Reseña del II curso Internacional Biotechnology and Petroleum.

Report on the II International Curse Biotechnology and Petroleum.

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From 2 to 6th of February took place the II International Course Biotechnology and Petroleum" at IDEA place in Sartenejas Caracas, Venezuela. The course was sponsored by ICGEB and UNU-Biolac Thanks to the good quality of the invited speakers we completed a very promising and successful course attended by around 30 students and researchers of Latin-American and Venezuela. A summary of the material covered during the course is:

Summary of Course/Meeting Programme

Bioconversion:

- Feasibility (biodegradation) of resins and asphaltenes
  - In situ heavy oil bioconversion
  - Bioconversion: State-of-the-art at UBP-IDEA
  - Strategies to stabilize biocatalytic agents
  - Bioconversion for heteroatom removal.

Bioremediation:

- How to do bioremediation on hydrocarbon contaminated soils
  - Bioremediation of hydrocarbon contaminated soils by solid culture: from lab. to industrial application
  - Bioremediation in Venezuela

MEOR:

- Microbially enhance oil recovery (MEOR): What is it? Does it work? How to do it?
- Quantitative parameters for the application of MEOR Successful MEOR experiences
  - Oil Well ecology: What's happening and who's living down there?
  - Biologically induced problems on the industry

Biofuels:

- Advantages, biology, oils metabolism and biochemistry, productivity of micro algae
  - Bioprocesses (massive production and biorefining)
  - Micro algae final products, possible applications and characteristics of oils
  - State of the art and successful applications
- Gas hydrates, current developments in biological techniques for its producti on

General interest:

- Extremophiles: An overview on organisms, advantages and possibilities
- Competitive issues relating to MEOR.
  - Participant's experiences:
    - ECOPETROL bioremediation experiences. Participant: Astrid pimienta
    - Cluster for Research in Oil Biotechnology (CROB) Participant: Carlos Blaha

After a short introductory words by the president of our Institution Dr Prudencio Chacón and welcome words from the course organizer: Dr. Vladimir León, we had the first Lecture by **Dr. Rafael Vazquez-Duhalt**, group chief at the "Instituto de Biotecnología", UNAM, Mexico: Biotransformation of asphaltenes The conclusions of the author on this subject were that Chloroperoxidase-mediated oxidation of organosulfur compounds, Peroxidase-mediated oxidation of polycyclic aromatic compound (PAH's), Chloroperoxidas and semi-synthetic biocatalyst cytochrome c are able to transform asphaltene fraction and remove Nickel and Vanadium were possible but there's still much work to be done. Among the challenges that remain to make these processes economically viable were the improvement of activity and stability at temperatures higher than 80°C, hydrogen peroxide stability of peroxide using enzymes and catalytic activity in non-aqueous media.

At the end of afternoon we had the second lecture of Dr. R. Vazquez-Duhalt on: "Design biocatalyst for no conventional media" the presenter opened with a short presentation of Berezin and the pioneers of research of biocatalysis in non-conventional media, and then began to present the advantages, challenges (Stability and low activity) and possible solutions (Solvent engineering and Enzyme modification) to overcome them. Then the need for solvent engineering for biocatalysis was defined as: "To rationalize the enzyme behavior in organic solvent reaction medium based on the interactions between proteins and solvent, and the physicochemical properties of the organic medium."

Dr Hans Kristian Kotlar, Specialist at StatoilHydro, Petrophysics and Production technology Department, Trondheim, Norway, gave his conference :" *In situ* heavy oil bioconversion". Dr. Kotlar began by explaining StatoilHydro's Applied Biotechnology program and the future of biotech in the value chain of the industry along with the different activities and products yielded by their biotech program:

- ✓ Gene library of different StatoilHydro reservoirs.
- ✓ DNA-probes for identification of oil/DNA–probes in exploration. Finding new oil.
- ✓ Preventive medication. *In situ* production of treatment chemicals.
- ✓ *In situ* upgrading of heavy oil:
    - Bioconversion of n-alkane/wax
    - Bioconversion of PAH/the ring opening process
        - Bioconversion of porphyrines
        - Bioconversion of asphalthenes
        - *In situ* oil reservoir bioconversion
- ✓ Biofuels:
    - Bioconverted diesel (from LGO)
    - Bioconversion of biodiesel (improve winter properties)
    - Bio-alcohols/2G➔

Then the approach to bioconvert crude oil to prevent wax precipitation in off shore pipelines by reducing its viscosity was tackled, beginning with the screening for bioconversion of Poli-Aromatic Hydrocarbons (PAH) by ring opening and for porphyrin degradation pathways and then explained the importance of crude oil viscosity on the mobility ratio – in traditional crude oil production according to Darcy's Law, and possible deviations from the law by heavy and extra-heavy crude oils within the reservoirs (they may not flow within a Newtonian fluid parameters).

