Institut de Recherche pour le Développement FRANCE
French National Research Institute for Sustainable Development

IRD Institut de recherche pour le développement

Con formato: Ancho: 21,59 cm, Alto: 27,94 cm

Jeunes Équipes Associées à l'IRD (JEAI) Program

Call for proposals 2018

Application form

Returns from the 2017 commission:

Great points:
- main objective and scope matching with the call: thematic of strong relevance
- Support to the creation of a master

Weakness:
- Lack of scientific question clearly identified / displayed
- Lack of conceptual vision and modelling
- Lacks in process identification - ecology
- No assessment of past integration
- We show that we collected a lot of funds so why supporting us if we are autonomous? (we have to better explain why we need support and not enlarge how we funded the projetcs…)

In brief:
- Improve team presentation and what will it give structure to
- Improve scientific aspects & process
- !!! support of the bolivian administration: need support letters of the head of each department and university dean

I – Summary form

1. Team

Full name	TracIng the TrIgger mechanisms of eutrophiCAtion and ContAmination of andean aquatic ecosystems (Bolivia).
Acronym	TITICACA
Country	Bolivia

Number of permanent researchers/professors involved	5
Number of engineers and technicians involved	1
Number of PhD students, post docs involved	1

Title, Last/First name of the JEAI Leader	M. Acha Dario
E-mail	darioacha@yahoo.ca
Home institution	UMSA – Instituto de Ecologia

Title, Last/First name of the JEAI correspondent	M. Guédron Stéphane
E-mail	stephane.guedron@ird.fr
IRD Research Unit / acronym	UR 219
Location and current home institution	ISTerre

Institution(s)/Employer(s) in the Developing countries of the JEAI members *(add as many rows as needed)*	
Institution/Employer 1	Instituto de Ecologia – Carrera de Biología - UMSA (Universidad Mayor de San Andres)
Institution/Employer 2	Instituto de Investigaciones Quimicas - UMSA (Universidad Mayor de San Andres)
Institution/Employer 3	Instituto de Biología Molecular y Biotecnología – Carrera de Biología – UMSA (Universidad Mayor de San Andrés)

IRD partner research unit(s) *(add as many rows as needed)*	
IRD partner research unit / acronym	Institut des Géosciences de l'Environnement (IGE) - UR 252
IRD partner research unit / acronym	Géoscience Environnement Toulouse (GET) - UR 234 IRD
IRD partner research unit / acronym	Biologie des Organismes et Ecosystèmes Aquatiques (BOREA) - UR 207

IRD's scientific assessment bodies related to the project *(one or more bodies in the case of interdisciplinary projects)*	CSS1

Full budget requested	50 000 euros

2. Research project *(see « Selection criteria », page 3 of the Call for proposals)*

■ Title

TITICACA: Traclng the Trlgger mechanisms of eutrophiCAtion and ContAmination of andean aquatic ecosystems (Bolivia).

■ Scientific disciplines

Environmental Biogeochemistry - ecology – limnology – microbiology – isotope geochemistry - hydrology

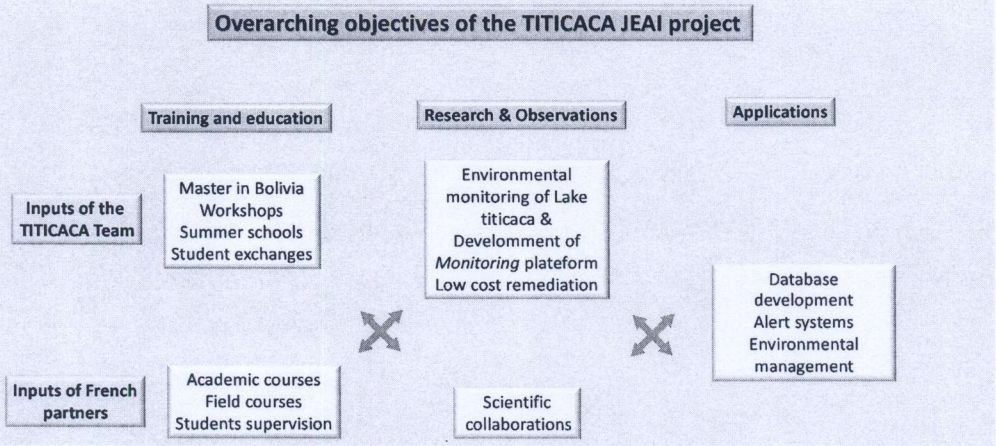
■ Keywords *(5 maximum)*

Contamination – Biogeochemistry – monitoring – remediation –aquatic ecosystems

■ Summary of the research project *(half-page maximum, font 10)*

Lake Titicaca is the only great lake in the world without any survey program, which makes it vulnerable regarding the current rising of climate change and anthropogenic pressure. Since it is located at 3800 m.a.s.l. in the tropical region it is subject to extreme daily and seasonal changes in physicochemical as well as biological characteristics. It is challenging, consequently, to identify significant changes related to climate change or anthropogenic pressure with single point observations. Therefore, the vulnerability of this important and unique ecosystem is still to be understood. Such comprehension is also crucial to develop the ability to predict the future fate and behavior of important events such as algal blooms and their related impacts on the water quality at short time scales (hours to days). The development of an observation and survey system would allow to pressure predictions of all kinds and use complex models that are underpinned by observations.
Without high quality observation data to constrain predictive models any forecasts of the biogeochemical and ecological functioning of the lake are highly unreliable. The installation of an observational in situ monitoring platform including IRD patented innovative water sensors, associated with weekly to monthly field sampling will provide well documented observations of the essential biogeochemical and limnological variables such as dissolved elements (nutrients, metals etc…), particles and biota (microbes, biofilm, plankton) properties with temporal, horizontal and vertical resolution.

The TITICACA project proposes first to develop an observational system in Lake Titicaca in order to better understand the reactivity and fate of the lake to human pressure (e.g., eutrophication and algal blooms) and to create an alert system to protect this fragile emblematic ecosystem.
The second objective of this project is to build up a "buffering" decontamination system (filtering garden) reserved for the treatment of polluted water (wastewater) by phytoremediation using a combination of totoras (endemic sedge) and periphyton to reduce urban emission of residual waters to the Lake.
Finally, the third objective is to build capacity (i.e., students, technical staff and researchers) to follow and improve set up devices and knowledge on the biogeochemistry and ecology of the entire Titicaca basin including Peru. Such objective is based on the narrow collaboration and involvement between UMSA and IRD partners in the new multidisciplinary Maestria (Masters) of biology and biogeochemistry, which is currently running with 25 students and is expected to have more students by 2019. Additionally, the faculty of pure and natural science at UMSA is developing a doctoral multidisciplinary program on earth sciences that aims to start some time in 2019.



■ Consistency of the team regarding the scientific project and complementarity of each of the JEAI's members *(half-page maximum, font 10)*

IE/IIQ/IBMB plays a major role in the knowledge transfer of UMSA since the 3 teams are implied in most of the Licence and (new) Master degrees teaching in ecology, geochemistry and microbiology. These young researchers bring new light in modern research at UMSA since they are all PhD graduated (the highest common degree at the UMSA is the Licence degree) and are very active in regional research projects management. For example, IIQ manages most of the contamination programs in the Titicaca upstream watersheds (e.g., IDH programs Milluni and Katari) and IE is leader in the receptacle compartment (i.e. Lake Titicaca – Lago Menor; IDH program EUTITICACA, LATICO2 and PIA-ACC UMSA project of eutrophication, phytoremediation and paleolimnology, ECERP binational survey expeditions on water quality and fish biomass evaluation). The high and modern scientific level of these projects is becoming recognized at the international level through their scientific publications (Acha et al., 2018; Hsu-Kim et al., 2018; Lanza et al. 2017; Rivera et al. 2016; Alanoca et al., 2016a; Alanoca et al., 2016b; Ramos Ramos et al., 2012) and the involvement of Northern countries partners (e.g., IRD, KTH…) in their own research programs.
Their research are positioned in the key issues highlighted by both governmental (e.g., MMAyA, binational (ALT)) and international (e.g., PNUD, GEF) institutions for the preservation of water resources and biodiversity on the Andean Altiplano.
The Biology department at Universidad Mayor de San Andrés is responsible of three 2 year Master Programs (see details in the main project and description de l'équipe sections), two of which are research oriented (meaning at least one year of research). One of the programs is focusing on molecular biology and biotechnology (started 2017), while the second is more multidisciplinary and biogeochemistry oriented (started February 2018 with a new group starting February 2019). We have already two master's students working on Totora *in-vitro* culture that will provide the Totora for phytoremediation and metabolic information about Totora management and response to pollution. We have another three master students working on the pilot scale phytoremediation system and two master students working on algae response to euthrophication and other factors related to the monitoring program. We expect to have at least two other master's students following the effectiveness of phytoremediation and changes in the surrounding ecosystem.
The professor responsible of Titicaca project will teach a full course in the second master program and all researchers are expected to give at least one talk and a seminar in one or both master programs. The multidisciplinary and biogeochemistry program are totally free and have a year and a half dedicated to independent research.
Bolivian researchers alternate between teaching in the graduate program (one term) and teaching in the undergraduate Biology and Chemistry programs (one term). All courses are related to the proposed Titicaca program (i.e. Environmental Management, Biotechnology, etc …).
Our Master's students are expected to produce at least one manuscript ready for submission to international per-review journals with at least some impact factor. Therefore, we expect to have at least seven manuscripts ready for publication or published by the end of the project.

■ **Integration of the team into the academic place of belonging and into the local, regional and international scientific community** *(half-page maximum, font 10)*

The main partner research unit (ISTerre/UGA) is heavily involved into the franco-bolivian partnership observing programs, coordinated by IRD and CNRS INSU and in particular limno- and bio-geochemical research. The associated French partner IGE/UGA is also involved in collaborative programs with UMSA and Bolivian Ministry for Environment and Water (MMAyA) focusing on monitoring water and nutrients transfer between soil surface, groundwater and Titicaca Lake. The associated French partners GET&BOREA have teamed up to build and maintain the first *in situ* biogeochemical monitoring platform in Lake Titicaca between 2012 and 2015.
Field observation activities are identified within LabEx OSUG@2020 as priorities. In addition to data collection, they are intended to develop international collaborations and trainings with the partner countries.
Bolivia is central to many observing activities at OSUG with several initiatives linked to monitoring the environments (hydrology, soils, glaciers and atmosphere).
Other partners in France are also deeply involved in observation and research activities: Laboratory of Bioinorganic Analytical and Environmental Chemistry (LCABIE).
Overall, the French partnership brings a fundamental expertise in biogeochemistry and limnology observations using in situ sensors, station and data management and, through their implication in international research will provide the opportunities to develop a long-term sustainable scheme for TITICACA activities and IE/IIQ-UMSA staff.

■ **Coherence with the research program of the IRD partner research unit** *(half-page maximum, font 10)*

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II – Detailed application

1. Description of the research project *(7 pages maximum, font 10)*

TITICACA : Tracing the Trigger mechanisms of eutrophiCAtion and ContAmination of andean aquatic ecosystems (Bolivia).

1- Introduction

Geographical context

Lake Titicaca is the most important water resource of the Andean Altiplano, a major source of fish for ~ 3 million people and the largest navigable water body in the world lying at an altitude of 3809 meters above sea level (a.s.l.). Despite important improvements in the last decade on the knowledge of its ecological functioning and limnology from 1980's, there is still a crucial need for both consolidation of the existing observation infrastructure and development of a more efficient observing system that would narrow major data and information gaps, and assist stake holders in planning new investments for the protection and improvement of the quality of this emblematic ecosystem.

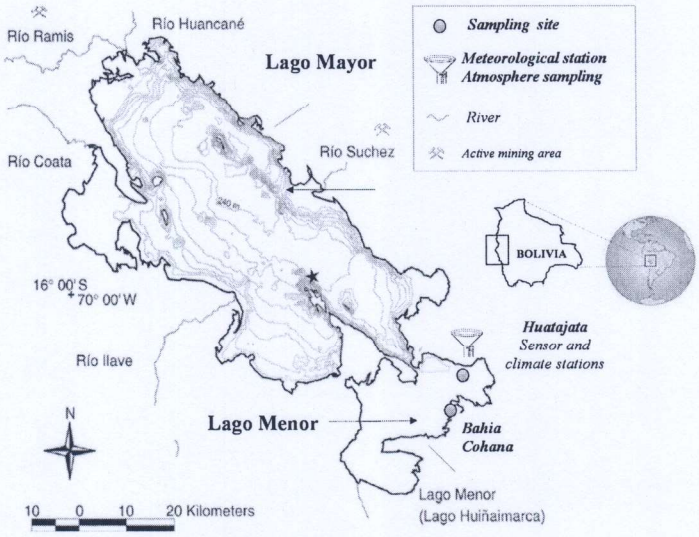

Fig. 1. General Map of Titicaca Lake and the Bolivian Altiplano

Owing to its tropical (~16°S) and high altitude location, Lake Titicaca's physicochemical characteristics are highly unusual. Dissolved oxygen concentration is around 60% of the saturation at the sea level and UVA and UVB radiation levels in the lake are extremely high (Pouilly et al., 2014) resulting in an hydrological regime dominated by evaporation (~ 95%) with precipitations centered on the rainy seasons.
Nowadays, the ecological equilibrium of the region is disturbed by a recent but very intensive urban demography and the intensification of mining activities, fisheries and agriculture around the Lake. The most preoccupying issue on the Bolivian side of the Lake (Lago Menor – southern basin of the lake) is the extremely rapid development of El Alto city, which population increased from 95,000 inhabitants in 1976 to around 1.2 million according to the last census (Mazurek, 2012) with minimal land planning. Wastewater from El Alto city, its facilities, manufactures and small scale industries, are discharged in the Katari river (Fig. 1), which flows to the Lago Menor with less than 50% of water treated (Chudnoff, 2009). Major emitted pollutants identified in the water arriving to Lake Titicaca include nutrients,

traces metals and organic contaminants (Archundia et al., 2017; Duwig et al., 2014), but also mercury (Hg) contamination which is one of the preoccupying issues in this fragile ecosystem (Guédron et al., 2017).
Clearly, there is a problematic deficiency of information on i) the evaluation of consequences of such anthropogenic emissions to the lake and on ii) the development of short and long term strategies to reduce the impact of these emissions.

