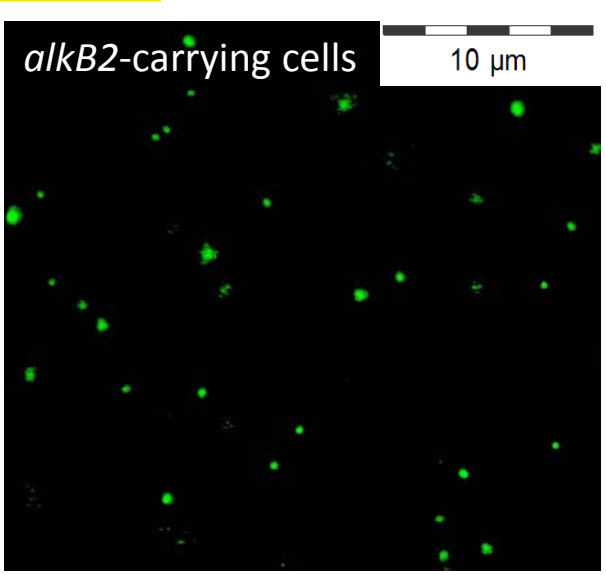
- **Detection of whole cells carrying specific genes** involved in hydrocarbons degradation processes
- Fluorescence *in situ* hybridization assay based on the fluorescent signal amplification system
- Accurate and rapid quantification of cells also at very low concentration

## geneCARD-FISH PROCEDURE:

- Preparation of the molecular probe
- Hybridization probe/DNA
- Fluorescence signal amplification
- **Detection of cells carrying *alkB* genes**



# geneCARD-FISH assay: detection of *alkB* genes involved in the hydrocarbons degradation




## geneCARD-FISH: application on *Alcanivorax borkumensis* SK2$^{T}$ pure culture

- No DNA extraction required
- Specific hybridization
- Maintenance of cellular morphology
- Fluorescent signal well distributed on the cellular membrane
- Low background noise during the microscopic analysis
- Good detection efficiencies
- Assay suitable for the application on environmental samples

KILL•SPILL FISH kits

# First Kill•Spill FISH kits are now commercially available …

- FISH protocols adapted to easy and standardized VIT® format allows fast and specific on-site monitoring

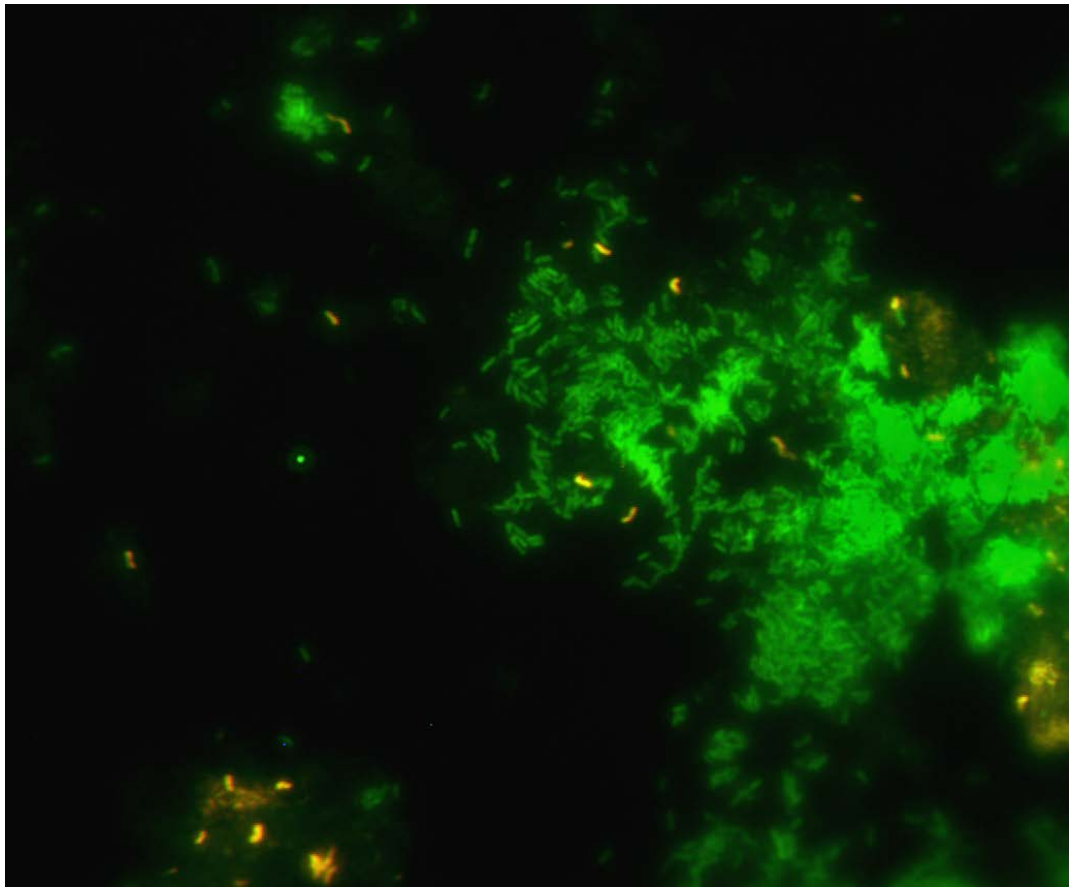
- Identification and quantification of various hydrocarbon-degrading bacteria using developed test kits:


- *Alcanivorax borkumensis*
- *Cycloclasticus pugetii*
- *Marinobacter* sp.
- *Oleispira antarctica*
- *Oleiphilus messinensis*
- *Thalassolituus oleivorans*

# Kill•Spill FISH kit

KILL•SPILL FISH kits

- Example for the analysis of hydrocarbon-degrading bacteria in natural sample using fluorescence microscopy



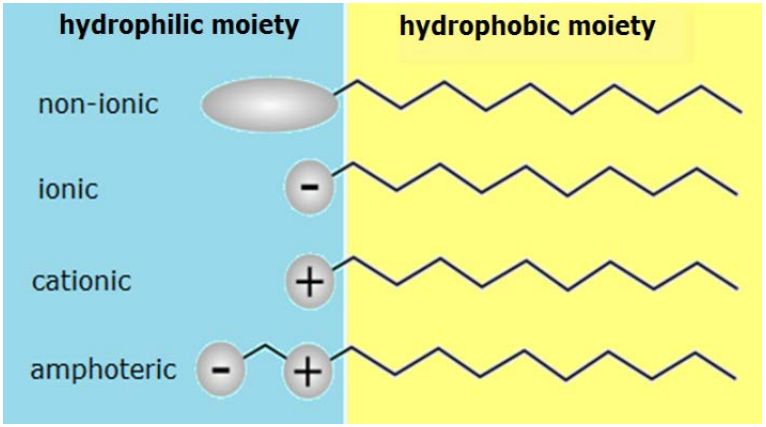
**Green**: *Alcanivorax borkumensis*, **Yellow**: *Oleispira antarctica*;
Total magnification **1000 x**

KILL SPILL

University of ULSTER

KILL•SPILL biosurfactants

# Available surface active products to date




- **Microbial Biosurfactants**:
  - Rhamnolipids
  - Sophorolipids
  - Biosurfactants + Oxygel ($O_2$ delivery) + treated $CaCO_3$ (adsorption/sinking agent) + hydrocarbon degrading bacteria.
- **Several plant surface active extracts/oils** from BioBased Europe Ltd (a Scottish company). NANOTERAGROUP
- **Work is in progress** to develop a biocatalyst of rhamnolipids produced by *Burkholderia* cells immobilised on delignified Cellulose for testing in environmental applications.

KILL SPILL

KILL•SPILL biosurfactants

# Available strains with ability to produce biosurfactants

University of ULSTER

| Strain | Biosurfactants (main congener) | Yield (g/L) | Surface tension (mN/m) | EI 24 (%) |
|---|---|---|---|---|
| Pseudomonas aeruginosa PAO1 | Rhamnolipids (Rha-Rha-$C_{10}$-$C_{10}$) | 2-3 | 24-29 | 53-64 |
| Pseudomonas aeruginosa ST5 | Rhamnolipids (Rha-Rha-$C_{10}$-$C_{10}$) | 1.5-2.5 | 25-29 | 52-65 |
| Pseudomonas aeruginosa DS10 | Rhamnolipids (Rha-Rha-$C_{10}$-$C_{10}$) | 1.5-3 | 25-31 | 52-61 |
| Burkholderia Thailandensis E264 | Rhamnolipids (Rha-Rha-$C_{14}$-$C_{14}$) | 2-4 | 26-33 | 67-70 |
| Burkholderia glumae | Rhamnolipids (Rha-Rha-$C_{14}$-$C_{14}$) | 1.3-2.2 | 28-30 | 65-72 |
| Burkholderia plantarii | Rhamnolipids (Rha-Rha-$C_{14}$-$C_{14}$) | 0.8-1.1 | 26-27 | 60-67 |
| Burkholderia kururiensis | Rhamnolipids (Rha-Rha-$C_{14}$-$C_{14}$) | 1.9-3.1 | 30-33 | 60-63 |
| Candida bombicola | Sophorolipids | 20-100 | 36-39 | 48-53 |
| Pseudozyma aphidis | Mannosylerythritol lipids | * | * | * |
| Bacillus | Surfactin | 0.2-0.8 | 24-31 | 58-65 |

* Currently under evaluation

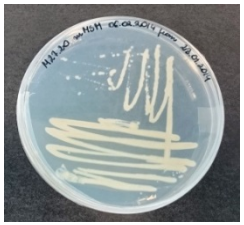
# Isolation and selection of novel marine aerobic microbes with biosurfactant production potential