The Stepwise approach searching for suitable biocatalysts/extremophiles was reviewed and effects of biocatalysis of heavy crude oil regarding viscosity, dispersion on aqueous media,

and recovery rates from StatoilHydro's laboratories different experiences in flask, column and radial reservoir models were shown.
The lecturer pointed out the difficulties to do quantitative analysis on total crude oil due to the variety of compounds that forms it (+18.000 different chemical species) and the potential that petroleomics (using cyclotron coupled mass spectrography) offers.
The review of GeneSpring analysis of the communities associated to crude oil and the biotechnological tool box for the industry were the last subjects to be reviewed before closing the lecture with a reflection on new applications of extremophilic microorganisms: as new enzyme systems (reservoir bacteria gene-pool, bio-prospecting, growth criteria of Thermophiles, knowledge of reservoir processes, new enzymes and new knowledge of hydrocarbon generation) to achieve the industries main goals: viscosity reduction and Bioprospecting for new products.
The first day finished with a short presentation of **Dr. Vladimir León,** Head of the Petroleum Biotechnology Laboratory at IDEA, Sartenejas, Venezuela. He presented a detailed view of the US patent presented by the IDEA Petroleum Biotechnology Unit on Bioconversion: the origin of the consortia used, its metabolic characteristic on different Polyaromatic molecules and the upgrading of different distillation cuts. As well as the results on cokification.
The second day was dedicated to bioremediation starting with **Dra. Refugio Rodriguez,** from CINVESTAV, México. Dra. Rodriguez divided her presentation in two lectures: i) How to do bioremediation on hydrocarbon contaminated soils:

Dr. Rodriguez began her lecture by listing and reviewing the sectors of industries (agro- and petro-chemical, mining, oil etc.) sources within the industries, the type of waste and the global amount of waste that are generated by these activities, and then referred to the Mexican cases of Tabasco and Veracruz on hydrocarbons (HCs) contamination.

The different fractions of crude oil were then reviewed and PoliAromatic Hidrocarbons (PAHs) toxicity was extensively explained. Technologies for soil remediation were briefly revised. The bioremediation was tackled by a brief mention of the kinds of organisms that help remediate soil (Bacteria, Fungi, Plants, and Worms) and then an extensive review on bioremediation technologies (*in situ*, and *ex situ*,), its different techniques (Bioaugmentation, Bioestimulation, composting, etc.) and a list of fungi able to mediate bioremediation. Factors affecting biological treatments were examined and alternative carbon sources (wheat straw, sugar cane bagass, etc.) for an initial low-cost growth of microorganisms were briefly studied.

The lecture concluded with an extensive review on the treatment of HCs (BTEX, fuels), and acid & bases spills and remediation and bioremediation statistics in Mexico.
And ii) Bioremediation of hydrocarbon contaminated soil by solid culture: from lab. To industrial application. During the introduction the lecturer pointed out that composting is used mainly for treatment of municipal residues but this technology is nowadays applied for soil remediation and that information of the use of low amounts of organic material for soil bioremediation is scarce.
Lab results regarding bioremediation for Total Petroleum Hydrocarbons (TPH) using orange peel or green coffee beans (with nutrients), showed that it was possible to use these products as a source of inoculums/nutrients. The characteristics of biopiles appropriated for soil remediation (that contains low (10 %) amounts of organic toxic compounds, Lignocellulosic, or agro industrial residues, added, etc.) along with agro industrial waste matter used for toxic organic compounds removal were extensively reviewed.