State of the art: A fragile ecosystem prone to eutrophication

The rising of anthropogenic emissions mostly affects Lake Titicaca's southern shallow basin (Lago Menor – 1,428 km^2; mean depth = 9 m; max depth = 40 m) which is more susceptible to eutrophication than the great oligotrophic lake due to great differences in volume (Lago Mayor - 7,131 km2; mean depth = 100 m; max depth = 285 m).
High nutrient loads (especially phosphate ~ 12.7 mg/L and ammonium~ 3 mg/L and DOC~ 15mg/L in the lower Katari river) from El Alto city induce a high eutrophic state of surface waters in the lower Katari basin, discharging these eutrophic waters in the Bahia de Cohana (Lago Menor). This is particularly worrying during the dry season when the rivers, both within and downstream of El Alto city, are mainly composed of untreated and treated wastewaters (Archundia et al., 2017). Indeed, **algae blooms in lake Titicaca** (Lago Menor) occurred regularly, for the first time, during the last decade and have been shown to be more frequent and intense during the last past 3 years (i.e., 2014 -2017). A previous high temporal resolution of the water column geochemistry (i.e., Titicaca Sensors project: 2013-2014, Point et al. 2013) using multi-parameter probes allowed identifying such short bloom events. Such monitoring platform allowed identifying at high resolution (15 minutes) variation in O_2, pressure, pH, conductivity (multi-parameter probe - NKE MP), chlorphyl-a and algal groups fluorescence (Bbe FluoroProbe), temperature variability at different depths (HOBO probes). We also complement our data with column profiles at two different locations.
Besides these short events, a great and long lasting event (i.e., March to April 2015 – Fig. 2a) have greatly impacted the ecological functioning of the small lake where more than 2 tons of fish, frogs and birds have died during the event. Such Bloom has been shown to change physicochemical characteristics of the lake temporary (e.g., drop in O_2 and rise in H_2S production affecting the water shallow column – Fig. 2b).

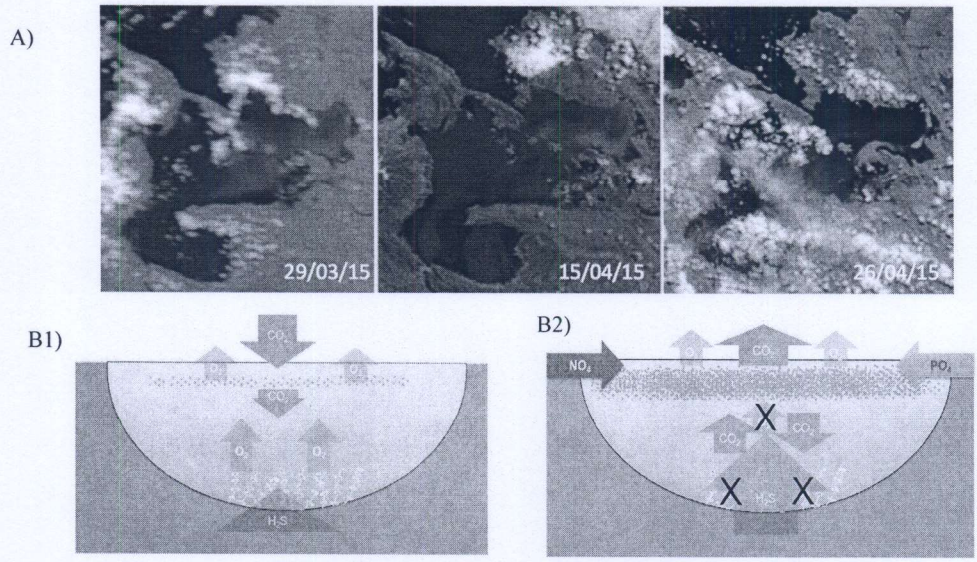

Fig. 2. a) Satellites images of the southern basin of Lake Titicaca during the bloom of 2015 and b) schematic illustration of Lake Titicaca ecosystem under B1) undisturbed conditions and B2) during a bloom event like the major 2015 event.

Besides biota, we also highlighted that such Algae blooms have altered geochemical cycles of contaminants such as mercury (Hg) increasing the production of the neurotoxic methylmercury (MeHg) in the water column due to the lasting of sub to anoxic conditions (Acha et al., 2018). Indeed, we reported that these eutrophication events implying

chlorophytes stimulated hydrogen sulfide production by sulfate-reducing bacteria (SRB) (Acha et al., 2018; Ayala-Parra et al., 2016; Russell et al., 2003), this latter being the most common Hg methylator microorganism in aquatic environments (Parks et al. 2013). Indeed, we demonstrated that during the major 2015 event, the bloom generated ideal conditions for mercury methylation and accumulation with an increase of methylmercury concentrations in filtered lake water by a factor of 1.3 (from 22 to 47 pg L^{-1} in water). A rise in concentration of toxic species such as methylmercury (MeHg) would have major consequences on the trophic transfer of organometallic compound in biota that is on the major resources in the Lake. Such trend in rising toxic MeHg concentrations in water column and biota (Fig. 3) due to the rise of eutrophication status of the lakes has also been highlighted during the geochemical study of the continuum Lake Titicaca - Lake Uru-Uru (ANR project La Pachamama, PI D. Amouroux; COMIBOL project, PI: D. Point; EUTITICACA project, PI: D. Achá; and TRACISOMER project, PI: S. Guédron) with extremely high MeHg percentages found in the eutrophicated shallow Uru-Uru ecosystem (Guédron et al., 2017).

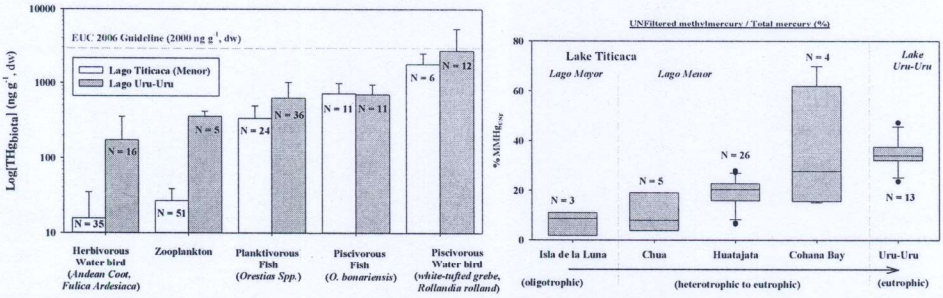

Fig. 3. (left) Log total concentration of mercury in food webs of lake Titicaca and of the highly eutrophic lake Uru-Uru. (Right) Box plot presentation with error bars for percentage methylmercury over total mercury for filtered and unfiltered surface waters along the upstream - downstream gradient from Lake Titicaca to Lake Uru-Uru. Vertical bar chart show the median (upper full line) and standard deviation (SD) of each data set (N is the number of samples).

2- Necessity of monitoring and alert system

Since it is located at 3800 m.a.s.l. in the tropical region it is subject to extreme daily and seasonal changes in physicochemical as well as biological characteristics. It is challenging, consequently, to identify significant changes related to climate change or anthropogenic pressure with point observations. It was not been possible yet to single out specific indicator of specific alterations. Therefore, the vulnerability of this important and unique ecosystem is still to be understood. Such comprehension is also crucial to develop the ability to predict the future fate and behavior of important events such as algal blooms and their related impacts on the water quality at short time scales (hours to days). High resolution constant long term monitoring is now possible thanks to recent technological advancements and may provide an alternative to better study highly variable and complex ecosystems such as Lake Titicaca

Global changes and perhaps climate change might enhance the recurrence of algae bloom events since current modeling suggests that high-altitude tropical regions will be the most affected by climate change (Bradley et al., 2006). The general perception seems to be a decrease in precipitation in southern Peru, which feeds Lake Titicaca (Vuille et al., 2008). Other models also suggest an increase in precipitation during the rainy season (December to March) and a reduction of rains during the dry season (winter) (Vera et al., 2006). Therefore, extreme events are more likely, regardless an increase or reduction of total rain, and the following alterations to fragile ecosystems as Lake Titicaca. Even more, since up to 71% of the surface water originates in glacial melting during the dry season (Guido et al., 2016), the reduction of the overall volume of the Lake Titicaca may also reduce its resilience to other stressors. Such scenario is particularly worrying for ecosystems already stressed by pollution. Thus both rising and uncontrolled anthropic pressure (including lack of wastewater treatment) combined with climate change would increase predisposition for eutrophication (Paerl and Paul, 2012; Whitehead et al., 2009). Extreme rain events that are likely to be increased by climate change could mobilize more nutrients, organic matter and metallic contaminants from the watershed runoff than the same amount of rain distributed in non-extreme events (Paerl and Paul, 2012).
Clearly current gaps in the observing system for the water biogeochemical composition changes are still numerous, in particular for (i) the increasing eutrophication of Lago Menor and the consideration of algal bloom events. **Lake Titicaca is the only Great Lake in the world without any current continuous long term observational and**

monitoring system. (ii) Secondary production such as sulfate reduction and the microorganisms implicated in the light of the limited oxygen conditions, eutrophication and sulfate enrichment of the ecosystem and their impact on plankton composition (iii) Periphyton microbial composition and contribution main geochemical cycles. (iv) Incidence of emerging contaminants and their impact on invertebrate community composition and top-down controls on phytoplankton communities. (v) Effect of nutrient enrichment on algae composition in macrophyte associated periphyton and sediment surface as potential source for algae blooms.
In our previous studies we have identified nitrogen and carbon isotope fractionation as very reliable and sensitive indicators to monitor the degree of anthropogenic pollution before eutrophication or algae blooms develop (Heredia, et al. 2017, in preparation). However, the tool was only tested in the most polluted areas and still has to be tested in areas with more diffused pollution.

Although the impact of such algal bloom has been quite well described in our study, the **trigger mechanism of such bloom event is nowadays weakly understood**. Since the biogeochemical and ecological processes driving the carbon cycle (photosynthesis / respiration, calcite precipitation), the transformation / transfer of trace elements between compartments (e.g., watershed, pore-waters…) and the dynamics of phytoplankton and zooplankton assemblages are all tied up, their study requires a well-designed and fully integrated monitoring strategy. Thus, spatial and high temporal resolution monitoring is needed to understand the mechanisms (e.g., hydrologic and climatic factors) and identify the sources (e.g., anthropogenic, agricultural) and pathways for the emissions of nutrients to which originate such event.

The key objective of this project are the understanding of (i) changes in the ecosystem mainly associated to climate change or eutrophication, (ii) the trigger mechanism of short and long lasting algal bloom, (iii) the sources, fluxes and impact of discharging watersheds at the lake scale level and the resulting production of toxic species (i.e., hydrogen sulfides, organometallics (e.g., MeHg) etc) and their impact on trophic chain (including fisheries). The final objective is to model data, and provide an alert system in parallel of the set-up of remediation purposes.