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

**144 pure isolates** obtained on mMSM agar **among them 79** having different colony morphology selected

**34** fast-growing isolates in liquid medium (1 or 0,5% glucose)

Bacterial isolate



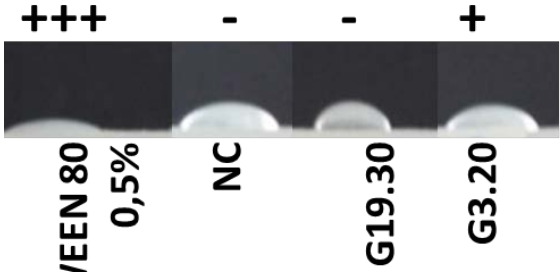
48-120 h of growth

5% inoculum

24-120 h of growth

Culture

## Drop Collapse



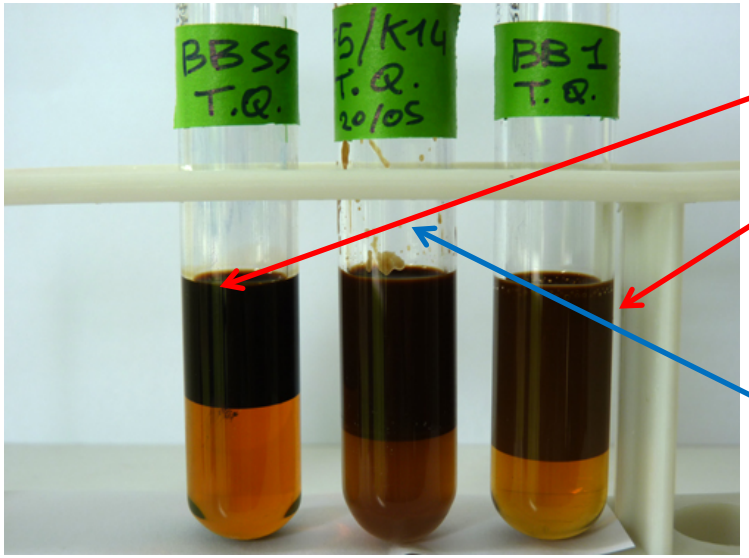

## Emulsification Index ($EI_{24}$)


Emulsion production and stability under extreme conditions

KILL•SPILL pilot scale production

# Biosurfactants produced at industrial pilot scale

| Sample | Crude Oil EI (%) |
|---|---|
| **Rhamnolipids** Actygea | 57 |
| **Sophorolipids** Actygea | 63 |
| **SC2000** (Commercial emulsifiers from vegetables) | 65 |
| **SuperSolv** (Commercial emulsifiers from vegetables) | 50 |

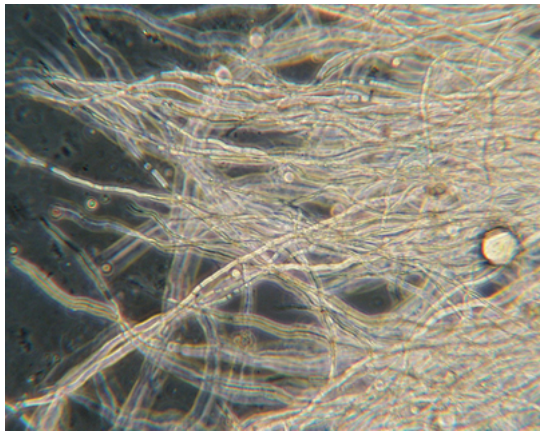



Commercial

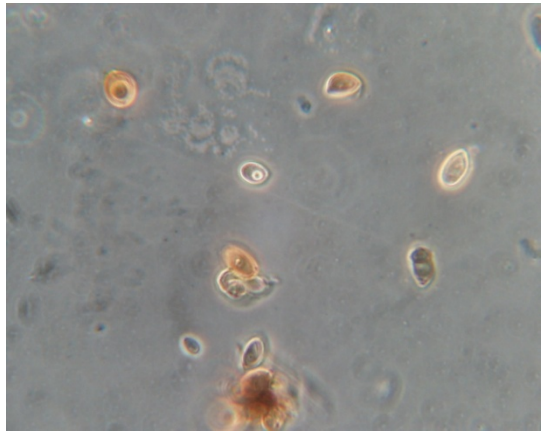

Test

KILL•SPILL pilot scale production

# Products: spores of *Cladosporium* sp. (bioaugmentation)



*Mycelium*



*Spores*

*<u>Cladosporium sp. characteristics:</u>*

- *Able to degrade 80% of 50-80 g/L crude oil added to liquid cultures or to sea sand microcosms*