The process of scaling to pilot plant level was extensively discussed including aspects such as soil characterization, availability and cost of different agro-industrial wastes, biopile physical and chemical design. Results of this pilot scale treatment showed its industrial viability (59% TPH removal in 45 days with a marked decrease in toxixity).
The lecture then proceeded to the industrial application of the biopile technology and an specific case was described and discussed (the treatment of 425 tons of sandy soil with an average TPH concentration of 8,900 PPM on 20 ton biopiles, achieving almost a 100 % Reduction of TPH concentration.
The lecture concluded with showing the statistics of bioremediation use on México by residue type and the statistics for soil remediation and costs.
We continued with **Dra. Carmen Infante**, Advisor of the researcher group of Petroleum Biotechnology at IDEA, on: Bioremediation in Venezuela. The lecture began with an extensive review on the types of environmental passives generated by the Oil Industry (pits, spills, drilling cutting, etc.) and the factors limiting the use of bioremediation, as well as the Venezuelan legislation for the application of this technology.
The procedure to evaluate the possibility for industrial application of bioremediation was extensively explained and case studies were presented. The process begins at laboratory scale biotreatibility studies (normally requiring 1 to 3 months) to determine if biotreatment is possible and to quantify bioremediation treatment rates, and its evaluation process: Toxicity before, during and after biotretment, Enumeration of bacteria, Kinetics of contaminant removal (Oil crude reduction, and SARA), CO2 Production and the need to apply bulking agents (as well as the application parameters for them). The definitions of Bioestimulation and Biaugmentation where introduces within this stage and a case study for selection of microorganisms for Biaugmentation was presented.
A Field level experience using 4 m^2 plots to prove the previously developed inoculum provided evidence that at field level the inoculums had no relevant effect on bioremediation rates or results. At this point the mayor factors affecting bioremediation by composting (Bulking agents, Fertilizers, Moisture control, and Aeration) were explained and a case study of drilling wastes remediation was presented.
Phytoremediation on the eastern part of the country was then reviewed and a case study using *Vetiveria zizanioides*. The lecture ended with a review on the biodegradabitity of Venezuelan crude oils in function of their API gravity, which led to the conclution that biodegradability of these crude oils is inversely proportional to their density (expressed as API gravity). The closing remark was that bioremediation on Biopiles was going to be the next step to use in Venezuela for bioremediation.
We finished the second day with **Dra. Esther Sulman**, Tver Technical University, Russia with the lecture: Biodegradation of oil slimes in Russia. Different technologies of oil-slimes processing and recycling with the help of mechanical, physico-chemical, chemical and biological methods are known. While choosing the recycling technology the volume and composition of hydrocarbon contamination, season are taken into account. The priority is given to the methods which are directed at the extraction of hydrocarbons from the place of contamination.

One of the most effective and universal technologies is microbiological purification of soils. Biological methods of water and soil purification are widely used in Russia and especially abroad. They are based on the ability of different groups of living organisms in the process of their metabolism to transform and accumulate a lot of contaminants in their biomass.

In present time in Russia 2 approaches to the purification from all pollutants are used: on the range and in bioreactors and biomodules. In the first case for the biodecomposition the ground of several hectares in area is built, aeration is organized periodically and the soil is ploughed up, in the second case sterilization is carried out in special heated reactors to which mazut-polluted soil, sediment and oil-slime are moved. The process of oil products decomposition by bacterial preparation is slow: under the range conditions – 3 summer months, in the reactors – 7 and more days. The degree of soil purification from oil products is 80…90%.

Open-cut soils sterilization is ineffective under the condition in Russia where the average temperature is not more than 5…6 °C, it is impossible to purify the soil in latitude higher than Moscow. Closed bioreactors of isothermal type are developed for the average low temperature. Such reactors can be in operation all-the-year-round to maintain optimal temperature conditions necessary for microorganisms reproduction and oil products biodestruction.

The introduction of microorganisms cultures is used only in case of breakdown pollution or in the absence of developed natural biocenose. However, the degeneration of microorganisms sometimes takes place before the required level of purification is achived, besides their use can destroy natural biocenose.

Specially chosen consortium is able to decompose not only oil light ends such as hexadecane but diesel oil and oil tailing, for example mazut, that is to destroy a wide spectrum of hydrocarbons. The consortium does not lose its oxidizing activity in the presence of hexadecane, diesel oil and mazut. Mineral fertilizers contribute to the acceleration of oil contaminants biodegradation. The medium with neutral acidity is ideal for biodecomposition. One of the methods providing oil contaminants dispersion and improving the contact with microorganisms is the introduction of active compounds.

The association of Rhodococcus, Actinomyces, Artrobactes, Thiobacterium, Pseudomons, Hydiomonas, Bacillus bacteria and Aspergillius, Fusarium, Penicillium, Trichoderma are usually used for purification.

The most active destructors of different oil fractions are microorganisms of Rhodococcus and Bacillus genus. At the department of Biotechnology and Chemistry of Tver State Technical University culture Bacillus subtilis (Bacillus subtilis VKPM 10040) was identified. This culture has plywood and oxidase activities. The temperature range of the culture development is 4 up to 45 °C, which is biologically close to the natural processes of oil-slime transformation.