To reach these objective we will focus on the following main scientific questions:

- **Which physicochemical and biological characteristics result from natural variability and which from climate change or euthrophication?**
- **Which ecological systems of the lake are more sensitive or a starting point for blooms?**
- **What are the main contributors (tributaries, fields, shallow sediments) of nutrient and the external forcing factors (climate vs anthropogenic forcing) for their mobilization?**
- **What type of nutrient (chemical forms, availability) trigger these blooms?**
- **What is the resilience capacity of the system to short and long term bloom events?**
- **How can we lower anthropogenic emission and provide low cost treatment systems?**

i) Observational and monitoring system

We recently started the project "**Observatorio permanente del Lago Titicaca**" (equipment funded by PNUD, P.I.s D. Acha, and X. Lazzaro) to create the **first permanent monitoring platform in Lake Titicaca** (Huatajata, Lago Menor). The platform (currently under construction) will be installed in front of Huatajata (Fig. 1) and equipped with series of automatic sensors (multiparameter YSI EXO2, Bbe FluoroProbe III, NKE SDOT and SPDT probes, and HOBO Agua Pro V2 temperature sensors) to generate high-resolution (15 minutes) bio-geochemical data in order to identify the diurnal, seasonal and annual natural fluctuations of this aquatic ecosystem (e.g., oxygen, nutrient, organometalic). In addition, such platform will permit the identification of short term fluctuations as the water biogeochemical and ecological processes at the sub-hour scale to quantify mechanisms and process which trigger such algal blooms and their temporal extents. Such high resolution *in situ* measurement strategy will bring new light on a cascade of temporal scales deployed at target interfaces areas where the biogeochemical gradients are the strongest. In the meantime, climatological data (pluviometry, wind velocity and UV-PAR) collected from our Campbell climatological station installed at Huatajata (Fig. 1) will bring information on climate forcing through the water column changes (e.g., resuspension of particles in shallow areas, water oxygenation…) and leaching of agricultural shore lines by rain events of various intensity.

All these high resolution multi-sensor data will be combined to **periodical field samplings** (15 day to week frequency of vertical profiles and transects) of dissolved nutrients, biota collection and identification (plankton, algae and pigments), (in)organic ligand, metals and metalloids, stable isotopic tracers (i.e., $\delta^{13}C$, $\delta^{15}N$), suspended particles,

surface and sediment samples concentration (size distribution and chemical composition). In addition, particular IRD patented Hg sensors (MMHg DGT sensors, P.I., D. Point) will be coupled to this periodical field monitoring to understand the evaluate the Hg methylation and contamination source dynamics (trophic chain) in the context of the general eutrophication of Lago Menor.

The coupling of these sensored and monitored parameters will allow the identification of forcing parameters of the changes in Lake physico-chemical and ecological functioning and of the trigger mechanisms of algal blooms with consideration of climate and anthropogenic forcing.

• In the case of physico-chemical, nutrients and Hg speciation analysis, measurements at IE/IBMB/IIQ-UMSA started in 2012 (including the acquisition of a Merx system for MeHg analysis and a HPLC for hydrogen sulfide, trimetroprim and sulfametoxazol determinations) and are operational since then. The project therefore benefits from a 4-year continuous record of essential limnological variables from the Lake Titicaca (Eutiticaca, TTKKS, La Pachamama projects and ECERP program).

• In the case of ecological compartments we have developed and used fluorescence, spectrophotometric, HPLC and microscopic techniques to characterize algae communities. More recently we have acquired the ability to analyze microbial communities through state of the art next generation sequencing and will soon have MinION nanopore sequencing system for field quantitative sequencing of RNA as an approach to analyze group specific activity. Dario & Xavier ,

Both the platform and periodical field samplings require specialized manpower to maintain, follow and improve the monitoring device and collect the data. In particular, data from the platform need to be complemented by *in situ* measurement to insure the quality and reliability of probes measurements (i.e., intercalibration of probes vs direct measurements and evaluation of probes drifts due to fooling etc…).

ii) Source, flux of nutrients and contaminants and their impact on water quality and biota

In face of rapid urbanization of the main cities (El Alto, Copacabana) and coastal areas of the lake, UMSA and IRD partners developed a currently running project to assess the vulnerability of surface water resources including Lago Menor funded by LABEX OSUG@2020 and IRD.

The objectives of this project is to (i) estimate the nutrients fluxes towards the Lake Titicaca (e.g., Katari watershed) and (ii) estimate the nitrogen pollution level and origin (with elemental and isotopic analyses) coupled with adequate hydrologic and geophysics techniques and the involvement of UMSA students and city planners to monitor and model the hydrosystem and aquifer (PI C. Duwig).

Although the first large and major eutrophication event occurred in the Cohana Bay, the current rapid urban development on the shores of the lake (i.e., east coast of the small lake and west coast of the great lake) will surely generate other anthropogenic point sources that main enhance and spread this phenomenon at a larger scale. Indeed, current political strategy of the Bolivian government is to develop economical and touristic activities on the shores of Lake Titicaca which have a great potential for commercial and touristic development. Such governmental policy is currently under achievement with the building of a new highway on the eastern shore of the small lake (to Peru via Copacabana), of the Copacabana airport (on the shores of the great Lake) and the subsidy of local fisheries and farms on both great and small lake to enhance economical exchanges with the neighboring Peru and increase touristic capacity.

One of the main objective of these periodical field samplings will be to quantify and decipher the respective contribution of nutrient emissions to the lake between from (i) the leaching of the Lake shores (including villages and agricultural fields), (ii) the urban tributaries (e.g., katari) and (iii) the resuspension of surface sediment (e.g., mostly during storm events in shallow areas).

Hence, the **identification and quantification of these () sources** around the lake with respect to their location and hydrological context (e.g., geomorphology, sediment facies, main currents) is a key information to understand and predict their impact in a near future. Understanding the sources, fate and behavior of nutrients at the lake level during and in-between algal bloom events will also help understanding specific processes such as the production of organometallics (i.e. MeHg) which were found to rise with rising eutrophication resulting in higher levels in high trophic level (Fig. 3). The exposure of fish farmed will also be studied.

Modeling and alert system

In fine, the understanding of the mechanisms and processes, the spatial repartition and periodicity of these events together with the identification of simple biogeochemical tracers will allow elaborating a prediction and alert system.

Obtained geochemical data will be modelled (i.e., phreeqC, Wham) to constrain and validate the geochemical processes and equilibrium changes occurring
In addition, a set of standardized protocols will be specifically designed for the observation this unique high altitude ecosystem to train technical staff of the Bolivian (e.g. MMAyA) and Peruvian (IMARPE) Environmental agencies and to deploy other stations and get a higher scale monitoring and observatory system (cf. the objectives of the OBLT – Lake Titicaca Binational Observatory, Lazzaro 2015, 2016).
The statistical analysis and biogeochemical modeling (phreeq-C and XXXX – ecological model ???), will complete and refine field observations and allow process identification for trigger mechanism identification in this high altitude ecosystem.
To maintain provision of unique data sets to the scientific community for Lake Titicaca-chemistry model validation TITCACA will ensure that all physicochemical measurements will be distributed to the wide community of research through an online Geovisor data base built at the UMSA (http://www.geovisorumsa.com/ Nuñez & Lazzaro 2015, 2016) in an open access policy and in compliance to the requested quality standards. Quality standards are those implemented by UEPA and EPA for the different measurements.

Deliverables

To reach the final objective, main efforts will be centered on the data acquisition, compilation and modelling including both geochemical ecological simulations.

- TITICACA will publish in the first year of the project, a series of papers in international peer-reviewed journal documenting baseline information on the changes in water quality and preliminary results on identified impact of current eutrophication of the aquatic ecosystem with UMSA as main author on at least half of them.
- Formatted data sets will be delivered on the Geovisor in year 1, 2, 3 and 4 of the project, documenting year 0, 1, 2 and 3 of measurements (data set submitted year N for observations of Year N-1)

3- Short and long term strategy to reduce anthropogenic emissions to the Lake: phytoremediation

Bolivia suffers of **water quality and treatment management** of the aquatic resources. Although a waste water treatment plant is currently treating ~ 30% of waste water from El Alto city, its efficiency has been shown to be weak leading to major releases of waste water flowing in the Katari River, directly in the small basin of lake Titicaca in Bahia Cohana (Archundia et al., 2017; Guédron et al., 2017). The major eutrophication event of 2015, which lead to dramatic biota death, has warned the Bolivian governance that organized a consultancy implying national and international organization to elect and identify conventional and alternatives methods to reduce anthropogenic wastewater discharges to the Lake. From this consultancy, the Bolivian government and international organization (i.e., BID, UN (PNUD, GEF) and AFD) free up more than 77 M$ into a large plan for the construction of new waste water treatment plants (WWTP). Besides this major WWTP funding, several alternatives have been selected to provide small scale or temporary solution to limit emissions i) during the WWTP setup period and ii) from remote sources (e.g., small cities or villages bordering the Lake unequipped with WWTP facilities).
Amongst these propositions, our project "**Bioremediacion de las zonas de Huatajata y Bahía cohana del Lago Titicaca y revalorizacion cultural economica de la totora**" was selected and funded (P.I.s D. Acha, and S. Guédron). This project was built based on the results of previous studies on the natural treatment of the water occurring in the Cohana Bay (Eutiticaca projects, D. Acha and PhytoBol project, P.I. G. Sarret).
The particularity of the shallow Cohana Bay (mean depth 1.5 m) relies on the high density of sedge (*Schoenoplectus totoras ssp.*), which covers the entire Bay (~ 15 km long). Totora's stems act as a support for the growing of periphyton (ensemble of bacteria and algae forming a biofilm on the stems) which as a great capacity to trap nutrients and a large range of contaminants. Preliminary results highlighted major decreases of DOC and metals (including mercury – Fig. 4) with increasing distance to the anthropogenic source (e.g., Katari River). In parallel, the change in $\delta^{15}N$ and $\delta^{13}C$ isotope signatures with distance to the Katari River allowed tracing both the trapping and dilution of anthropogenic emissions along the bay (Fig. 4).

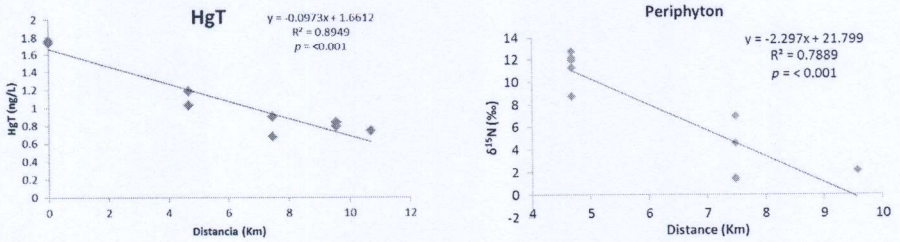

Figure 4 : Decrease of mercury (THg) concentrations in water (left panel) and change of nitrogen isotopic signature ($\delta^{15}N$) of periphyton (right panel) from urban impacted (high $\delta^{15}N$ values) to pristine (low $\delta^{15}N$ values) with increasing distance to the entrance of the Katari (km 0) into the Cohana Bay.

From these results, we designed a phytoremediation system using native macrophytes (totoras) to provide pilot small scale waste water treatment plants which will be deployed in two areas; i) in the downstream part of the Katari watershed and ii) on the shores of lake Titicaca to treat wastewater from the Huatajata village. The development of such alternatives or phytoremediation strategy do not pretend to replace conventional WWTP system but is developed as a low cost - buffering system to lower the fluxes of nutrients and contaminant from urban areas to the lake.
Such strategy is particularly important for nutrients as phosphorus and nitrogen which are known to promote algal development and toxic metals and metalloids such as Hg and As.

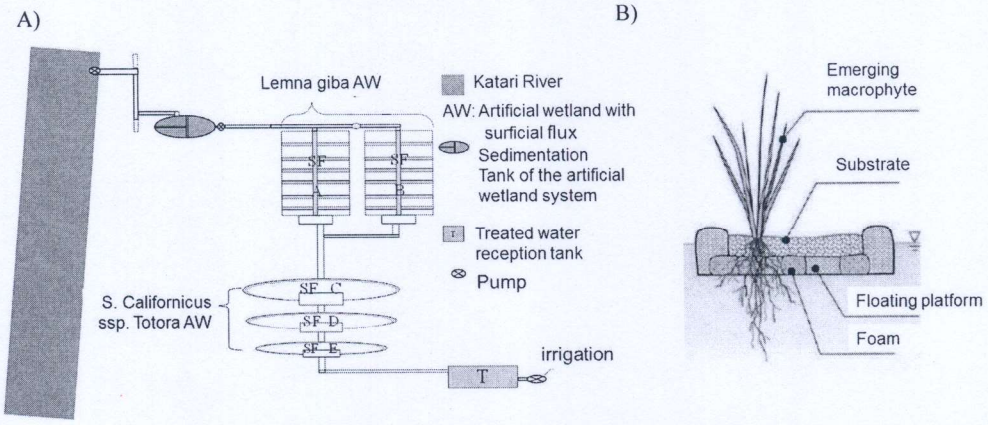

Figure 5: Scheme of A) totoras artificial wetland to treat wastewater from the Katari river and B) of the floating macrophytes treatment system

The resulting extracted plant will then be valorized through paper making or artisanal products (chairs, boats, handicrafts...) which are a major touristic commercial product of the region.

The major challenge of these pilot sites relies on the:
• **Identification of the major sinking mechanisms** of the root and totora's stem/periphyton system in relation to source type. For example, the incorporation of nutrients and contaminants in periphyton cells will be quantified by using incubation techniques (e.g., multi-contaminants spiking coupled with desorption with EDTA at the end of the incubation to quantify the sorbed vs internalized contaminant proportions).