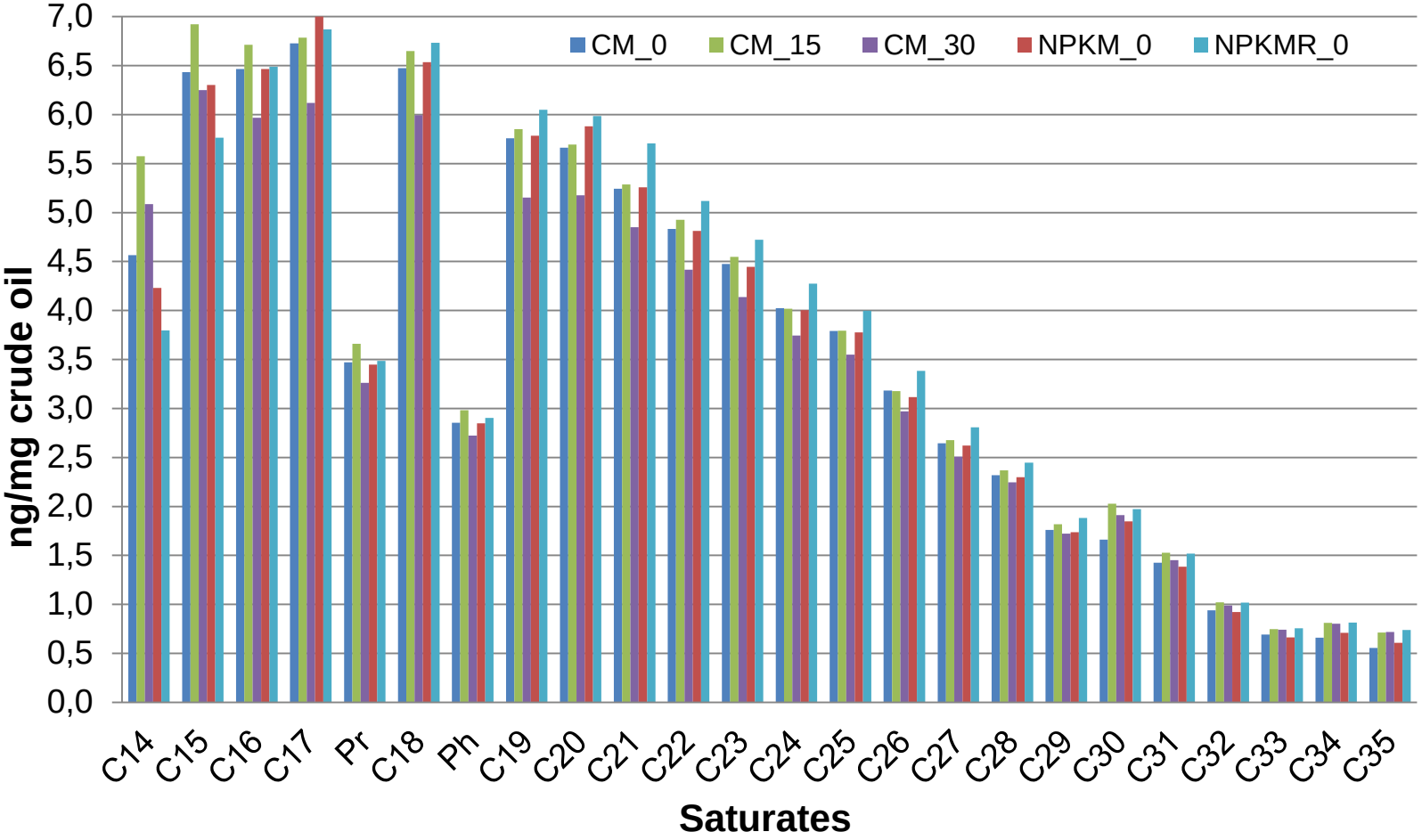
*<u>Cladosporium sp. advantages:</u>*

*- Spore forming organism;*

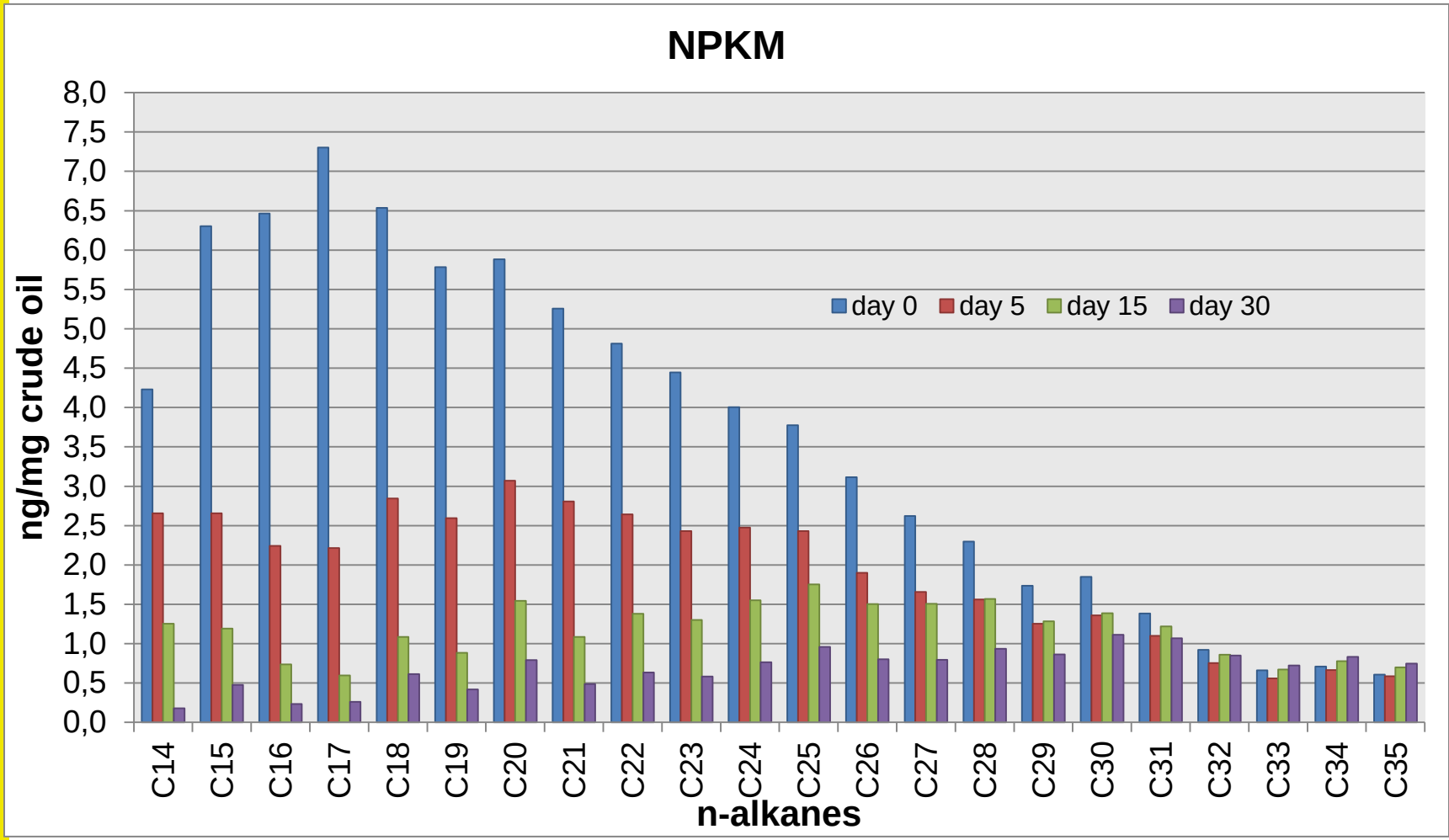
*- Easily stored in dry form & easy to blend with nutrients;*

*- Preferentially grows on solid substrates;*

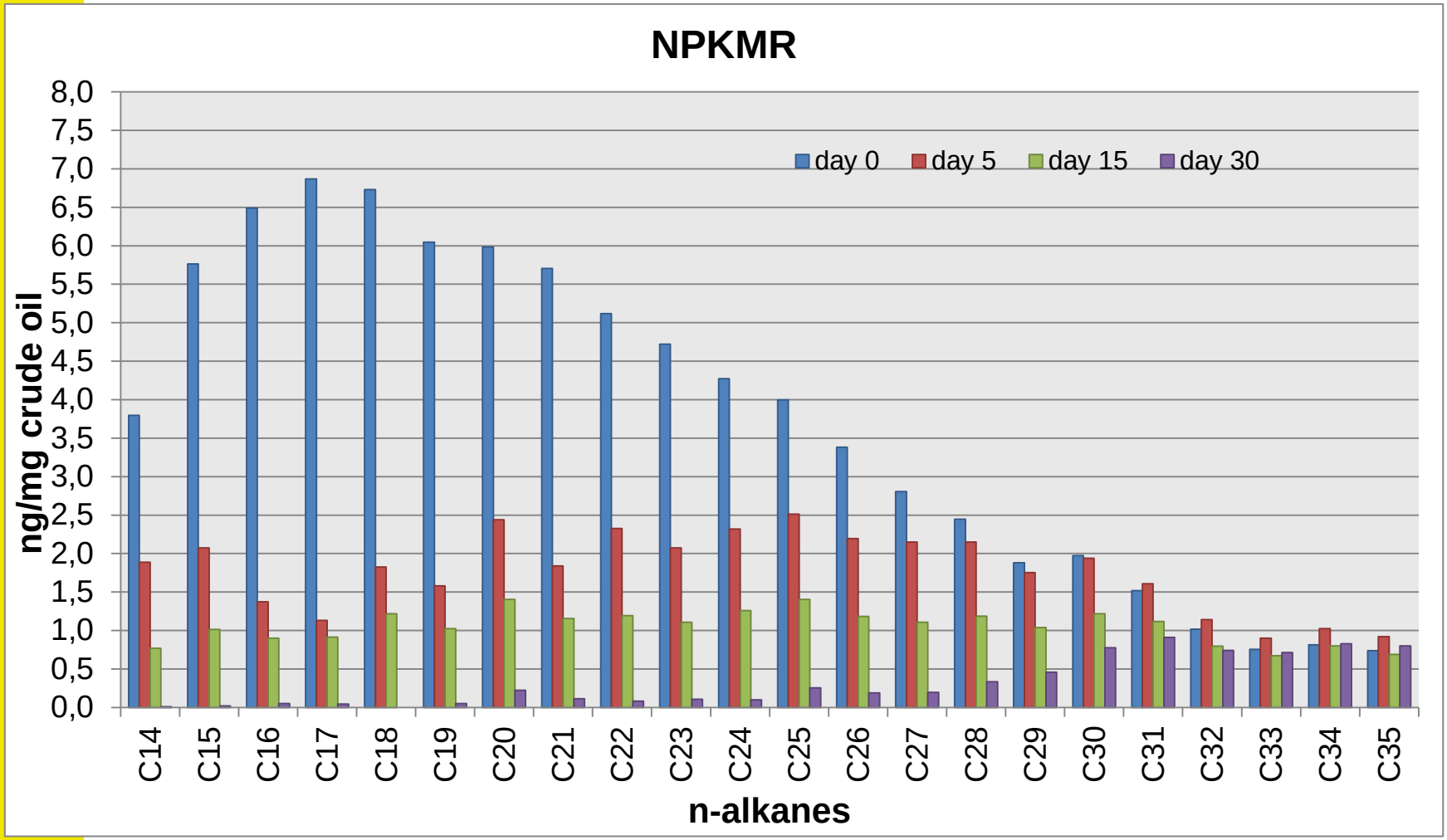
# Effect of Bioremediation Agents (biostimulants) **Concentration profile of alkanes** (Control) at **time 0, 15, 30 days**



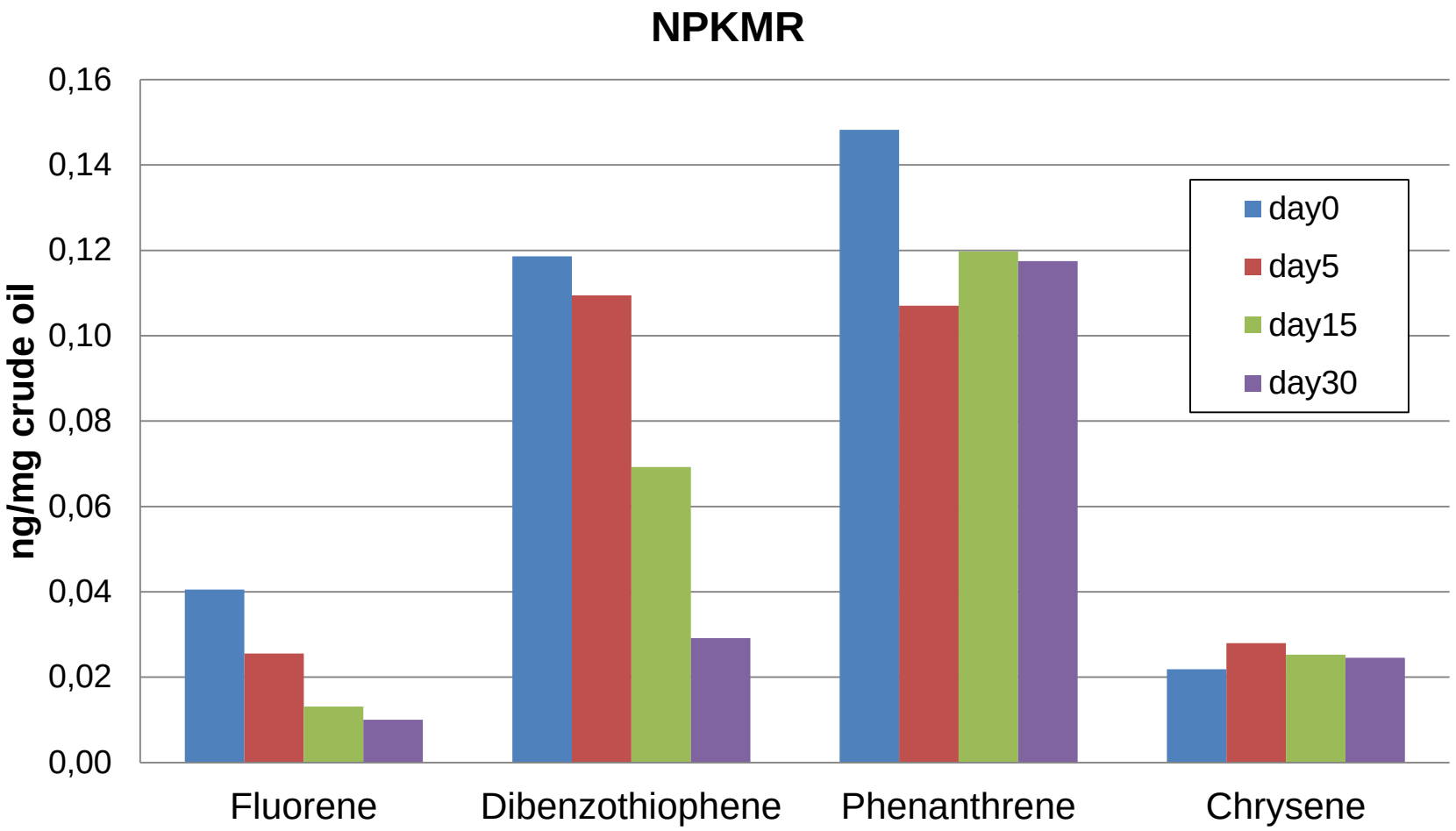
# Results of the NPKM Treatment (stimulation with N, P, K & ABA-microbes)