So the development of microorganisms consortium with Bacillus subtilis VKPM 10040 allows transforming the oil-slime in bioreactors and special module not only under natural conditions in Russia but in other countries on the ranges which do not have drastic temperature drops.

The third day we started with two lectures of **Dr. Michael J. McInerney**:
George Lynn Cross Research and Endowed Professor, University of Oklahoma, USA i) Microbially Enhanced Oil Recovery (MEOR): what is it, does it work, how to do it?
Oil reservoirs are home to phylogenetically and metabolically diverse microbial communities. However, we are only beginning to understand the phylogenetic diversity, metabolic capabilities, ecological roles, and community dynamics of oil reservoir microbial communities. Even simple questions such as whether an organism is autochthonous or allochthonous are difficult to answer. The lack of appreciation of the microbiology of oil reservoirs often leads to detrimental consequences such as souring or plugging. However,

an understanding of the microbiology can be used to enhance operations. From the results of field trials and laboratory experiments, it is clear that microorganisms can also be used to mobilize entrapped oil in reservoirs. The biotechnologies that are the most promising include: 1) nitrate and/or nitrite addition to control H_2S production, 2) oxygen injection to stimulate hydrocarbon metabolism to produce surface active agents and/or methane to mobilize crude oil, 3) the injection of fermentative bacteria and carbohydrates to generate large amounts of acids, gases, and solvents to increase oil recovery and oil production rates of individual wells, and 4) nutrient injection to selectively plug high permeability zones, which will improve volumetric sweep efficiency and oil recovery. Some biosurfactants can significantly lower the interfacial tension between oil and water and one field trial showed that large amounts of biosurfactant can be made *in situ*. However, biosurfactants that lower interfacial tension by 1000-fold or more will be needed before biosurfactant-mediated oil recovery is effective. In many cases, it is not certain whether an inoculum is needed or not.

Many of the commercial microbial technologies have been shown to slow the rate of decline in oil production and extend the operational life of marginal oil fields. With marginal oil fields, the goal is keep the well producing rather than maximizing the ultimate amount of oil recovered from the reservoir. The risk for implementing MEOR is low in marginal fields as these fields are near the end of their economic lives. The data needed to assess performance, e.g., oil production rates and operating costs, are relatively easy to obtain. With larger, more productive oil fields, increasing the ultimate recovery factor is the goal, but this requires more extensive analysis of the reservoir and mathematical models to predict the outcomes of treatments. Many companies simply do not wish to risk high production fields for microbial experimentation. Given the future demand for energy and the likely dependence on petroleum resources to meet this demand, petroleum engineering and microbiology disciplines must come together to develop the needed technologies.

And the second lecture ii) Quantitative parameters for the application of MEOR: Successful field experiences. The efficacy of biosurfactants for oil recovery was tested in model laboratory systems and in two field trials. Laboratory experiments showed that 10 to 40 mg/l of JF-2 biosurfactant in the presence of 0.1 mM 2,3-butanediol and 1 g/l of partially hydrolyzed polyacrylamide (PHPA) recovered 10-40% of residual oil from Berea sandstone cores. When PHPA was used alone, about 10% of the residual oil was recovered. Interfacial tension (IFT) decreased in a stepwise manner as biosurfactant concentration increased with marked reductions in IFT occurring at biosurfactant concentrations of 10 and 40 mg/l. When the biosurfactant concentration was greater than 10 mg/l, residual oil recovery linearly increased with biosurfactant concentration. Our work shows that biosurfactant concentrations in excess of the critical micelle concentration can recover substantial amounts of residual oil. *In situ* production of biosurfactants may be an economic method to recover additional crude oil from low production oil reservoirs. We tested whether *Bacillus licheniformis* strain RS-1 and *Bacillus subtilis* subsp. *spizizenii* NRRL B-23049 that produce lipopeptide biosurfactants can grow and produce their biosurfactants in a carbonate oil reservoir. Two wells received an inoculum of the above strains and nutrients (glucose, sodium nitrate, and trace metals), two wells received just nutrients, and one well received only formation water and served as the negative control. The lipopeptide biosurfactant was detected only in the produced fluids of inoculated wells (average concentration of 90 mg/l). This concentration is ~ 9-times the minimum concentration required to mobilize entrapped oil from sandstone cores. Most probable number analysis showed that the number of biosurfactant producers in the produced fluids from the inoculated wells doubled during the four-day incubation time and was ~2-fold higher than that in the produced fluids from the wells that received only nutrients. Biosurfactant-producing isolates from produced fluids from the inoculated wells had 16S rRNA gene, *gyrA* and *srfA3/licA3* sequences with 100% homology to the inoculum strains. A repetitive extragenic palindromic PCR reaction on DNA from the above isolates and inoculated strains showed identical patterns. Measurements of total produced fluid and the water/oil ratio of the inoculated wells showed that about 44 m^3 of additional oil (net cumulative increase) was recovered. This works shows that bioaugmentation of oil reservoirs with biosurfactant-producing bacteria is feasible and improves oil recovery.