• **Study of their fate once incorporated in the receiving compartment** (e.g., periphyton and /or sediment matrix). Both Cohana bay periphyton and /or sediment matrix will be compared to those of the pilots remediation sites installed

in Katari and Huatajata for our knowledge of the incorporation mechanisms (e.g., organic and inorganic solid phase speciation to evaluate the stability of neoformed phases), but also to validate past and present emission inventories (through sediment core reconstruction of elemental accumulation rates), and to test the validity of our hypothesis of sequestration. The coupling of chemical speciation with EXAFS spectroscopy of periphyton will bring new lights on the speciation and distribution of contaminants in the biological compartments of the periphyton and the sediment matrix. In particular, this information will allow estimating the potential detoxification/sequestration mechanism vs availability of the contaminants.
Functional and taxonomic diversity of algae and bacteria in the periphyton will be studied to understand the different processes that may explain the fate of contaminants as well as the production of other contaminants such as H2S. The health and growth rates of Totora will also be evaluated under submerged and floating conditions to estimate nutrient consumption and the effect of periphyton abundance and composition on Totora development. At the same time we will evaluate changes in algae composition and distribution associated to physicochemical conditions at high resolution levels as well as their response to eutrophication. Such response will be evaluated both in periphyton and phytoplankton. Finally, changes in macroinvertebrate community will be evaluated as a function of euthrophication as a proxy to evaluate the global ecosystem impact of eutrophication and phytoremediation process.
In the case of Lake Titicaca, TITICACA will benefit from a 5 to 8-year continuous record in 2022. This will be sufficient if clear trends are characterizing the site. In this context, we will document:
• Trends in dissolved and particulate elemental concentrations (inlet vs outlet of the pilot system) and comparison with Cohana bay
• Trends in concentrations in the sediment compartment including solid phase speciation to estimate the stability of the encountered neoformed phases.
• Fate of contaminants in the recovered totoras and periphyton after each year of operating pilot systems and ability to recycle and/or transform collected organic materials (e.g., paper fabrication, artisanal objects...).

Deliverable: TITICACA will publish in the last year of the project, 2 papers in international peer-reviewed journal documenting trends of nutrients and contaminants properties in the consortium periphyton-plant-sediment with UMSA as main author on at least one of them.

4- Financial request for responding to scientific objectives:

Maintaining the operation at Lake Titicaca sites is expensive. It is estimated that overall cost (consumable and personal) is approximately 10 k€/year. In addition, calibration and maintenance of instrumentation will require additional costs of approximately 1 to 2 k€/yr. TITICACA request a small fraction of the overall costs to pay for 1) consumables (~4 k€/yr), 2) small equipment (0.7 k€/yr) and field work (1.0 k€ x 3 yr)

5- Expected results

- A series of publication on the origin, mechanisms and impact of eutrophication on the ecology and biogeochemistry of Lake Titicaca and on the new developments of phytoremediation using endemic species published in international peer-reviewed journals
- 4-year of Titicaca and associated watersheds quality-controlled data set formatted and transferred online
- A larger pool of IE-IIQ/UMSA permanent and non-permanent personal trained to performed scientific analysis
- The recognition of the IE school in Biogeochemistry as a key South American player in the field and the development of a MS program at UMSA to support attractiveness of the research team and to extend the program to the Peruvian side (see details in the following section).
- A report on sustainability of the TITICACA activities including scientific, financial and human aspects describing the 5-10 year strategy of the Titicaca project.

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2. Description of the team *(7 pages maximum, font 10)*

■ Team composition

The team will bring out the adequacy of the team members with its objectives. The team will also describe the strategic objectives of its home institution(s) and how the project ties into national or regional research priorities.

The team has been working in a very close and strong collaboration since 2011 when the first draft of the INSU/EC2CO COMIBOL project (P.I. D. Point) proposal for creating a research project at Lakes Uru-Uru and Poopo was written. After its approval and its implementation, the team enlarged the area of investigation and began working towards the implementation of the first monitoring probes through the Titicaca Sensors project (P.Is. D. Point , X. Lazzaro & A. Groleau) and through punctual field campaigns to set up the first bio-geochemical and ecological data set.

In 2011 the IE team, in close collaboration with French partners, began working towards the establishment of a biogeochemistry observatory in Lakes of the Altiplano (i.e., Lakes Titicaca and Uru-Uru). A proposal was submitted and funded by the ANR in 2012 (ANR LA PACHAMAMA, PI: D. Amouroux). At the same time, UMSA with his partner IRD-GET (D. Point) got funded new instrumentation including the Merx system for MeHg analysis and an HPLC which allowed to process almost all the generated samples during the Pachamama project to be analyzed in Bolivia. These new bought or lend instruments have been working continuously among the cited programs. These equipment were all installed at the Huatajata station during field campaigns of month duration (La Pachamama project 3 field campaigns):

- To characterize mercury speciation with respect to seasonal variability, source, biota interaction and anthropogenic influence.
- To characterize biogeochemical mechanisms and processes involved in Hg methylation
- To study benthic exchanges at the sediment/water interface.

These objectives are in line with IE goals: to study (micro-)biological and geochemical cycling of (in)organic contaminants with scientific rigor and then transfer these results to the society.

In the short-term, the team intends to consolidate the research structure of the Titicaca stations whereas in the mid-term, the team expects to generate an academic program at graduate level in bio-geochemistry at UMSA. During the last three years the team, as part of a scientific consortium, has worked in capacity building by training IE/IIQ/IBMB personnel both locally and abroad through different projects (i.e., Tracisomer, Katari, la Pachamama, PaleoBol…). Finally, in the long-term the maintenance of the monitoring sensor-platform is fundamental to provide continuous biogeochemical information to groups working in validating numerical models as well as studying possible effects of climate change on the region.
It is important to mention that the implementation of the previous Titicaca Sensor station meant a qualitative leap in the activities led by the IE and IRD/BOREA, challenging the ability of the team to adapt rapidly to a sudden positive growing. Until now we have succeeded on the endeavor but support and exchange of experiences will be fundamental to adequately plan next steps and future growth.

As previously mentioned in details in the section « Cohérence de l'équipe au vu de la problématique scientifique et complémentarité de ses membres » the 3 members of the team will bring complementary knowledge and methodology to response to the scientific and teaching objectives of TITICACA. As mentioned in the complete scientific program, the objectives of the TITICACA project and team respond to the key issues highlighted by both governmental (e.g., MMAyA) and international (e.g., PNUD, GEF) institutions for the preservation of water resources and biodiversity in the Andean Altiplano. Briefly, the 3 members of the TITICACA team (IE/IIQ/IBMB) will adequately combine their knowledge in ecology, microbiology and biogeochemistry of organic and inorganic contaminants to provide integrated datasets that will allow answering the overarching scientific objectives and give a complete "bio-geoscience" approach in the Master courses and future doctoral courses.

IE/IIQ/IBMB plays a major role in the knowledge transfer of the UMSA since they are implied in most of the Licence and Master degree teaching in ecology, geochemistry and microbiology. These young researchers bring new light in modern research at the UMSA since they are all PhD graduated (the highest common degree at the UMSA is Licence degree) and are very active in regional research projects management. For example, IIQ manages most of the contamination programs in the Titicaca upstream watersheds (e.g., IDH programs Milluni and Katari) and IE is leader in the receptacle compartment (i.e. Lake Titicaca – Lago Menor; IDH program EUTITICACA, LATICO2 and PIA-ACC UMSA20 project of eutrophication and phytoremediation, ECERP binational whole-lake monitoring program). The high and modern scientific level of these projects is becoming recognized at the international level

through their scientific publications (Acha et al., 2017; Alanoca et al., 2016a; Alanoca et al., 2016b; Ramos Ramos et al., 2012) and the involvement of Northern countries partners (e.g., IRD, KTH...) in their own research programs.

The 3 members of the team have and will continue sharing their knowledge and scientific tools developed in the above mentioned previous scientific programs. IE members (e.g., D Acha and C Molina) will lead the following (data management and online production) and maintenance of the probe platform and phytoremediation pilot sites. In parallel to the data production obtained with the probe platform, regular and punctual field campaign will allow the monitoring of algal and microbial communities and biomarkers (e.g., pigments and biota byproducts such as hydrogen sulfides). Both the IIQ (M.Ormachea, O. Ramos-Ramos and L. Alanoca) IBMB (I.Morales) partners will be involved in such field campaigns through the chemical survey of both metal(loids) speciation and nutrient at the reference sites in Lake Titicaca. The combination of such data set will allow bringing an integrated view of the process and mechanisms implied in major changes of lake bio-geochemistry. In addition, the comparison of both probe and chemistry dataset will allow inter-calibrating specific parameters obtained by both tools.

▪ **Presentation of the team's activities**

In addition to the research activities described above (see 1), the team will present the strategy and the planned activities in terms of capacity-building, scientific facilitation, knowledge sharing and transfer of technology. The team will explain how the implementation of these different activities will help structure the team and strengthen it.

There is a growing need in **cross-disciplinary research and education from the theoretical to the technical approach**. Inside the main scientific objectives the team wants to create an interactive dynamic with the new transdisciplinary educational program to directly involve students in the running modern research. The common strategy is to federate and facilitate exchange of ideas in the team around a pool of students involved in specific topics which will allow the implementation of new knowledge in direct interaction with other students and researcher involved in the project.

The team also plans to intensify capacity building by bringing more experts from Europe and the American continent to La Paz. In addition, it plans to organize a series of seminars given by recognized scientists. Under this option, more people, mainly young scientists, will be able to be trained and interact with recognized scientists from different parts of the world. This will also serve as a way to facilitate exchange of ideas and plan join collaboration in terms of data analysis and new experiments to be performed in Bolivia. Given the strategic location of Bolivia, all this training could be easily shared with colleagues in neighbor countries like Peru, Chile, Argentina and Brazil. Recent discussions between neighboring countries during a workshop session of the International colloquium on current and ancient contamination in Andes aquatic ecosystems hold in May 2016 in La Paz have initiated projects of educational and research exchanges between these institutions.
Even further, the fact that the IE/IIQ/IBMB is part of Universidad Mayor de San Andrés, the largest public university in Bolivia, guarantees the transfer of technology to young scientists and by training students (as research assistants for instance) formally, through courses, or informally by working directly on the station or in field research.
For the future, and within the framework of JEAI, we intend to consolidate the functioning of the stations, send some students to Europe and Northern America for studying at graduate level (masters and doctorates). We expect that creating a relatively large pool of geoscientists and ecologists around the TITICACA team and project will help continue running the station and complying with the high standards applied today. The continuity of international collaboration is a key factor to pursue this goal.
As a result of this JEAI, our team expects to have a critical mass in terms of scientists ready to work at the required level. New and novel scientific data and publications, produced in Bolivia but used by scientists of the Latin America (and other regions) will become available for the international scientific community.

A need for development in master and to build a doctoral school

The recent acceptance of a new and free interdisciplinary Master (PI Dario Acha) centered on biology which started in 2018 is a great opportunity for both partners to build capacity in modern research including all the approaches of our research program. This new master is built on the international format of Master with a duration of two years (the current version last for 4 to 6 years) including a research period of more than a year. The Master will be validated with (i) 39 credits of courses and seminars and (ii) the acceptance of a peer-reviewed paper. Such format of master is appropriated for punctual involvement of the IRD partner in the courses (including field courses) and seminars which can be centered over the period of a MLD or short mission. Several interventions are already planned on specific topic including (i) Tools and methodology to build a scientific project and write a scientific publication, (ii) biomonitoring and biogeochemistry of metals in aquatic and terrestrial environments (iii) benthic and pelagic ecology and (iv) use of ecological and biological proxies for paleo-environmental studies.

In parallel, summer schools are organized since 2016 on geophysics tools to study and manage aquifers around the Lake, the main drinking water resources in the Northen Altiplano. The input of biogeochemical monitoring tools are underachievement in such summer school which will be a great plus-value to the existing programs.

Beside this very promising new Master, there is a real need in **building capacity for PhD**. Up-to-date, all PhD students are formed in Northern countries (i.e., France, Canada and Norway).
The continuity of such partnership involvement is the building of a doctoral school in the UMSA - La Paz on a multidisciplinary geoscience format including all the careers (i.e., chemistry, ecology, biology, atmospheric sciences, hydrology…). Such construction is currently under discussion. Dario: any news !??? It is now a faculty project that should be running some time 2019 or at most early 2020.
Do we add a section on the implication of the UGA (Université Grenoble Alpes) in this doctoral school construction ? + The IRD??

Finally, the objective is to open such building capacity to the neighboring Peru universities to build a cross-border common program at the entire watershed level that includes Peru. Previous discussion and exchanges with Cusco and Lima universities gave promising willpower for an involvement in such cross-border program.