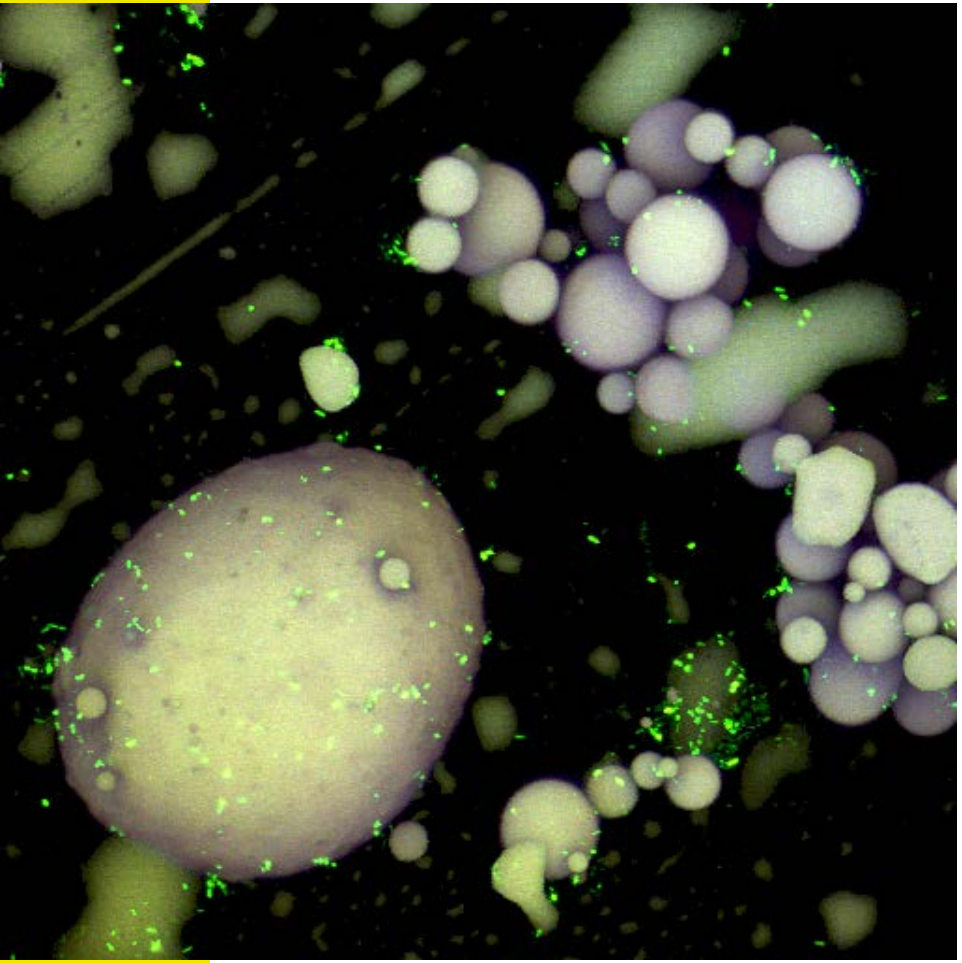
# Results of the NPKMR Treatment (plus Rhamnolipids)

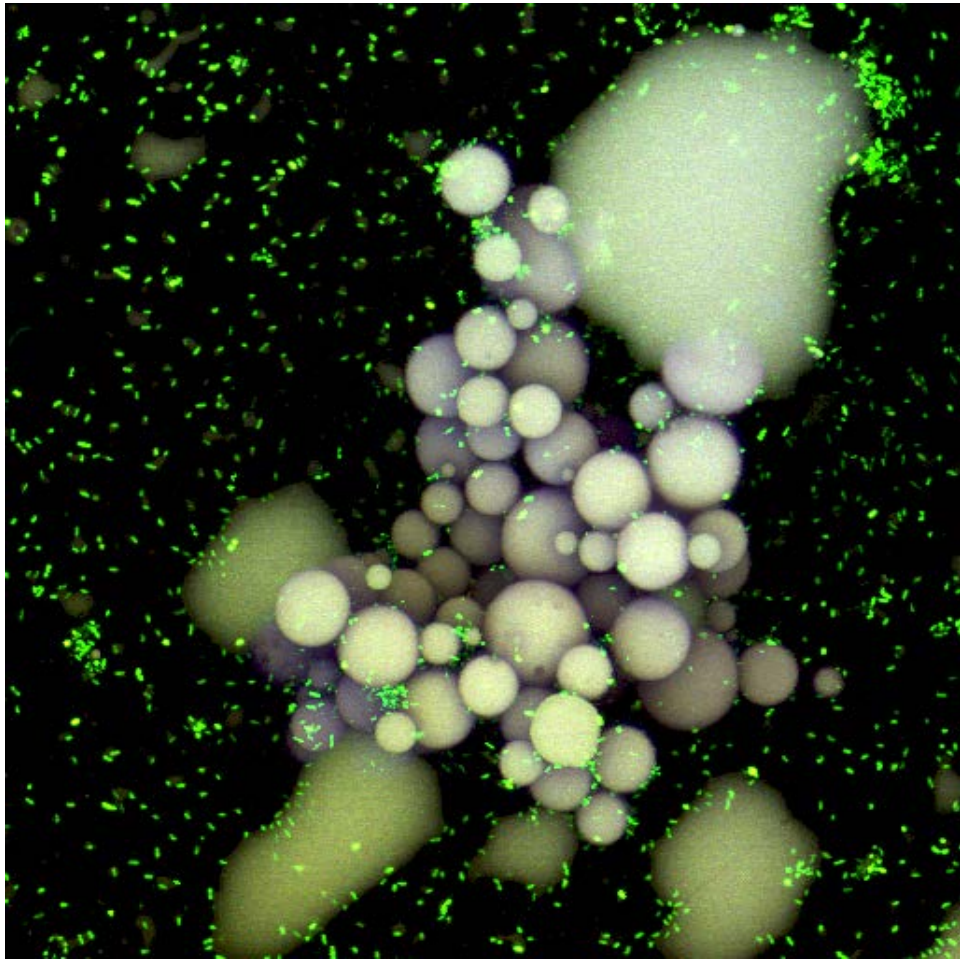


# NPKMR treatment: Profile of PAHs



# Understanding biosurfactant/microbial action: Crude oil in seawater





**The “grape bunch formation” effect**

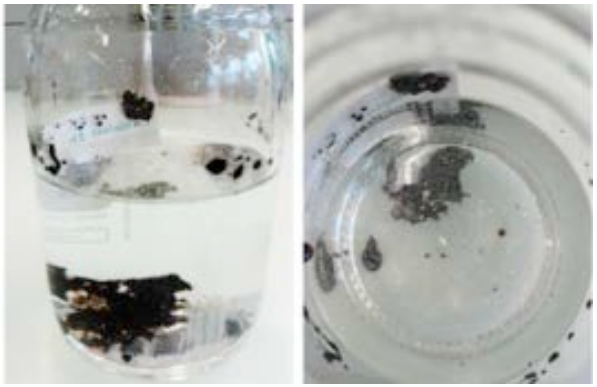
KILL SPILL

microsTECH
WHERE SCIENCE BECOMES REALITY

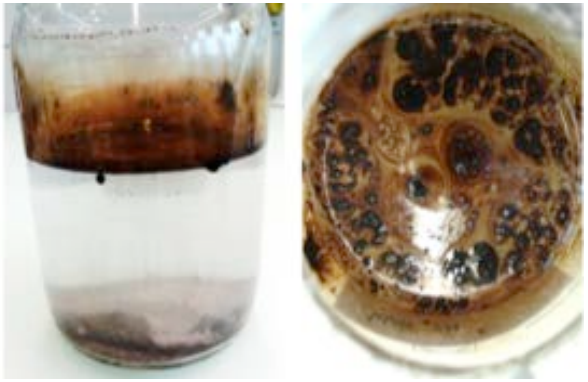
# Advantages of functionalized $CaCO_3$

- Functionalized $CaCO_3$ only sinks if sorbed with oil
- Oil carpet is completely removed
- Formation of dense drops

Functionalized $CaCO_3$



Non-functionalized $CaCO_3$



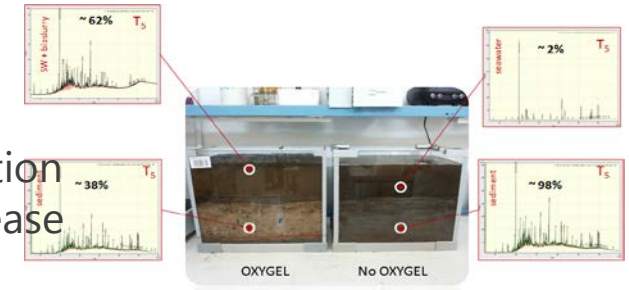
Sinking capacity: Marine water, simulated swell (200 RPM), 2h

KILL•SPILL sorbents

# Enhancing aerobic biodegradation with Oxygen releasing compounds: *Gel form*

***Oxygel***™

- **Without additives**:
  - Suitable for injection into sediments
  - Oil desorption & degradation stimulation by oxygen release




- **With additives (solvents & surfactants from Bio-Based):**
  - Suitable for free oil absorption into its matrix
  - Oxygen release for enhanced degradation.