In the afternoon we continued with **Dr. Nils-Kåre Birkeland**, Bergen University, Norway, with the lecture: The Oil Reservoir Ecosystem. What's happening and who's living down there? Petroleum reservoirs are considered mainly as anaerobic ecosystems inhabited by a wide range of microorganisms with various metabolic features, including chemolithoautotrophy and heterotrophy. Hence, subterrestrial ecosystems may be the site of significant microbial activities due to the in situ presence of substantial amounts of electron donors (e.g. acetate, hydrogen and hydrocarbons) and electron acceptors (e.g. CO_2). At geological scale, microbial processes may result in crude-oil biodegradation, as observed in numerous subsurface biodegraded oil reservoirs. While several microorganisms retrieved from petroleum reservoirs should be considered as indigenous to these ecosystems, the presence of many of them could be the result of oil exploration and production and may have detrimental effects on oil industry activities. This is the case for most sulfate-reducing bacteria that have been recovered from produced oil-well waters, which are involved in oil souring and biocorrosion phenomena. In contrast, other types of microorganisms such as many fermentative bacteria and methanoarchaea have physiologies compatible with the in situ physico-chemical conditions and thus most likely represent indigenous microorganisms. An overview of the oil reservoir microbiology and the possible ecological roles of these subsurface microorganisms are presented.

We finished the third day with the lecture: Biologically induced problems on the industry by **Dra. Sylvie Le Borgne**, Universidad Autónoma de México, Mexico, LeBorgne's lecture began with an introduction on prokaryote's general characteristics, a flowchart of the exploitation-production process of the oil industry and the different points and levels where biologically induced problems occur and a summary of the relevant metabolic processes (Sulfate-reduction, Methanogenesis, and fermentation).

The lecture then moved on to the microbiology of oil reservoirs and the different nutrients and characteristics (both physical and chemical) of the different waters that can be found in the reservoirs and related to the industry (Formation water, Injection water and Produced water).

A review of the diversity and metabolism of sulfate-reducing bacteria (SRB), methanogens, and fermentative bacteria, and the relevant reactions and metabolite formation that can lead to problems were studied extensively and in depth (Ferment glucose to lactate, acetate, ethanol, hydrogen and CO2 substrates for sulfate reducers and methanogens, Ferment complex nutrients as yeast extract and peptone, H_2S). The presence of "harmful" microorganisms (whether autochthonous or introduced during drilling or secondary recovery by water injection) along the production line was reviewed and special emphasis was made on SBR, traditionally considered as the principal problem for oilfield operators due to H_2S generation in production gases and fluids in well heads. The principal problems on the industry were H_2S formation, Biofilm formation due to its role in reservoir sulfide ‘souring’, plugging Formation and Biomass accumulation and Microbially Induced Corrosion (MIC). A reflection on how little we know of oil well microbial ecology and how much basic research is to be done closed this section of the lecture.

MIC and the role of not only SRB but also of biofilms on its onset along with the possible molecular reactions within them that can lead to MIC were studied.

The lecture concluded with practical cases (an offshore seawater injection system and a Sour gas pipeline) where the use of molecular techniques demonstrated the presence of both, SRB and fermentative bacteria.

The fourth day we started with the lecture: State of the art and successful applications of microalgae biofuels **Dra. Claudia María Lapa Luz Teixeira** (INT, Brazil), The different cultivation systems were extensively explained and exemplified (open systems I. E: different kinds of open ponds, lakes; closed systems: I. E.: tubular and flat panel, photoreactors). Post-cultivation processes were briefly explained (Harvesting and biomass separation, drying, oil extraction and Biodiesel production).