The overarching objectives are:
• To maintain provision of unique data sets to the scientific community for biogeochemical and ecological functioning of Lake Titicaca to reach a model validation
• To maintain and further develop the scientific capacity of IE IIQ and IBMB personnel to exploit these data in a wide context, including modelling activities
• To develop a recognized excellence in the field supported by a university graduate degree program

Financial request for responding to overarching objectives
Two main topic require financial supports:
1) Participation of UMSA personal to data management training courses organized by IRD/IE in both Europe and Bolivia
2) To maintain and further develop the scientific capacity of IE/IBMB/IIQ-UMSA personnel to exploit physico-chemical and sensor data in a wide context, including modelling activities (capacity building at individual level).
Community capacity-building on an individual level requires the development of conditions that allow individual participants to build and enhance knowledge, skills and tools. TITICACA will contribute to the establishment of the proper conditions that will allow IE/IIQ-UMSA personal to consolidate the existing scientific background. This strategy applies to both IE/IIQ-UMSA permanent personal and IE/IIQ-UMSA non-permanent personal including students. Clearly, a fundamental requisite for maintaining and developing scientific capacity is the presence of highly-skilled personnel that can operate instruments, analyze results, and identify problems and network with other scientists worldwide. In the framework of the current project, our objective is to contribute to a necessary level of technology transfer and capacity building to ensure sustainability of measurements at sensor station and laboratories, at least in the medium term (5-years beyond the end of this project). It is important that IE/IIQ-UMSA scientists maintain the capacity to perform data handling, analysis and use multi-sensor and station and laboratories in an independent manner.
Action to support this overarching objective will be:
• Training sessions of IE/IBMB/IIQ-UMSA personal at ISTerre, IGE, GET and BOREA. This has been initiated since 2011. Long-term training sessions at host institution will permit to develop strong partnership at individual level between Bolivian and French scientists.
• Participation of IE/IBMB/IIQ-UMSA personnel to basic and advanced courses organized by IRD/ISTerre/IGE in advanced chemistry (analytical chemistry and physical chemistry (e.g., synchrotron)) and data analysis
• Organization of workshop and courses in Bolivia such as those organized in 2015 and 2016 (i.e., International colloquium on current and ancient contamination in Andes aquatic ecosystems, 2016, Universidad Major de San Andrès – La Paz (Bolivia); Establishing a strategy for an environmental study, sampling , dissemination and exploitation of results for a peer-review international publication; basics in soil and water physics and chemistry (courses in English, IIQ, 2015/2016, Stéphane Guédron & Céline Duwig)
It is estimated that overall cost for these scientific building capacities operation will be approximately 5 k€/year.

Deliverable: participation of IE/IBMB/IIQ-UMSA permanent and non-permanent personal to training sessions, workshop and courses organized in France and Europe. Organization of 1 specific international workshop in Bolivia opened to the whole IE/IBMB/IIQ-UMSA team.

Financial request for responding to overarching objectives 2: participation of IE/IBMB/IIQ-UMSA personal to training courses organized by IRD/ISTerre/IGE/GET/BOREA and French partners in France and Europe. We consider 4 participation to Maestria courses and workshops (4x 2.5 k€) for the duration of the project. In addition some financial support for organizing two training workshops or summer schools in La Paz is requested (1.5 k€ x 2 yr) for the coupling of geophysical and biogeochemistry in a summer school on the Katari watershed and Cohana Bay co-organized by the IGE/ISTerre partner.

3) To develop a recognized excellence in the field supported by a university graduate degree program (capacity building at Institutional level)
Community capacity building on an institutional level is a necessary step to maintain and further develop the expertise of IE/IBMB/IIQ-UMSA, attracting students beyond the normal recruitment area of La Paz. MS programs in applied biogeoscience (including geochemistry) are uncommon in South/Latin America. There is a need to offer a cost-effective alternative to European/US university programs.
Partnership in the development of the new MS program (Maestria de Biologia) will be pursued with support of the international community developing in the first years the concept of applied field courses as optional courses to student enrolled in the Biology and Chemistry department. The goal of TITICACA on this respect is to participate in the design, improvement and development of new fields for the scientific program of the new MS initiated at the UMSA in the strategy of implementation (following university objectives and regulation) and prepare a formal proposal for its final implementation. In this sense, it should be kept in mind that decision to open the course remains beyond the control of this project. The steps to accomplish this objective are:
• Design an academic program based on current needs in Biogeochemistry. Discussion with other well established programs around the world will be used to guarantee integrity of the program but a careful analysis of conditions within the Latin-American region will be an important part of the analysis. By understanding strengths and weaknesses of similar programs under similar conditions the likelihood of success will be clearly improved.
The final objective would be to build a cross-border program with Peruvian universities that are also affected by this issue.

Different options should be taken into account considering possible limitations on the implementation phase.
• Once the academic program is in place TITICACA will work in close collaboration with the Department of Biology and Chemistry in the strategy of implementation of the program, possible limitations in terms of bureaucratic requirements and ways to increase the visibility and access to this program outside La Paz region. The legal requirements and regulations will be an important part of the process but also the accommodation of the undergraduate physics curriculum to the new graduate program should be part of the proposal.
• Finally a formal proposal to build a doctoral school that carefully takes the academic program, the strategy designed previously and the general legal framework at UMSA, will be prepared for submission by the Department of Biology and Chemistry to higher levels of academic governance. In this part we are asking for formal support through a professional expert in higher education and, especially, with experience in preparing academic programs like the one proposed here. This question was raised with the UGA directorship during their recent visit in La Paz (18-25.06.2017) and resulted in a support of the UGA directorship for student exchanges between UMSA and UGA which will be effective in 2018 through the funding of UGA grants (Labex@international) for Bolivian master students in 2018.

Deliverable: a proposal with organizational structures, and effective method of management and even control to UMSA to develop a MS and PhD program in Environmental Biogeochemistry.
Financial request for responding to overarching objectives 3: modernization of the videoconference system (including larger-bandwidth internet connection) at IE/IIQ-UMSA to open remote-sessions (2 k€/yr) and a consultant to help TITICACA to finish the academic proposal for UMSA (1 k€).

■ Team's assets and weaknesses analysis
The team will analyse the team's assets and weaknesses and describe the strategy the team will implement to develop its outcomes and makes up for its weaknesses. The team will specify its needs in terms of capacity-building.

Assets:

- A strong group of local scientists is already in place. The team has shown its capabilities by running the preliminary Titicaca Sensors station for more than four years almost uninterruptedly. This implied learning at a rapid pace about new instruments and procedures related to data QA/QC as well as data management.
- Proven ability to work in good coordination and interact with different scientific groups abroad.
- Strong support from the Institute of Ecology (IE), Aquatic geochemistry (IIQ) and microbiology (IBMB) of the UMSA: salaries for all permanent personnel are covered by the university.

- Great capacity and complementarity in terms of knowledge and analytical devices (chemistry labs and probes) in the 3 labs

Weakness:

- After more than 10 years of presence of IRD partners (i.e., expatriation of Marc Roulet, David Point, C. Duwig, Xavier Lazzaro and Stéphane Guédron) who participated in the setting of the analytical devices no short term perspectives of expatriation for an IRD partner.
- Lack of trained technical staff employed in the long term (Short term contracts by UMSA).
- Lack of new professor-researcher recruitment at UMSA
- UMSA does not provide funds for expendables (except very simple things).
- UMSA does not provide funds for scientific or training exchange (i.e. international meetings abroad)
- There are no schools in geosciences in any university in Bolivia.

■ **Team's publications** *(common publications to at least team members)*

- **Accepted publications :**

S. Bouchet, M. Goñi-Urriza, M. Monperrus, R. Guyonneaud, P. Fernandez, **C. Heredia**, E. Tessier, C. Gassie, **D. Point,**, **S. Guédron, D. Achá**, **D. Amouroux**, 2018. Linking microbial activities and low molecular weight thiols to Hg methylation in biofilms and periphytons from high altitude tropical lakes (Bolivian altiplano). Environmental Science and Technology, (2018), in press.
S. Guédron, D. Point, D. Acha, S. Bouchet, A. Baya, **C. Molina**, E. Tessier, M. Monperrus, **M. Flores, P. Fernandez** Saavedra, **M.E. Ezpinoza, C. Heredia, F. Rocha**, A. Groleau, E. Amice, **J. Yupanqui, L. Alanoca, C. Duwig, G. Uzu, X. Lazzaro**, A. Bertrand, C. Barbaud, F.M. Gibon, C. Ibanez, C. Zepita, L. Chauvaud, D. Amouroux; Mercury contamination level and speciation inventory in the hydrosystem of Lake Titicaca: current status and future trends. Environmental Pollution, (2017), 231, 262-270.
W.G. Lanza, D. Acha, D. Point, J. Masbou, **L. Alanoca**, D. Amouroux, **X. Lazzaro**; Association of specific algal groups to methylmercury accumulation in periphyton of a tropical high-altitude Andean Lake. Archives of Environmental Contamination and Toxicology (2017), 72(1), 1-10.
Molina C.I., Lazzaro, X., Guédron, S., & Achá D.. Contaminación de la bahía de Cohana, Lago Titicaca: desafíos y oportunidades para promover su recuperación. (2017). Editorial letter of Revista Ecología en Bolivia (www.ecologiaenbolivia.com).
Archundia D., **Duwig C., Spadini L., Uzu G., Guédron S., Morel M.C.**, Cortez R., **Ramos Ramos O., Chincheros J., and Martins J.M.F.**, 2017. How uncontrolled urban expansion increases the contamination of the Titicaca lake basin (El Alto - La Paz, Bolivia). Water, Air and Soil Pollution, 228:44.
L. Alanoca, D. Amouroux, M. Monperrus, E. Tessier, M. Goni, R. Guyoneaud, **D. Acha**, C. Gassie, S. Audry, **M. Garcia**, **J. Quintanilla, D. Point**; Diurnal variability and biogeochemical reactivity of mercury species in an extreme high altitude lake ecosystem of the Bolivian Altiplano. Environmental Science and Pollution Research (2016), 23, 6919-6933.
L. Alanoca, S. Guédron, D. Amouroux, S. Audry, M. Monperrus, E. Tessier, S. Goix, **D. Acha**, **P. Seyler, D. Point**. Synergistic effects of mining and urban effluents on the level and distribution of methylmercury in a shallow aquatic ecosystem of the Bolivian Altiplano. Environmental Science: Processes and Impact (2016), 18, 1550–1560.
Schreck E., **Sarret G.**, Oliva P., Calas A., Sobanska S., **Guédron S.**, Barraza F., **Point D.**, Huayta C., Couture R.M., Prunier J., Henry M., Tisserand D., Goix S., **Chincheros J.**, Uzu G., 2016. Is Tillandsia capillaris an efficient bioindicator of atmospheric metal and metalloid deposition? Insights from five months of monitoring in an urban mining area, Ecological Indic., 67: 227-237.

- **In prep. publications :**

D. Achá, S. Guédron, D. Amouroux, **D. Point, X. Lazzaro**, **P. Fernandez and Sarret G**. Algae bloom exacerbates methylmercury and hydrogen sulfide contamination at an emblematic high altitude lake (Titicaca). En Préparation.
P. A. Baya, **D. Point, S. Guédron**, E. Tessier, **D. Acha, X. Lazzaro**, M. Monperrus, D Amouroux et al. Spatio temporal distribution and biogeochemistry of mercury compounds in Lake Titicaca. En Préparation.
Point, D., Baya, A., Molina, C., Masbou, J., Bouchet, S., Amouroux, D., Lorrain, A., **Lazzaro, X., Ibanez, C., Acha, D.**, Bertrand, S., Bertrand, A., Barbaud, C., Delord, K. Comparison of Hg concentration, speciation and stable isotopic composition in the food webs of lake Titicaca and lake Uru-Uru from the Bolivian Altiplano region. En Préparation.
S. Guédron, S. Audry, D. Acha, **C. Heredia**, I. **Quino Lima, S**. Bouchet, A. Groleau, E. Amice, T. Condom, D. Point and D. Amouroux. Methylmercury production during early diagenesis processes in sulfate rich sediment of Lake Titicaca (Bolivia): contribution to surface water levels. En Préparation.

- **Ouvrages ou chapitres d'ouvrage**

Pouilly M., **Lazzaro X., Point D**. & Aguirre M. (2014) Línea base de conocimientos sobre los recursos hidrológicos e hidrobiológicos en el sistema TDPS con enfoque en la cuenca del Lago Titicaca. IRD, IUCN, Quito, 320 p. ISBN: 978-99974-41-84-3. https://portals.iucn.org/library/node/44673.
Guédron S. (ed.), **Acha D.** (ed.), Vella M.A. (ed.), and **Ramos Ramos O.E.** (ed.), 2016. International colloquium on current and ancient contamination in Andes aquatic ecosystems = Coloquio internacional sobre la contaminación actual y histórica en los ecosistemas acuáticos Andinos = Colloque international sur la contamination actuelle et historique des écosystèmes aquatiques andins. Proceedings. Universidad Mayor de San Andrés, La Paz (Bolivia), 03-05 May 2016, 44 p. http://www.documentation.ird.fr/hor/fdi:010067481

- **Conference Acta (46)**

Duwig C., Archundia D., Uzu G., **Guédron S., Ramos Ramos O.**, 2018: Consecuencias de la fuerte antropización en los recursos hídricos de la cuenca Katari. Coloquio internacional en el marco de los 50 años del IRD en Bolivia: "Vulnerabilidad de los recursos hídricos en la cuenca Katari", UMSA, La Paz, March 28, 2018.