- **With a catalyst (OxygelPLUS™)**
  - Release of oxidative radicals
  - Chemical oxidation of recalcitrant pollutants

# Oxygen releasing compounds: *Dry form*

KILL•SPILL all-in-one

***Aerobeads*™**

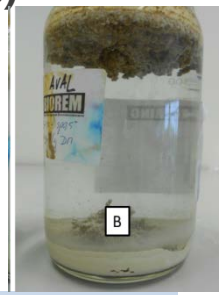
**Composition:**

- Dried Oxygel™
- Functionalized $CaCO_3$ (Microstech)

- **Without additives**:
  - Adsorption of a floating oil layer
  - Slow release of Oxygen over time for enhanced natural attenuation

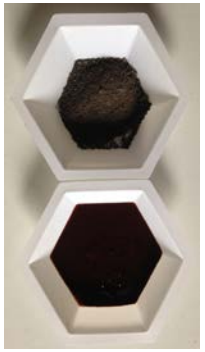
- **With additives (Solvents / surfactants, lyophilized bacteria, micro-nutrients)**
  - 'All-in-one solution'
  - Adsorption of a floating oil layer
  - Enhanced biodegradation on ocean floor

*Work in progress*



- **With a catalyst (AerobeadsPLUS™)**
  - Release of oxidative radicals
  - Chemical oxidation of recalcitrant pollutants

*Work in progress*



# SLOW-RELEASE MICROPARTICLES

## Gel-Beads - Dry Alginate Beads (DABs)

**Immobilized preparation for bioaugmentation and bioremediation of oil-spills in sea-water**

Wet Preparation

Dry Preparation

### What's inside?

HC degrading microorganisms

(Bio)Surfactants

P,N nutrients

Other additives

### Advantages

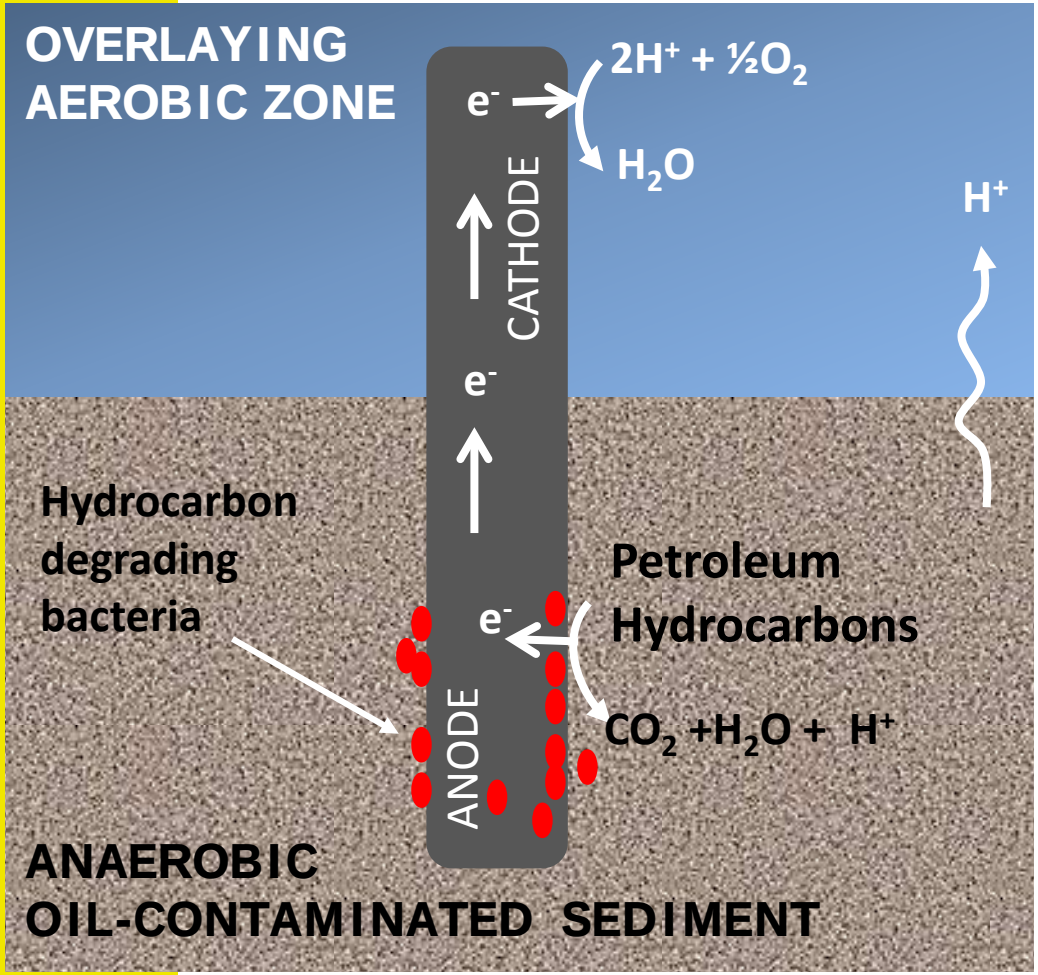
High operational stability

Low water content - resistance to the biodegradation or microbial contamination

Immediately ready for "on-field" operations

KILL•SPILL DABs

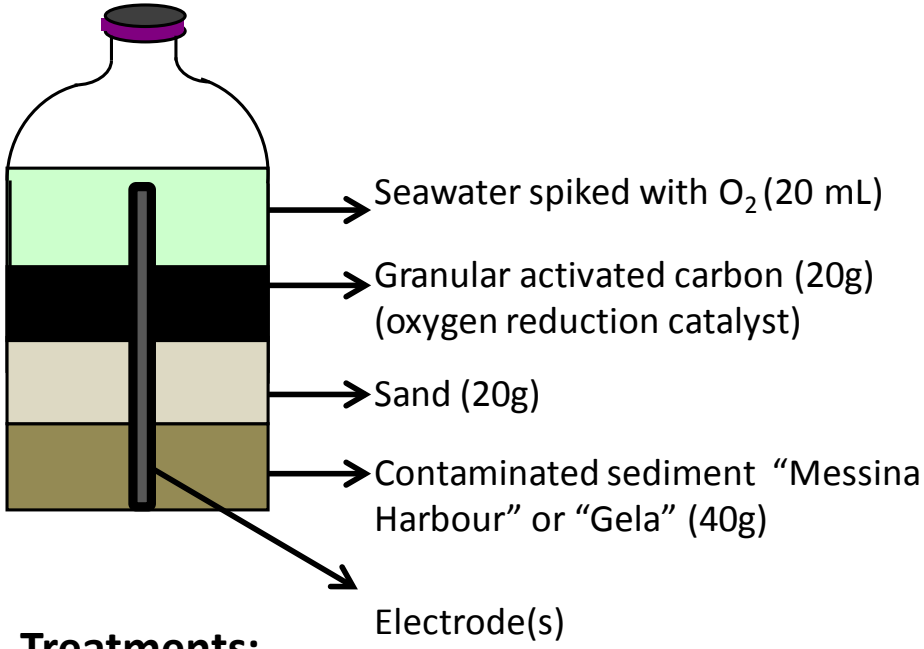
# The Kill•Spill Snorkel: Breathing a "spatially distant" electron acceptor




- **Oxidative biodegradation processes** in sediments are typically **rate-limited** by poor availability of high-potential electron acceptors (e.g., **$O_2$**)
- The **Kill•Spill Snorkel** aims to **accelerate biodegradation** by creating an **electrochemical connection** between the anaerobic sediment and the overlaying aerobic water
- Takes advantage of the capability of certain bacteria to anaerobically oxidize organic substrates with an electrode (ANODE) serving as **respiratory electron acceptor**

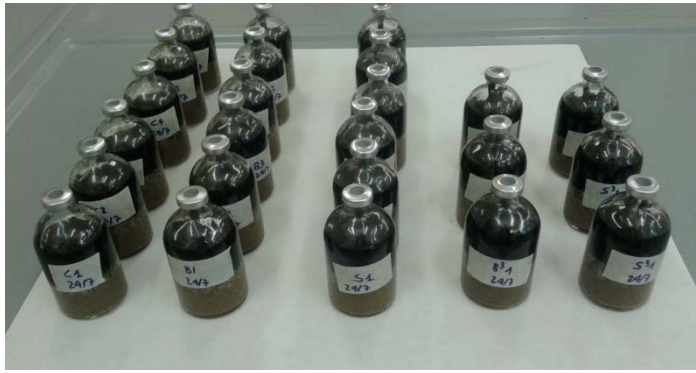
# Experimental setup:
# The Kill•Spill Snorkel "Proof-of-Principle"

## Sacrificial microcosms in 120 mL-serum bottles




Sediment from **Messina (Italy) Harbour** spiked with IFO 180

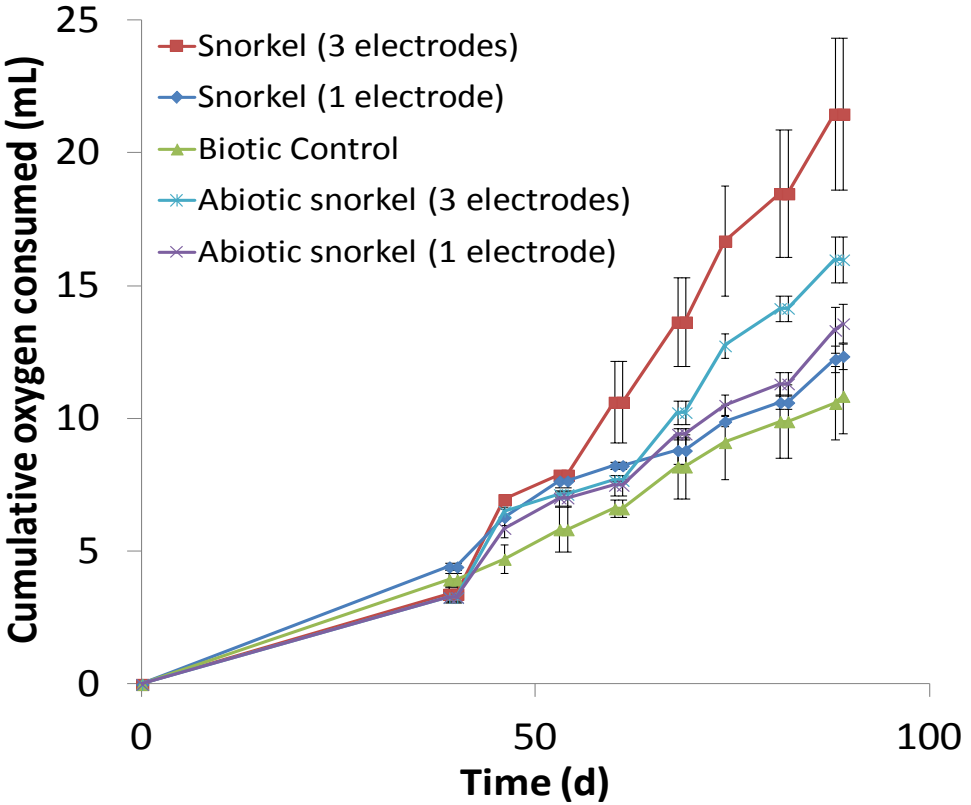
Sediment from **Gela (Italy) oil-spill**