An extensive overview of the advantages (greater productivity in biomass and in oil than oleaginous systems, better quality and more variety of final products, lower land and water quality usage, etc.), chemical composition of oils from microalgae, lipid content, candidate microalgae for biodiesel production, Worldwide Biodiesel Production Initiatives and Programs, Technical and Economic Difficulties for Microalgae Cultivation for Biodiesel Production, Microalgae Vs. oleaginous production cost comparison, and the main challenges to reduce product costs were all explained and/or exemplified.

The lecture then moved on to the initiative of Brazil’s Instituto Nacional de Tecnología (INT) to increase biomass production thru the Sistema BBA, Pumping by Air Bubbling System (airlift). This system increases biomass production ≈ 2.8 times under laboratory conditions and is under patent request. Under pilot scale on 1,000 m^3 systems this method has achieved Biomass productivity of productivity 51t/ha.year using the Microalgae *Dunaliella tertiolecta*. A Microalgae farm model (1 ha) using open ponds equipped with BBA agitation system was presented.

The lecture concluded with an overview of possible Strategies to increase added value to microalgae cultivation for the biodiesel production exploitation of the biomass residue from oil extraction and exploitation of the byproduct Glycerol from the biodiesel production.

The second lecture during the morning was presented by **Dr. Cleveland M. Jones,** Brazil: Gas hydrates, current developments in biological techniques for its production. Gas hydrates are an energy resource composed of natural gas in a solid state, in which the gas molecules are surrounded by water molecules, in a relatively stable composition. One volume of gas hydrates is equivalent to approximately 164 volumes of methane. Gas hydrates may represent more than double the energy content of all other hydrocarbon resources. Gas hydrates are found in equilibrium under conditions of high pressures and low temperatures, and occur in arctic regions (permafrost) and in the continental shelf – in marine surface and subsurface deposits, above seismically observable BSR (bottom-simulating reflectors). The importance of gas hydrates is related to their potential for exploration and production as a source of natural gas; to the known problems they cause in drilling and production systems; to their climate change effects – negative (GHG) and positive (CO2 sequesltration); to the clathrate gun hypothesis effect; and to their potential as a logistics solution for natura gas transportation. Various microbiological investigations of gas hydrates suggest the potential of biological applications for producing hydrates through destabilization. Among these are processes involving microbial conversion of

CO_2, biological in-situ methane production, and organisms which produce antifreeze proteins (AFPs), which inhibit the crystallization of hydrates and eliminate more rapid recrystallization or “memory effect”. These concepts require more research to explore techniques to uncover “green inhibitors” for hydrates. This represents a challenge to researchers involved in projects related to monetization of the very significant gas hydrate accumulations worldwide: microbiological processes may be the key to their economical recovery.

The afternoon of the fourth day was dedicated to presentations of the participants, the fifth day we had the lecture: Economic and competitive issues relating to MEOR by **Dr. Cleveland M. Jones** and finally the lecture: Extremophiles: An overview on organisms, advantages and possibilities .by **Dra. Sylvie Le Borgne** ,Universidad Autónoma de México, Mexico, Lecture introduction was an overview on what extremophiles are, the difference between extromophiles and extremotolerants, the definition of “normal” environment (Neutral pH, Temperarature –20 < T < 40ºC, Atmospheric Pressure, Salinity <3.75% (w/v), etc.) and “extreme” environment (whether due to non standard physical, geochemical or biological conditions) and examples of natural and artificial (anthropogenic) “extreme” environments. Extremophilic microorganisms were classified according to the extreme parameter they need (or more than one in the case of Poli-Extremophiles) and their diversity, phylogeny and location within the universal tree of life.

The potential of these microorganisms stems not only due to the basic science questions they may answer (Origin of life on earth, Life on other planets, Mechanisms of adaptation, etc.) but also due to their practical applications (Extremozymes, protein engineering, Environmental / Petroleum biotechnology, etc.) they may have. The potential in environmental biotechnology was extensively detailed and examples of microorganisms able to degrade pollutants under extreme conditions were given.

The later part of Dr. LeBorgne’s lecture was based in her own experience and ongoing research on the isolation of Hydrocarbon (HC) halophilic degraders and haloalkaliphilic sulfur-oxidizers. This research stems from the common occurrence that conventional microorganisms are not adapted for HC degradation under high salinity conditions. Biodesulfurization of gases by haloalkaliphilic sulfur-oxidizing bacteria (SOB), the sulfur cycle, reactions for Sulfoxidation, Types of sulfur-oxidizer microorganisms that produce elemental sulfur and Distribution of sulfur compounds according to pH, were given and/or explained using graphs, tables and general schematics.