Ormachea M., Alanoca L., Huallpara L. and **Guédron S.**. Efectos de la actividad minera sobre el sistema hídrico de Milluni. Coloquio: "Vulnerabilidad de los recursos de agua en la subcuenca Katari del Lago Titicaca (Altiplano Norte, Bolivia)", 28-29 Marzo 2018, UMSA, La Paz Bolivia.

S. Guédron, S. Audry, **D. Acha, C. Heredia**, S. Bouchet, **D. Point**, J. Thébault, L. Chauvaud and D. Amouroux. Methylmercury production in surface sediments and exchanges with overlying water of Lake Titicaca (Bolivia). 13th International Conference on Mercury as a Global Pollutant – Providence, Rhode Island, July 16-21, 2017.

D. Acha. S. Guédron, D. Point, D. Amouroux, P. Fernandez, S. Bouchet and **X. Lazzaro**. Eutrophication and algae blooms may have similar effects on methylmercury accumulation at high altitude sulfate-rich environments. 13th International Conference on Mercury as a Global Pollutant – Providence, Rhode Island, July 16-21, 2017.

S. Bouchet, D. Amouroux, M. Goni, M. Monperrus, R. Guyoneaud, **C. Heredia**, E. Tessier, **D. Point, S. Guédron and D. Acha**. Linking microbial activity and Hg bioavailability to Hg methylation in Lake Titicaca hydrosystem (Bolivian Altiplano). 13th International Conference on Mercury as a Global Pollutant – Providence, Rhode Island, July 16-21, 2017.

L. Alanoca, S. Guédron , M. Monperrus, D. Amouroux, E. Tessier, P. Seyler, M. Goni, R. Guyoneaud, **D. Acha** , S. Audry, M. E. Garcia, **J. Quintanilla and D. Point**. Biogeoquímica del mercurio en el lago tropical de altura Uru Uru (Altiplano boliviano). International colloquium on current and ancient contamination in Andes aquatic ecosystems, La Paz – May 3– 5, 2016, pp: 11.

D. Amouroux, **D. Point, S. Guédron, D. Acha, X Lazzaro**, L. Chauvaud, S. Bouchet, A. Baya, M. Monperrus, E. Tessier, R. Guyoneaud, M. Goni, J. Thebault, A. Groleau, A. Lorrain, E. Amice, T. Lebec, S. Rocha, C. Heredia, M-E. Espinoza, M. Flores & R. Katari. Processes controlling Methyl-Hg formation and degradation in Lake Titicaca hydrosystem (Bolivian Altiplano). International colloquium on current and ancient contamination in Andes aquatic ecosystems, La Paz – May 3– 5, 2016, pp: 12.

S. Guédron, S. Audry, **D. Acha** & D. Amouroux. Methylmercury production and exchanges in sediments of Lake Titicaca. International colloquium on current and ancient contamination in Andes aquatic ecosystems, La Paz – May 3– 5, 2016, pp: 13.

D. Achá Cordero, C. Heredia, P. Fernandez, M-E. Espinosa, D. Point, S. Guédron, A. Groleau, D. Amouroux, J. Nuñez, G. Lora and **X. Lazzaro**. New lights on Lake Titicaca eutrophication process and perspectives about monitoring and remediation. International colloquium on current and ancient contamination in Andes aquatic ecosystems, La Paz – May 3– 5, 2016, pp: 16.

X. Lazzaro, H. Rybarczyk, T. Meziane, C. Hubas, D. Lamy,**D. Point**, J.M. Martine, **S. Guédron, C. Duwig**, A. Groleau, S. Rocha Lupa, M.P. Alcoreza Ortiz, W.G. Lanza Aguiar, A.J. Flores, E.Z. Loyza Torrico, C. Ibañez Luna, J. Nuñez Villalba, C. Gamarra Peralta, C. Villanueva Quispe, L. La Cruz, V. Villafañe, W. Helbling, A. Lebourges-Dhaussy, J. Guillard, I. Domaizon, C. Kruk, N. Mazzeo, M. Meerhoff, M. Pereira Sandoval, J. Delegido, A. Ruiz, J. Moreno, C. Molina Arzabe & **D. Achá** Cordero. Accelerated eutrophication in Lake Titicaca: Historical evolution, mechanisms, monitoring, and observatory approach. International colloquium on current and ancient contamination in Andes aquatic ecosystems, La Paz – May 3– 5, 2016, pp: 22-23.

Amouroux, D., **Point D., Guédron, S., Acha D., Lazzaro X.**, Chauvaud L., Bouchet S., Baya L., Monperrus M., Tessier E., Guyoneaud R., Goni M., Thebault J., Groleau A., Lorrain A., Amice E., Lebec T., Rocha S., Heredia C., Espinoza M-E., Flores M., and Katari R. In situ exploration of processes controlling Hg biogeochemistry in Lake Titicaca hydrosystem (Bolivian Altiplano), oral presentation. International Conference on Mercury as a Global Pollutant- Jeju, Corea (06.2015).

Amouroux, D., **Point D., Guédron, S., Acha, D., Lazzaro, X.**, Chauvaud, L., Bouchet, S., Baya, A., Monperrus, M., Tessier, E., Guyoneaud, R., Goni, M., Thebault, J., Groleau, A., Lorrain, A., Amice, E., Lebec, T., Rocha, S., Heredia, C., Espinosa, M. E., Flores, M., Katari, R., 2014. In situ exploration of processes controlling Hg biogeochemistry in Lake Titicaca hydrosystem (Bolivian Altiplano). 24e Réunion des Sciences de la Terre – Pau, France (10.2014).

Baya, P. A., **Point, D., Guédron S., Lazzaro, X., Espinoza. M. E.,** Amouroux D., Chauvaud, L., Amice, E., Thebault J., LeBec T., **Acha. D.**, 2014. Distribution and sources of methylmercury (MeHg) in high altitude lakes ecosystems: The Lake Titicaca case study. 24e Réunion des Sciences de la Terre – Pau, France (10.2014).

3. **Team members** *(add as many rows as needed)*

a. **Summary table**

Permanent team members

Last/First name	Position in the team (leader, correspondent, member)	Location (Town, Country)	Higher degree (date)	Institution/Employer	Scientific discipline	Status (researcher, engineer, technician, post doc, PhD student, other : to be specified)	Work time dedicated to the JEAI during 3 years (%)
Acha Dario	responsable	La Paz (Bolivie)	PhD, 2009	Instituto de Ecologia, UMSA (Universidad Mayor de San Andrés)	Microbiologie et biogéochimie	Professeur	80 %
Molina Carlos	Membre	La Paz (Bolivie)	PhD, 2010	Instituto de Ecologia, UMSA	Ecologie benthique	Assistant Professeur	30 %
Morales Isabelle	Membre	La Paz (Bolivie)	PhD, 2003	Instituto de Biología Molecular y Biotecnología – Carrera de Biología – UMSA	Ecologie	Professeur	20 %
Ormachea Mauricio	Membre	La Paz (Bolivie)	PhD, 2015	Instituto de Investigaciones quimicas, UMSA	Géochimie de l'eau (As)	Assistant Professeur	20 %
Ramos Ramos Oswaldo	Membre	La Paz (Bolivie)	PhD, 2014	Instituto de Investigaciones quimicas, UMSA	Géochimie eau, sols et sédiments	Professeur	20 %
Alanoca Lucia	Membre	La Paz (Bolivie)	PhD, 2016	Instituto de Investigaciones quimicas, UMSA	Géochimie (Hg)	Ingénieur de recherche contractuel	20 %

Non-permanent team members (host researchers, PhD students...)

Nom, Prénom	Fonction au sein de l'équipe (responsable, correspondant, membre)	Localisation géographique (Ville, Pays)	Diplôme acquis le plus élevé (date d'obtention)	Etablissement de rattachement	Discipline scientifique	Statut (chercheur, ingénieur, technicien, post doc, doctorant, autre : à détailler)
Guédron Stéphane	Correspondant	Grenoble (France)	PhD	ISTerre/IRD/UGA	Biogéochimie	CR1 IRD
Sarret Géraldine	Member	Grenoble	PhD, HDR	ISTerre/IRD/CNRS/UGA	Biogéochimie	DR CNRS
Duwig Céline	Member	Grenoble	PhD, HDR	ISTerre/IRD/UGA	Hydrologie/géochimie	CR1 IRD
Bouchet Sylvain	Member	Zurich (CH)	PhD	EAWAG	Géochimie (ligand et métaux)	Post Doctorat
Lazzaro Xavier	Member	Paris	PhD	BOREA/IRD	Limnologie	CR1 IRD
Point David	Member	Toulouse	PhD	GET/IRD	Biogéochimie	CR1 IRD
Anthony Gautier	Member	Toulouse	Engineer	GET/IRD	In situ Hg sensors	Contractor.
Uzu Gaëlle	Member	Grenoble	PhD, HDR	ISTerre/IRD/UGA	Aérologie/géochimie	CR1 IRD
Espinoza Maria-Elena	Member / student	Grenoble/La Paz	Licenciatura 2016	UMSA/ISTerre (M1 UGA 2016/ 2017)	Ecology	Student
Heredia Carlos	Member / student	Grenoble/La Paz	Licenciatura 2016	UMSA/ISTerre (M1 UGA 2017/ 2018)	Geochemistry & ecology	Student
Flores Marizol	Member / student	Grenoble/La Paz	Licenciatura 2016	UMSA/ISTerre (M1 UGA 2017/ 2018)	Hydrogeochemistry	Student
Flores Aviles Gabriela	Member / student	Grenoble/La Paz	Master	PhD Student	Hydrogeochemistry	Student

b. Individual forms *(to be filled by the leader, the correspondent and the other team members*)*

** The other team members for whom an individual form is required are:*
- *Members from developing countries institutions,*
- *Members permanently employed ,*
- *Members involved in the JEAI's activities during the 3-year support period from IRD.*

■ **Team leader** individual form

Title, Last/First name	Dr ACHA Dario
Position	Professeur
Institution/Employer	Instituto de Ecologia
Type (public, private)	Public
Scientific discipline	Biogéochimie de contaminants métalliques, microbiologie et écologie des écosystèmes aquatiques
Research thematic(s)	Microbiologie et biogéochimie des écosystèmes aquatiques d'altitude
Nationality	Bolivien
Work address	Campus de Cota-Cota, UMSA, La Paz Bolivie
Phone number	59122712902
Cell Phone number (not mandatory)	59173746065
E-mail	darioacha@yahoo.ca, dacha@fcpn.edu.bo

■ **Partnership with IRD** *(Support that the team leader has already benefited from IRD)*

Implication in research programs since 2010

■ **Summary of the research career** *(half-page maximum, font 10)*

I obtained my honors degree in Biology at Universidad Mayor de San Andrés (La Paz – Bolivia) in 2004, where I conducted my thesis on microbial involvement on mercury methylation in the periphyton (Acha et al., 2005). During the same year I started my master's degree at Trent University (Canada) which I converted into a Ph.D. in 2006. I obtained my Ph.D at Trent University in 2009. My research was focus on biogeochemistry of mercury, mainly sulfate-reducing bacteria involvement on mercury methylation and demethylation in the periphyton of tropical macrophytes and the water column of boreal lakes. In 2010 I became associate professor at Universidad Mayor de San Andrés and in 2011 I obtained a permanent position as a professor at Universidad Mayor de San Andrés. Since then I became head of Environmental Quality Unit (Unidad de Calidad Ambiental), which includes a lab that provides analytical services. In 2015 I was elected dean of the Biology Department at Universidad Mayor de San Andrés. My research focus is on how the biota influences the geochemistry of contaminants at tropical aquatic environments. I am or have been head of four research projects: 1) EUTITICACA, which studied different approaches to characterize and monitor contamination causing part of the Titicaca lake to become eutrophic. 2) LATICO2, which studied the dominant processes controlling carbon geochemistry in the lake Titicaca. 3) PIA-ACC UMSA20, which is trying to identify bio-indicators of climate change and pollution in sediment profiles of several emblematic lakes in the Bolivian Altiplano region. 4) Bioremediation of Huatajata and Cohana Bay at Lake Titicaca and cultural and ecological re-valorization of Totora. I have also collaborated in several other concluded and ongoing projects, four of which were funded by France. I teach two undergraduate courses at Biology department and I will teach a graduate course in our new Master program starting in 2018.