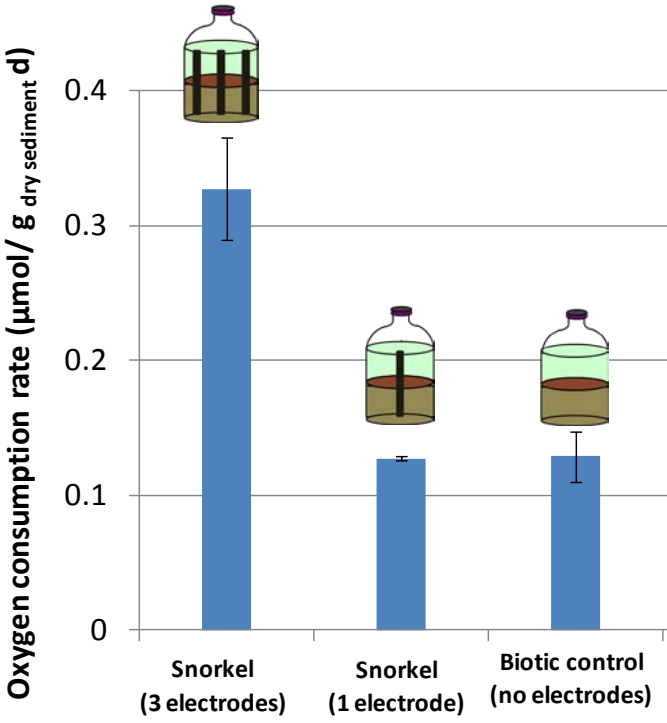


**Treatments:**

1. Snorkel with 3 electrodes
2. Snorkel with 1 electrode
3. Biotic control with no electrodes
4. Abiotic (Autoclaved) Snorkel with 3 electrodes
5. Abiotic (Autoclaved) Snorkel with 1 electrodes

# Preliminary results: Oxygen Consumption Rate by "Gela Sediments"

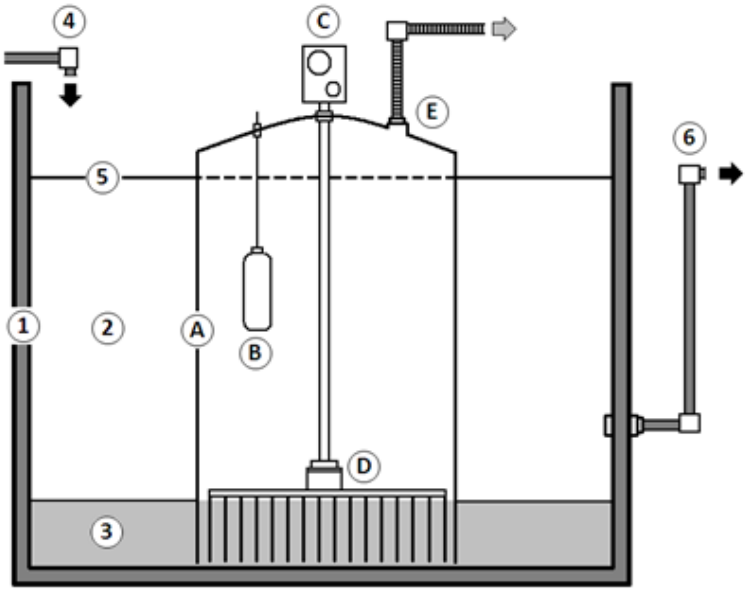


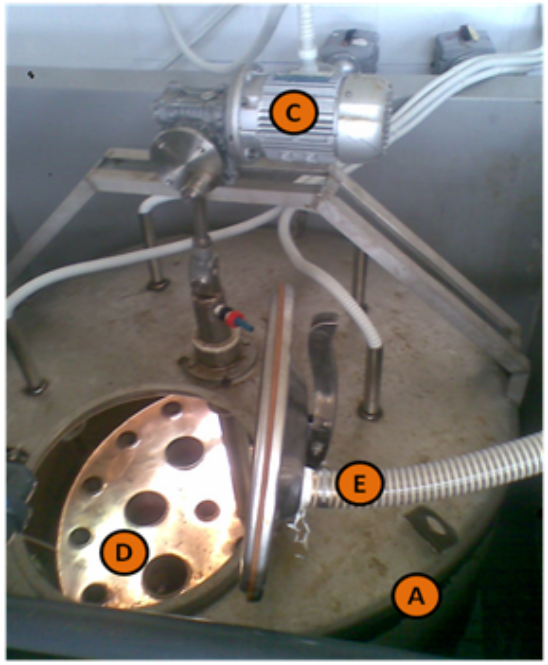

- Oxygen consumption rate (OCR) in the **Kill•Spill Snorkel** (3-electrodes setup) is **2.5 higher** than in the corresponding biotic control (identical setup but with no electrodes)
- **Petroleum hydrocarbon analyses** are in progress to verify if the enhanced OCR corresponded to enhanced biodegradation
- Enhanced OCR also in the abiotic snorkel (3-electrode setup), possibly due to electrochemical oxidation of inorganic species in the sediment (e.g., $S^{2-}$; $Fe^{2+}$)

KILL•SPILL sediment cleaner

# Sediment cleaner prototype: Modular Slurry System (MSS)




A

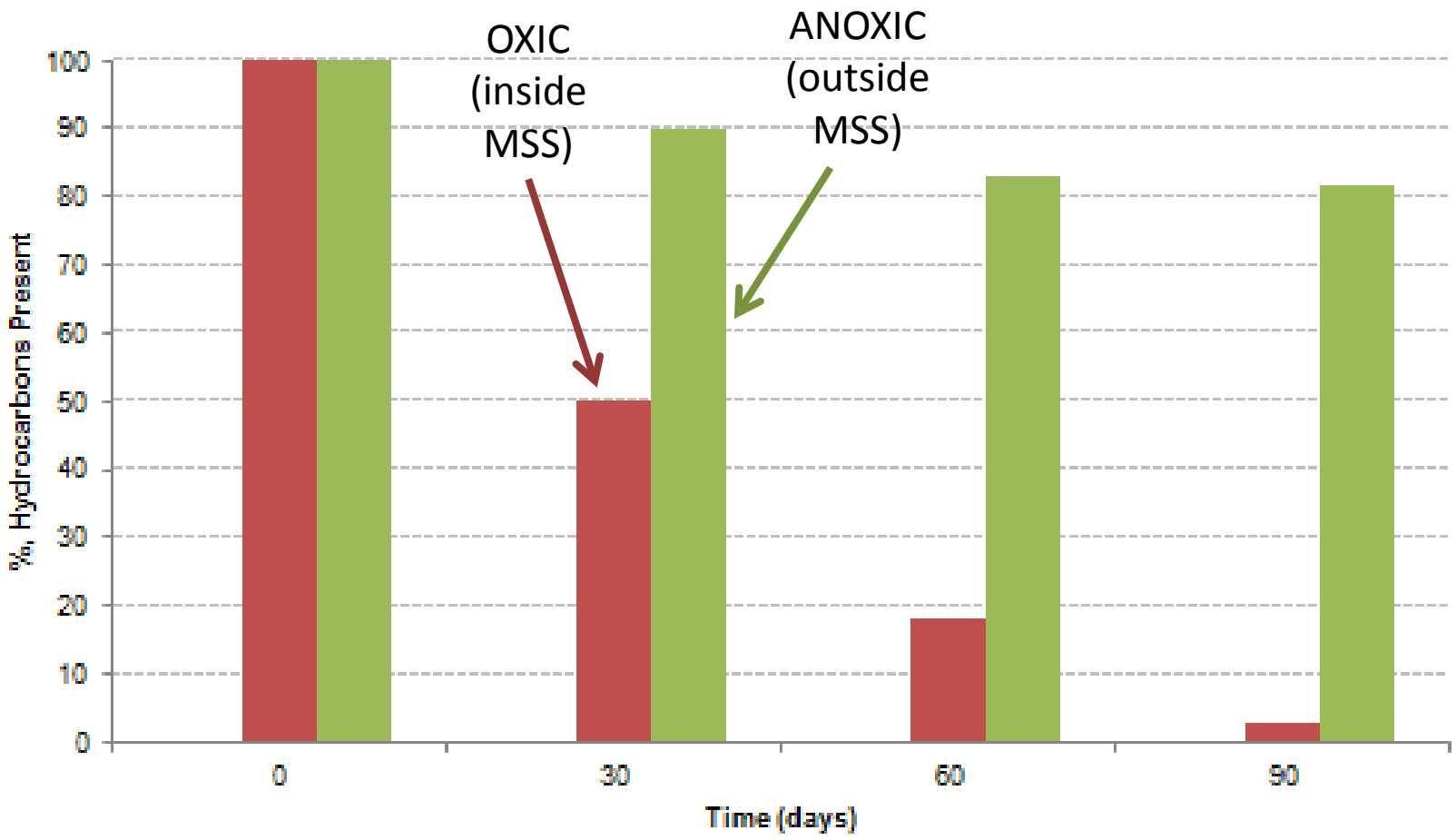



B

Schematic representation (A) and picture (B) of "Biostimulation System" proposed in this work. In this "open" system, the seawater is filled *in continuous* in reaction tank (mesocosm) during the all experimental period. 1, Mesocosm tank; 2, seawater; 3 marine artificially polluted sediments; 4. fill line; 5, level of seawater; 6''too full'' system and line of discharge of water. A, "Biostimulation System", thermostat system; C, external engine whit air pump; D, steel plate of insufflation air system; E, line for filter air system.