■ **Major publications** *(half-page maximum, font 10)*

Achá, D. et al., 2018. Algae bloom exacerbates methylmercury and hydrogen sulfide contamination in the emblematic high altitude lake (Titicaca - Bolivia). in prep.
Hsu-Kim, H., Eckley, C.S., **Achá, D.**, Feng, X., Gilmour, C.C., Jonsson, S., Mitchell, C.P.J., 2018. Challenges and opportunities for managing aquatic mercury pollution in altered landscapes. Ambio 47, 141-169.
S. Guédron, D. Point, **D. Acha**, et al. (2017) Mercury contamination level and speciation inventory in Lakes Titicaca & Uru-Uru (Bolivia): current status and future trends. Environmental Pollution, Accepted.
Lanza WG, **Achá D**, Point D, Masbou J, Alanoca L, Amouroux D, Lazzaro X (2017) Association of a Specific Algal Group with Methylmercury Accumulation in Periphyton of a Tropical High-Altitude Andean Lake. Arch Environ Contam Toxicol 72: 1-10

Alanoca L, Amouroux D, Monperrus M, Tessier E, Goni M, Guyoneaud R, **Acha D**, Gassie C, Audry S, Garcia ME, Quintanilla J, Point D (2016) Diurnal variability and biogeochemical reactivity of mercury species in an extreme high-altitude lake ecosystem of the Bolivian Altiplano. Environ Sci Pollut Res 23: 6919-6933
Alanoca L, Guedron S, Amouroux D, Audry S, Monperrus M, Tessier E, Goix S, **Acha D**, Seyler P, Point D (2016) Synergistic effects of mining and urban effluents on the level and distribution of methylmercury in a shallow aquatic ecosystem of the Bolivian Altiplano. Environmental Science: Processes & Impacts 18: 1550-1560
Rivera SJ, Pacheco LF, **Achá D**, Molina CI, Miranda-Chumacero G (2016) Low total mercury in Caiman yacare (Alligatoridae) as compared to carnivorous, and non-carnivorous fish consumed by Amazonian indigenous communities. Environmental Pollution 218: 366-371
Achá D, Pabón CA, Hintelmann H (2012) Mercury methylation and hydrogen sulfide production among unexpected strains isolated from periphyton of two macrophytes of the Amazon. FEMS Microbiol Ecol 80: 637-645
Achá D, Hintelmann H, Pabón CA (2012) Sulfate-reducing Bacteria and Mercury Methylation in the Water Column of the Lake 658 of the Experimental Lake Area. Geomicrobiol J 29: 667-674
Achá, D., Hintelmann, H. and Yee, J., 2011. Importance of sulfate reducing bacteria in mercury methylation and demethylation in periphyton from Bolivian Amazon region. Chemosphere, 82(6): 911-916.
Acha, D. et al., 2005. Sulfate-Reducing Bacteria in Floating Macrophyte Rhizospheres from an Amazonian Floodplain Lake in Bolivia and Their Association with Hg Methylation. Appl. Environ. Microbiol., 71(11): 7531-7535.

■ Recent activities in terms of capacity-building, scientific facilitation, knowledge sharing (participation to symposium, expertise, ...) and transfer of technology (half-page maximum)

Since 2011, I am head of Environmental Quality Unit (Unidad de Calidad Ambiental), which includes a lab that provides analytical services. In 2015 I was elected dean of the Biology Department at Universidad Mayor de San Andrés. I teach two undergraduate courses at Biology department and I will teach a graduate course in our new Master program starting in 2018.

Acha, D.; Guedron, S.; Poin, D., et al. 2017. Eutrophication and algae blooms may have similar effects on methylmercury accumulation at high altitude sulfate-rich environments. 13th International Conference on Mercury as a Global Pollutant. Providence, R.I. USA.
Guedron, S.; Audry, S.; **Acha, D.**, et al. 2017. Methylmercury productiion in surface sediments and exchanges with overlying water of Lake Titicaca (Bolivia). 13th International Conference on Mercury as a Global Pollutant. Providence, R.I. USA.
D Amouroux, D. Point, S. Guédron, **D Acha**, et al. 2016. Processes controlling Methyl-Hg formation and degradation in Lake Titicaca hydrosystem (Bolivian Altiplano). International colloquium on current and ancient contamination in Andes aquatic ecosystems. May. La Paz - Bolivia
S.Guédron, S. Audry, **D. Acha**, D. Amouroux 2016. Methylmercury production and exchanges in sediments of Lake Titicaca. International colloquium on current and ancient contamination in Andes aquatic ecosystems. May. La Paz - Bolivia
L Alanoca, S. Guédron, M Monperrus, D Amouroux, E Tessier, et al. 2016. Biogeoquímica del mercurio en el lago tropical de altura Uru Uru (Altiplano boliviano). International colloquium on current and ancient contamination in Andes aquatic ecosystems. May. La Paz – Bolivia
D. Amouroux, D. Point. S. Guedron, **D. Acha**, et al. 2015. in situ exploration of processes controlling hg biogeochemistry in lake titicaca hydrosystem (bolivian altiplano). 12th International Conference on Mercury as a Global Pollutant. Jeju Korea.
D. Acha, W.G. Lanza, C. A. Piza, D. Point, et al. 2015. factors controlling methylmercury accumulation in river sediments and lake periphyton of a tropical high altitude basin (bolivian altiplano). 12th International Conference on Mercury as a Global Pollutant. Jeju Korea.
S. Bouchet, M. Monperrus, **D. Acha**, C. Heredia, et al. 2015. in situ exploration of the photochemical and biological processes controlling hg biogeochemistry in high altitude bolivian aquatic ecosystems (lake titicaca and uru uru, altiplano). 12th International Conference on Mercury as a Global Pollutant. Jeju Korea.

■ **Correspondent** individual form

Title, Last/First name	Dr Guédron Stéphane
Position	Chargé de recherche
Institution/Employer	IRD
Research unit	ISTerre –UR 219
Position *(Delete as appropriate)*	Chargé de recherche
Scientific discipline	Biogéochimie des contaminants métalliques, reconstitutions paléoenvironnementales
Research thematic(s)	Biogéochimie
Nationality	Français
Work address	Université Grenoble Alpes, ISTerre, CS 40700 38058 GRENOBLE Cedex 9
Phone number	04.76.63.59.28
Cell Phone number (not mandatory)	06.61.777.263
E-mail	stephane.guedron@ird.fr / stephane.guedron@univ-grenoble-alpes.fr

■ **Summary of the research career** *(half-page maximum, font 10)*

I obtained my PhD degree in soil and water geochemistry at University Grenoble Alpes in 2008, where I conducted my thesis on Impact of former goldmining on mercury fluxes towards aquatic ecosystems in French Guiana. I followed by a 3 year assistant professor position at Institute Forel (Geneva University, Switzerland) until 2010. My research was focused on the biogeochemistry of mercury, including mercury methylation and demethylation and accumulation in benthic organism in lakes and on alpine paleo-environmental reconstructions of the Holocene (main Nation Swiss funds research projects (FNRS) as PI: i) Bay of Vidy (Lake Geneva, Switzerland): geochemistry of Hg and MMHg in the water column, sediment porewaters and Hg bioaccumulation in Chironomus Riparius, ii) Venice lagoon (Italy): Bioaccumulation of mercury in benthic invertebrates of the Venice Lagoon and iii) Czorsztyn reservoir (Poland) – Chromium speciation in the waters, colloids and sediments porewaters and iv) Sino-Swiss Joint Research Projects: The Distribution, Methylation, and Bioaccumulation of Mercury in Sediments of Baihua Reservoir in Guiyang, China).
In late 2010 I was hired at the IRD as researcher in the ISTerre laboratory in the University Grenoble Alpes. My current research focuses mainly on surface biogeochemistry of metals and metalloids and on paleo-environmental reconstructions. I am or have been (co)-PI of 5 research projects or workpackages: 1) Mezquital valley project (PI) - Mexican CONACyT program – (IRD - UNAM university, Mexico): Mercury and arsenic transfer and fate in soils irrigated by the waste waters of Mexico city, 2) French Guiana Interconnect ANR program (2011-2015, Co-PI workpackage3) INTERCONNexions between terrestrial and aquatic bioaccumulations of organometalic compounds in food webs, 3) ANR La Patchamama (2013-2016 – PI Task 2) : Lacs de l'Altiplano (Bolivie): exploration des processus (a)biotiques in situ contrôlant la bio-géochimie aquatique du mercure à l'échelle moléculaire et isotopique, 4) PaleoBol (2014 – 2018 - PI) : Reconstitution Paléo-environnemental à l'échelle de l'holocène des changements climatiques et des flux de métaux dans les archives sédimentaires du lac Titicaca (Bolivie) and 5) Labex@osug2020 - Tracisomer (2015 – 2017 - PI) : Traçage isotopique des sources et flux de mercure dans le continuum Rio Katari – lac Titicaca (Bolivie)
Currently, I am co-PI with my bolivian partner (D Acha) of 2 new projects: 1) PIA-ACC UMSA20: identification of bio-indicators of climate change and pollution in sediment profiles of several emblematic lakes in the Bolivian Altiplano region and 2) Bioremediation of Huatajata and Cohana Bay at Lake Titicaca and cultural and ecological re-valorization of Totora (GEF).

■ **Recent Publications** *(2016-2017)*

Cossa, D., Fanget A.-S., Chiffoleau J.-F., , Bassetti M.-A., Buscail R., Deninelou B., Briggs K., Arnaud M., Guédron S. and Berné, S. 2017. Chronology and sources of trace elements accumulation in the Rhône pro-delta sediments (Northwestern Mediterranean) during the last 400 years. Progress in Oceanography, 163, 161-171.
Cossa D., Durrieu de Madron X., Schafer J., Guédron S., Marusczak N., Castelle S. and Naudin J.J. 2017. Sources and exchanges of mercury in the waters of the Northwestern Mediterranean margin. Progress in Oceanography, 163, 172-183.
Guédron S., Point D., Acha D., Bouchet S., Baya P. A., Tessier E., Monperrus M., Molina C.I., Groleau A. , Chauvaud L., Thebault J., Amice E., Alanoca L., Duwig C. , Uzu G., Lazarro X. , Bertrand A., Bertrand S. , Barbraud C., Delord K., Gibon F.M., Ibanez C., M. Flores, Fernandez Saavedra P., Ezpinoza M.E., Heredia C. , Rocha F., Zepita C., and D.

Amouroux, 2017. Mercury contamination level and speciation inventory in the hydrosystem of Lake Titicaca: current status and future trends. Environmental Pollution, 231, 262-270.
Weide, M., Fritz, S, Hastorf, C., Bruno M., Baker, P., Guédron, S., and Salenbien, W., 2017. A~ 6000 yr diatom record of mid-to late Holocene fluctuations in the level of Lago Winaymarca, Lake Titicaca (Peru/Bolivia). Quaternary Res.: 1-14
Charlet, L., Blancho, F., Bonnet, T., Garambois, S., Boivin, P., Ferber, T., Tisserand, D., Guedron, S., 2017. Industrial Mercury Pollution in a Mountain Valley: A Combined Geophysical and Geochemical Study. Proc. Earth and Planetary Sci. 17, 77-80.
Strady E., Tuc Dinh Q., Némery J., b, Nguyen T.N., Guédron S., Nguyen N.S., Denis H., and Nguyen P.D., 2017. Spatial variation and risk assessment of trace metals in water and sediment of the Mekong Delta. Chemosphere, 179: 367- 378.
Archundia D., Duwig C., Spadini L., Uzu G., Guédron S., Morel M.C., Cortez R., Ramos O., Chincheros J. and Martins J.M.F., 2017. How uncontrolled urban expansion increases the contamination of the Titicaca lake basin (El Alto - La Paz, Bolivia). Water, Air, & Soil Pollution, 228 (1), 44.
Cossa D., Durrieu de Madron X., Schafer J., Lanceleur L., Guédron S., Buscail R., Thomas B., Castelle S., Naudin J.J., 2017. The open sea as the main source of methylmercury in the water column of the Gulf of Lions (Northwestern Mediterranean margin). Geochimica et Cosmochimica Acta, 199, 222-237.
Strady, E., Hanh D.V.B., Nemery J., Guédron S., Tuc D.Q., Denis H., Dan N. P., 2016. Baseline seasonal investigation of nutrients and trace metals in surface waters and sediments along the Saigon River basin impacted by the megacity of Ho Chi Minh (Vietnam). Environmental Science and Pollution Research, 24(4), 3226-3243.
Alanoca L., Guédron S., Amouroux D., Audry S., Monperrus M., Tessier E., Goix S., Acha D., Seyler P. and Point D., 2016. Synergistic effects of mining and urban effluents on the level and distribution of methylmercury in a shallow aquatic ecosystem of the Bolivian Altiplano. Environmental Science: Processes & Impacts. 18, 1550 - 1560.
Guédron S., Amouroux, D., Sabatier P., Desplanque C., Develle A-L., Barre J., Feng C., Guiter F., Arnaud F., Reyss J-L. And Charlet L., 2016. A hundred year record of industrial and urban development in French Alps combining Hg accumulation rates and isotope composition in sediment archives from Lake Luitel. Chemical Geology: 431: 10-19.
Schreck E., Sarret G., Oliva P., Calas A., Sobanska S., Guédron S., Barraza F., Point D., Huayta C., Couture R.M., Prunier J., Henry M., Tisserand D., Goix S., Chincheros J., Uzu G., 2016. Is Tillandsia capillaris an efficient bioindicator of atmospheric metal and metalloid deposition? Insights from five months of monitoring in an urban mining area, Ecol. Indic., 67: 227-237.
Gimbert, F., Geffard, A., Guédron, S., Dominik, J. and Ferrari, B., 2016. Mercury tissue residue approach in Chironomus riparius: involvement of toxicokinetics and comparison of subcellular fractionation methods. Aquatic Toxicology, 171: 1-8.
Guédron S., Devin S., Vignati D.A.L., 2016. Total and methylmercury partitioning between colloids and true solution: From case studies in sediment overlying and pore waters to a generalized model. Environ. Toxicol. and Chem., 35: 330-339.