# Sediment Cleaner prototype: Modular Slurry System (MSS)

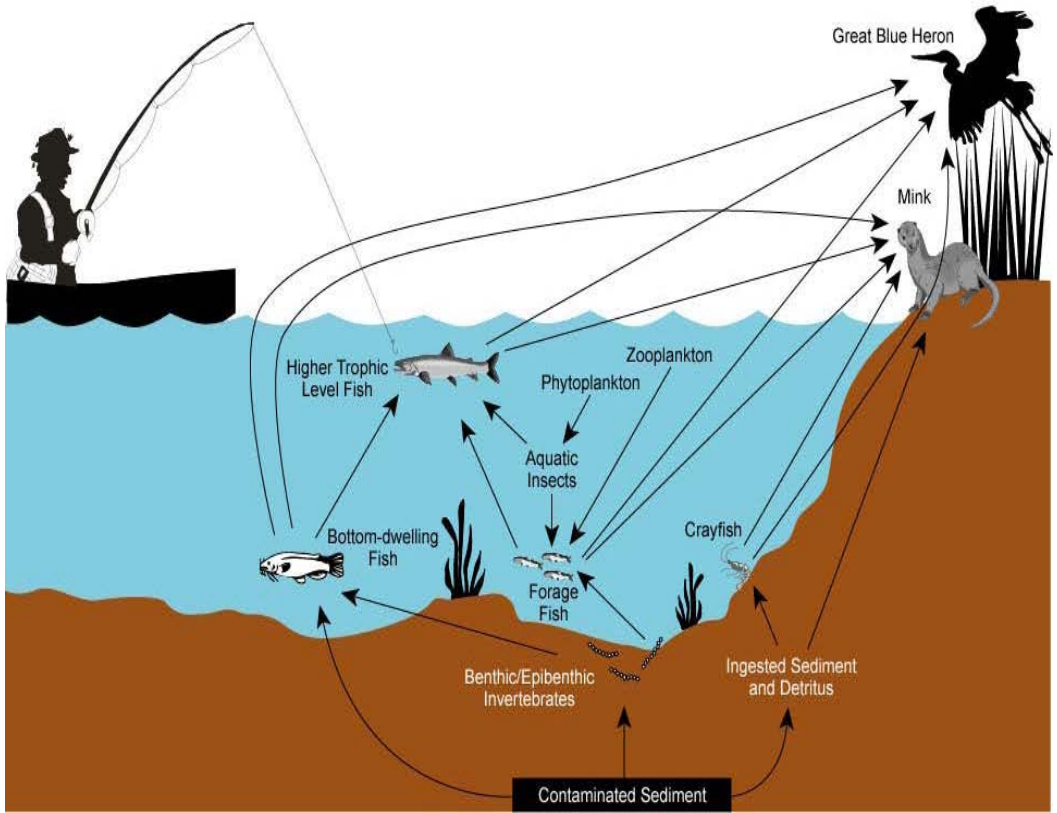
KILL•SPILL sediment cleaner




| Total Extracted Hydrophobic Fractions | OXIC | AN |
|---|---|---|
| 90 days | 780 ± 80 mg $Kg^{-1}$ | 5400 ± 120 mg $Kg^{-1}$ |

# PASSIVE SAMPLING OF HYDROPHOBIC ORGANIC COMPOUNDS (Sediment capping)

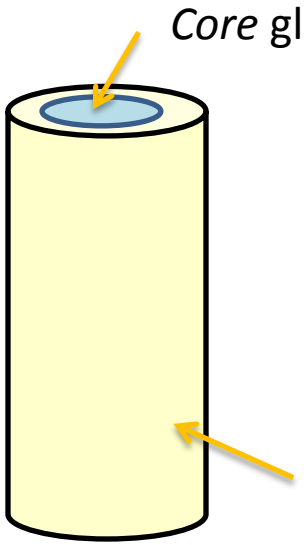
- **Evaluate** the amount of Hydrophobic Organic Compounds (**HOCs**) in water and sediment porewater.
- **HOCs sorbed** amount onto the **fiber** correlated to the **mobile contaminants** concentration.
- Evaluation of **$[HOC]_{mobile}$** strongly related to the **biovailable concentration**.
- Provide  a measure of the **HOCs availability** and their migration properties



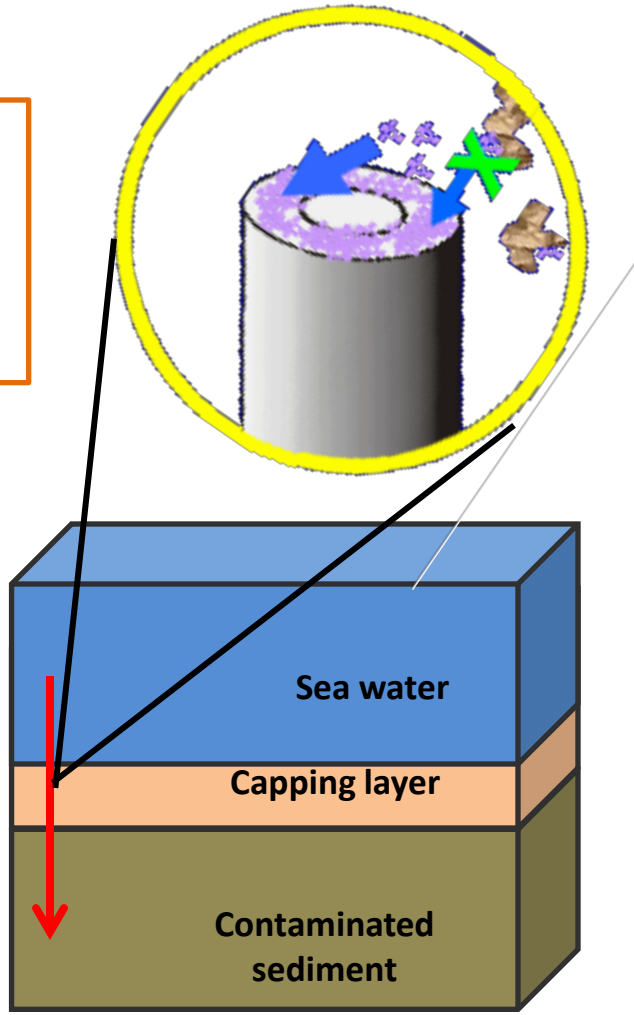

Passive Sampler Devices can be placed in situ for **evaluating** HOCs amount and/or for **monitoring**  a remediation process effectiveness

# PDSM-SPME

PolyDimethilSiloxane-Solid Phase Micro Extraction




PDMS fiber absorb the PAHs concentration in the water column and in the porewater

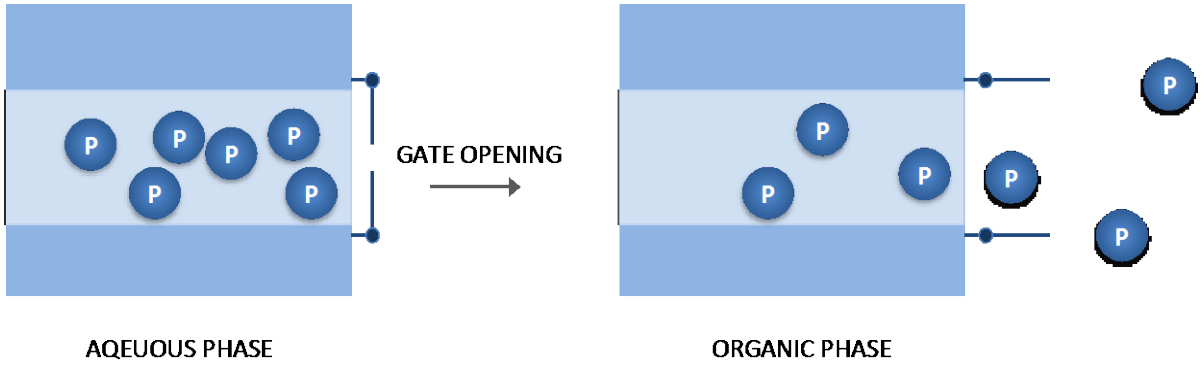


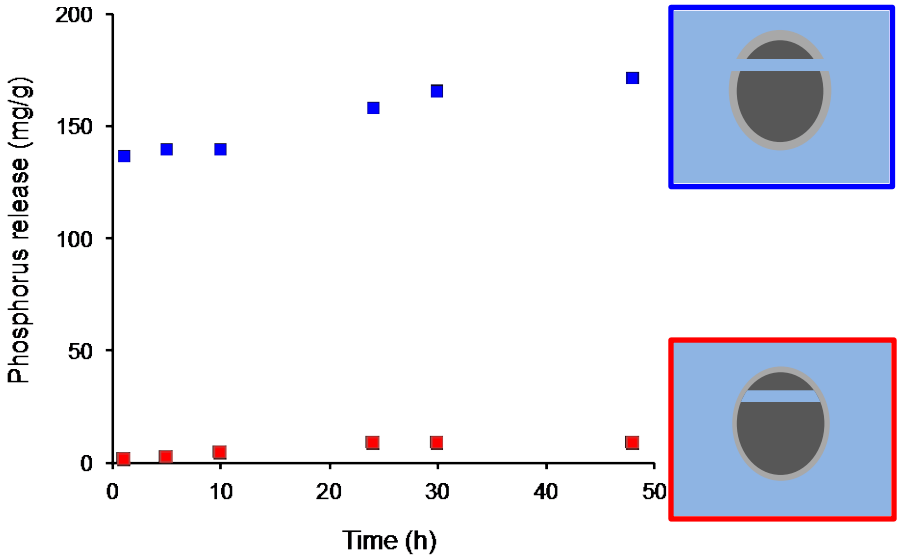

To assess **capping efficiency** the fibers are put into the capping layer and collected after a fixed time for evaluating the PAHs released through the capping layer.

# Mesoporous $SiO_2$ nanoparticles: Formulations to intensify natural (biostimulation) and/or bioaugmentation processes

KILL•SPILL mesoporous

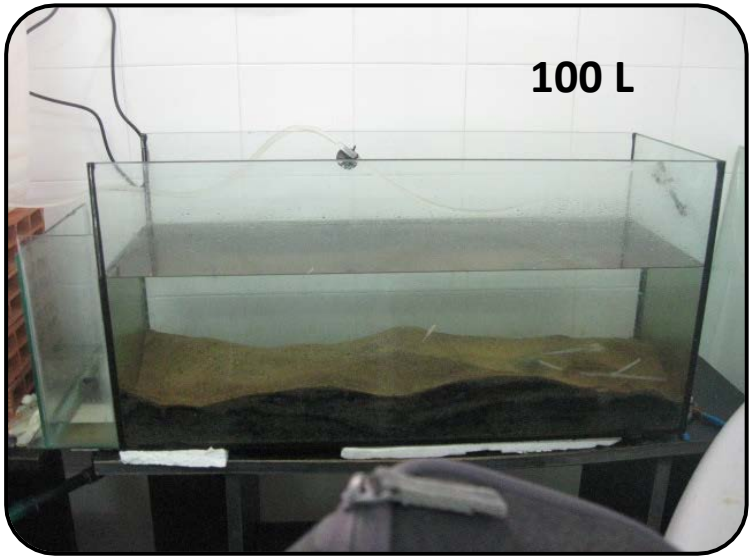
Development of a "smart gate" system allowing the release of the nutrient in the contact of an organic phase

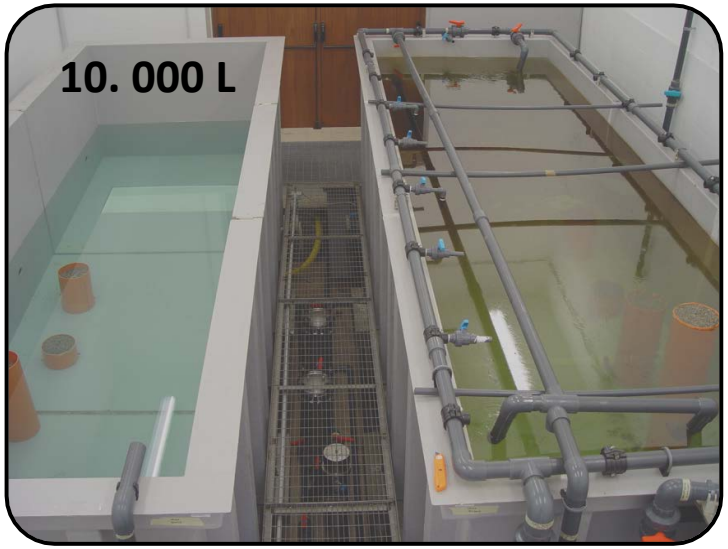



Phosphorous release assayed in the presence of petroleum (10 µL/mL of water)

# DEMOSTRATION Facilities at IAMC/CNR: Micro-, & Mesocosms Scale Systems




**Indoor** Mesocosm Facility


**Outdoor** Mesocosm Facility

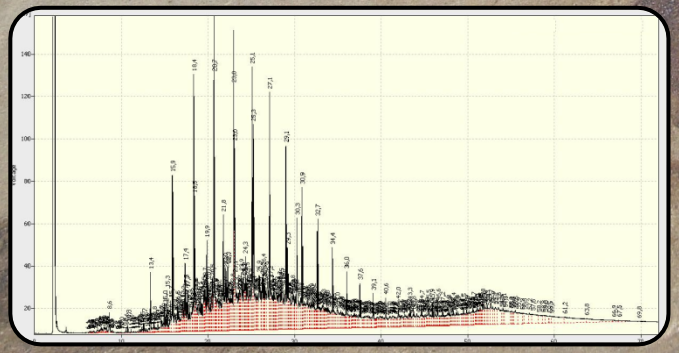
# Gela (SR, Sicily, Italy)

One of the biggest Refinery of Europe
Refining capacity of 100 kbbl/d

# On 4th June 2013, a spill from pipeline of “Topping 1” installation of ENI Refinery of Gela (5 tonnes Crude Oil )

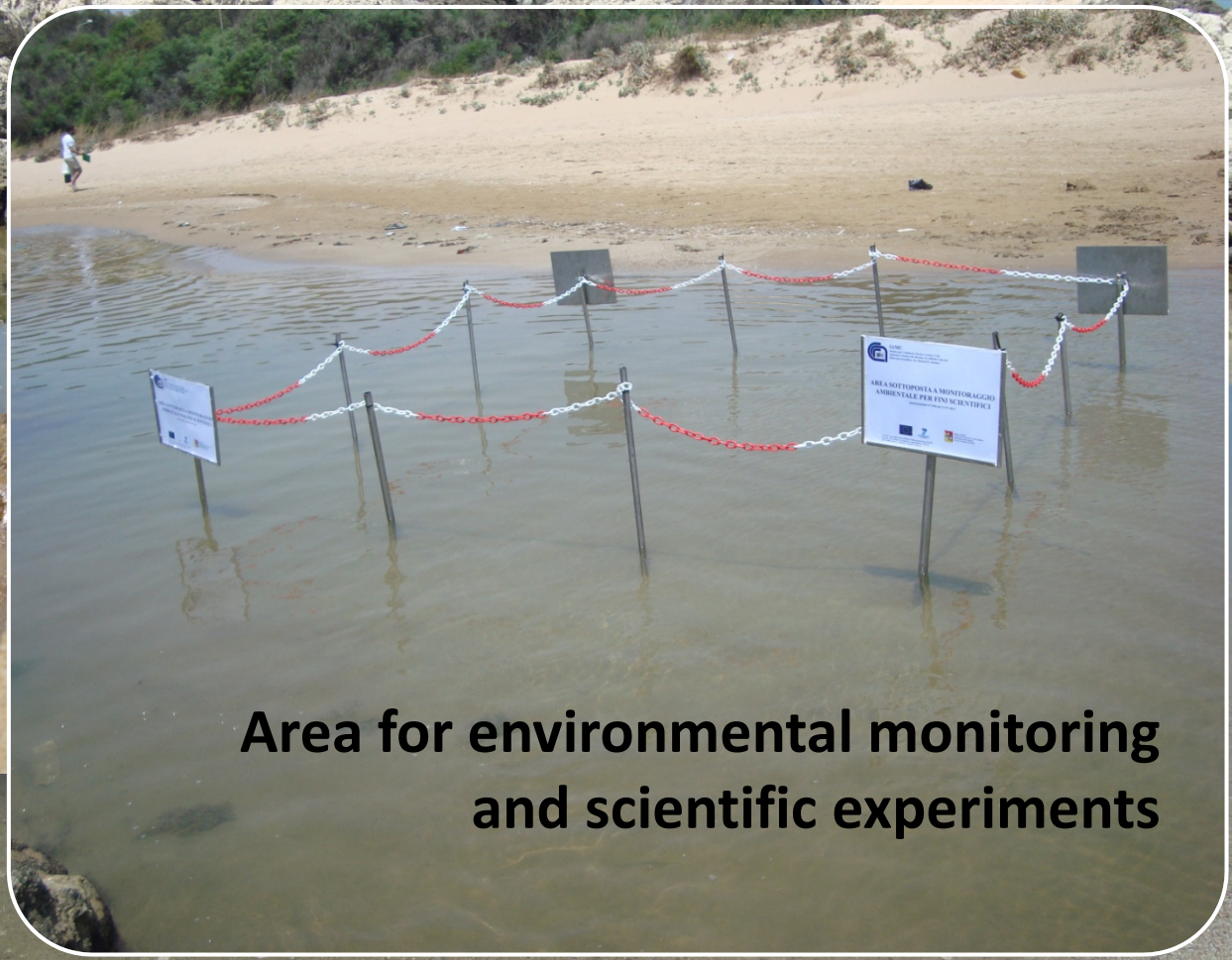
…quick action by Italian Naval Authority and ENI S.p.A to contain the spill…

# However… an opportunity for us!



KILL SPILL

IAMC
Istituto per l'Ambiente Marino Costiero
Consiglio Nazionale delle Ricerche




**Area for environmental monitoring and scientific experiments**

# Concluding Remarks

- Kill*Spill is developing several bio-based products for combating marine oil spills.
- By the end of the project, it is expected that at least 15 distinct products will be available for mitigation activities.
- The Oil Spill Response Industry is starting to accept bio-based technologies for marine oil spills.
- Many challenges remain to be addressed!

# Thank you for your attention!

Kill•Spill - Integrated Biotechnological Solutions for Combating Marine Oil Spills

Project co-funding by the European Union within the 7th Framework Programme under Grant Agreement No. 312139 is gratefully acknowledged

www.killspill.eu