■ **Recent activities in terms of capacity-building, scientific facilitation, knowledge sharing (participation to symposium, expertise, ...) and transfer of technology** (half-page maximum)

I teach in several graduate courses (Licence and Master courses) on Environmental Modeling/systemic analysis, Natural environmental Chemistry: interface chemistry, reactive transfers, Paleo-environmental studies, peat bog studies, and biogeochemical cycles. I teach both in Northern (Univ. Geneva, Univ. Grenoble Alpes, Univ. de Savoie) and southern (Bolivia) countries. I will be involved in the new UMSA Master program starting in 2018.
I organized the first International colloquium on current and ancient contamination in Andes aquatic ecosystems in May 2016 (La Paz – Bolivia) and participated to several events of popularization of science (courses in high school, fête de la science, and general public publications).
I am elected member of the sectorial scientific commission of the IRD (CSS1) since 2016.

■ Member team individual form N°1

Title, Last/First name	Dr MOLINA Carlos
Position	Assistant professeur
Institution/Employer	Instituto de Ecologia
Type (public, private)	Public
Scientific discipline	Ecologie des écosystèmes aquatiques, géostatistiques, génomique
Research thematic(s)	Ecologie benthique des écosystèmes aquatiques d'altitude
Nationality	Bolivien
Work address	Campus de Cota-Cota, UMSA, La Paz Bolivie
Phone number	
Cell Phone number (not mandatory)	
E-mail	amoar6088@gmail.com

■ **Partnership with IRD** *(Support that the team member has already benefited from IRD)*

Through different research projects and professional training scholarships (from undergraduate to postgraduate), I was supported and formed by IRD researchers

■ **Summary of the research career** *(half-page maximum, font 10)*

By means the institutional agreement between French Cooperation IRD (ORSTOM during this time), and Ecology Institute from the Greater San Andres University (UMSA), I had the initial opportunity to work as a research assistant in the zooplankton area for the BioBAB project (Biodiversité du Bassin Amazonien Bolivien – Dr. Gabriel Wasson head of project). Completing my undergraduate formation, I had the opportunity to carry out my research thesis about the biodiversity of aquatic invertebrates in high Andean rivers under the influence of the retreat of the glaciers (Diversité biologique - Dr. Didier Paugy head of project). This research made it possible for me to be accepted at the National University of Tucumán from Argentina for initial doctoral studies. The PhD research work was framed within the project ATI U2SIS (Action Thématique Interdépartementale - Utilisation des Sols, Sédiments et Impacts Sanitaires) and then this project was concreted by the first South American JEAI project (Jeune Equipe Associée à l'IRD) and plus to a doctoral scholarship from DFS (Département Soutien et formation). The theme of PhD project was to try to explain the source of organic matter on the food web structure of aquatic invertebrates using biogeochemical tracers (stable isotopes of δ13C and δ15N), with the main task to understand the mercury pollution of the Bolivian Amazon floodplain. After my doctoral formation I was supported by the IRD to be part of the great group of researchers on the topic of aquatic ecology of the TOXBOL project (ANR Programme Santé-Environnement et Santé-Travail: Polymetallic contamination and impact on the environment, health and society) and Comibol project (INSU ECCO: Processing, transfer and isotopic fractionation of two mineral contaminants - Zn, Sn - in the sediment, water interfaces, trophic structure of a lacustrine ecosystem of the Bolivian highlands).

■ **Major publications** *(half-page maximum, font 10)*

• **Molina C.I.**, Gibon F.-M., Dominguez E., Pape T., & Rønsted N. (*accepted*). Associating immatures and adults of aquatic insects using DNA barcoding in high Andean streams. Ecología en Bolivia.
• Rivera, S.J., Pacheco L.F., Acha D., **Molina C.I.** & Miranda-Chumacero G. (2016). Low total mercury in Caiman yacare (Alligatoridae) as compared to carnivorous, and non-carnivorous fish consumed by Amazonian indigenous communities. Environmental Pollution 218:366-371.
• **Molina C.I.** & Puliafico K. 2016. Life cycles of dominant mayflies (Ephemeroptera) on a torrent of the high Bolivian Andes. Journal of Tropical Biology and Conservation. 64(1): 275-287.
• **Molina C.I.**, Salinas O.V., Sainz L. & M. Pouilly. (2015). Ministerio de Relaciones Exteriores. Línea base de usos, emisiones y contaminación por el Mercurio en Bolivia, Ministerio de Relaciones Exteriores. La Paz - Bolivia. 133p.
• Maldonado C., Antonelli A., **Molina C.I.**, Zizka A., Persson C., Alban J., Chilquillo E. Rønsted N. 2015. Estimating species diversity and distribution in the era of Big Data: To which extent can we trust public databases?. Global Ecology and Biogeography 24(8).
• **Molina, C.I.** & Point, D. 2014. Heavy metal contamination in the thophic chain of Titicaca, Uru-Uru and Poopó Lakes. Pp. 265-278. In: Pouilly M., Lazzaro X. & Point D. (*Eds.*) Baseline regarding knowledge of water resources in TDPS system, focusing on the Lake Titicaca. IRD-IUCN, IRD La Paz Bolivia. 308p.
• Pouilly M., Rejas D., Pérez T., Duprey J.L., **Molina C.I.**, Hubas C., & Guimarães J.R.D. (2013). Trophic structure and mercury biomagnification in tropical fish assemblages, Iténez River, Bolivia. PLOS ONE. 8(5): 3382–3391

• Gibon F.-M. & **Molina, C.I.** (2013). Contribution to the Knowledge of the Andean Stonefly Genus Claudioperla Illies, with Description of New Apterous and Micropterous. Neotropical Entomology. 42:170-177. 83
• **Molina C.I.**, C Ibañez & F.-M. Gibon. (2012). Biomagnification process of heavy metals of a hiperhaline lake (Poopó, Oruro, Bolivia): risks to consumer health. Ecología en Bolivia 74(2).
• **Molina C.I.**, Gibon F.-M., Oberdorff T., Dominguez E., Pinto J., Marín R. and Roulet M. (2011). Macroinvertebrate food web structure in a floodplain lake of the Bolivian Amazonia. Hydrobiologia 663: 135-153.
• Rueda P.M., Gibon F.-M. and **Molina C. I.** (2011). The genus Oecetis McLachlan in Bolivia and northwestern Argentina (Trichoptera: Leptoceridae), with new species and identification key for males of Oecetis species from Mexico, Central and South America. Zootaxa 2821: 19–38.
• Banegas M, Marín, R., **Molina C.I.**, Lino F. 2011. Ecosistemas acuáticos, recursos hídricos e hidrobiológicos. *In*: Programa de las Naciones Unidas para el Medio Ambiente (PNUMA). Perspectivas del Medio Ambiente en el Sistema Hídrico. GEO Titicaca.
• **Molina C.I.**, Gibon F.-M., Duprey J.-L., Dominguez E., Guimaraes J.-R. and Roulet R. (2010). Transfer of mercury and methylmercury along macroinvertebrate food chains in a floodplain lake of the Beni River, Bolivian Amazonia. Science of the Total Environment Pollution 408:3382–3391.
• **Molina C.I.**, Gibon F.-M., Sánchez, Y., Achá D., Benefice, E., y Guimaraes J.-R. (2010). Implicancia ambiental del mercurio en ecosistemas acuátios de la Amazonía: situación en Bolivia. Revista virtual REDESMA Vol. 4(2).
• **Molina, C.I.** & Gibon F.-M. 2009. A new Bolivian species of Cailloma Ross & King 1952 (Trichoptera, Hydrobiosidae), with a remarkable adaptation to high altitude. Revue francaise dèntomologie (N.S.) 31(1): 23-29.
• **Molina C.I.**, Gibon F.-M., Pinto, J. & Rosales, C. 2008. Estructura de macroinvertebrados acuáticos en un río altoandino: variación anual y longitudinal en relación a factores ambientales. Revista Ecología Aplicada. 7(1,2). 105-116.
• **Molina, C.** 2008. Uso de isótopos estables en ecología. 83p. En: Pacheco, L. & Roldán, A. (eds.). Biología. Santillana de Ediciones, S.A., La Paz, Bolivia. ISBN: 978-99905-2-413-0.

■ Recent activities in terms of capacity-building, scientific facilitation, knowledge sharing (participation to symposium, expertise ...) and transfer of technology (half-page maximum)

In 2013, through a grant in Denmark, I had the opportunity to be part of a strong interdisciplinary group of researchers on the molecular issues. Through this group, I was trained to use the genomic and bioinformatic tools to the biodiversity studies (DNA-metabarcode and NGS: New Generation Secuency). Finally, I'm supporting a research project on the study of the microbial diversity of lacustrine sediments from South Lipez, Bolivia (hipersaline lakes), through the technology of New Generation Secuency (involved within Dr. Achá and Dr. Guédron Project).

■ Fiche individuelle membre 2

Civilité, nom, prénom	Dr Morales-Belpaire Isabel
Profession	Professeur
Etablissement de rattachement	Instituto de Biología Molecular y Biotecnología -UMSA
Type (public/privé)	Publique
Discipline scientifique	Pollution by organic molecules, specially pesticides. Bacterial and fungal degradation of organic molecules. Biological nitrogen fixation
Thématiques de recherche	Biogéochimie des contaminants organiques et écologie - milieux aquatiques
Nationalité	Bolivian-Belgian
Adresse professionnelle	Carrera de Biología, Calle 27 s/n Campus Universitario Cota Cota
Tél.	591-2-2792582
Tél. portable (facultatif)	591-73212330
Courriel	ivmorales@umsa.bo

■ **Partenariat avec l'IRD** *(soutien éventuel dont a déjà bénéficié le membre de l'équipe)*

None

■ **Résumé du parcours professionnel** *(une demi-page maximum, corps 10)*

From 1992 to 2003 I have worked as a researcher in the Soil Unit of the Institute of Ecology. Research subjects : soil fertility, salinity and soil enzymes
From 2003 to 2007 I have worked at the Bioengineering Unit of Université catholique de Louvain. Research subject: fate of proteins in different environmental matrices.
From 2008 to the present I am researcher at the Environmental Biotechnology Unit of Instituto de Biología Molecular y Biotecnología. Main research subjects : fungal and bacteria biodegradation of dyes and organophosphate and piretroid insecticides, use of diazotrophic bacteria for biofertilization in Altiplano. All research work on biofertilization for altiplano crops has been coordinated in diverse meetings with local actors. Results of research work has also been explained to farmers in workshops.

■ **Publications significatives** *(une demi-page maximum, corps 10)*

Alfaro-Flores, A., **Morales-Belpaire, I**, Sneider, M. (2015) Microbial biomass and cellulase activity in soils under five different cocoa production systems in Alto Beni, Bolivia. Agroforestry Systems 89 pp 789-798
Salas-Veizaga,D. **Morales-Belpaire, I.**, Terrazas-Siles, E. (2013) Evaluation of the genotoxic potential of reactive black 5 solutions subjected to decolorizing treatments by three fungal strains. Ecotoxicology and Environmental Safety 89 (2013) 125–129
Salas-Veizaga, D., **Morales-Belpaire,I.**, Terrazas-Siles,E. (2012). Capacidad decolorativa de *Coriolopsis polyzona*, *Pycnoporus* sp. y *Penicillium* sp. sobre Reactive Black 5 a diferentes condiciones de cultivo. BIOFARBO 20(1):41-48
Morales-Belpaire I, Gerin PA.(2012) Monitoring the active conformation of green fluorescent protein (GFP) and β-glucosidase adsorbed on soil particles.The Protein Journal 31(1):84-92
Morales-Belpaire, I., Miranda-Torrez, G., Mendez-Pinaya, V., Morales-Arias, C. 2011. "Producción *in situ* de biofertilizantes para la quinua" Book published by PIEB.
Morales-Belpaire,I.; Gerin, P.A. 2008 Fate of amyloid fibrils introduced in wastewater sludge. Water Research 42, 2008, p. 4449-4456
Morales-Belpaire, I.; Gerin. P.A. 2007 Factors affecting the fate of active proteins introduced in wastewater sludges: Investigation with green fluorescent protein. Water Research 41(8): 1723-1733

■ **Activités récentes de formation, d'animation, de valorisation de la recherche (participation à des colloques, des expertises...) et de transfert à la société** *(une demi-page maximum, corps 10)*

Professor at the UMSA, in at the Environmental Biotechnology Unit of Instituto de Biología Molecular y Biotecnología. Most given courses focus on the interactions between microbiology and organic contaminants.

■ Fiche individuelle membre 3

Civilité, nom, prénom	Dr Ormachea Mauricio
Profession	Assistant professeur
Etablissement de rattachement	Instituto de Investigaciones quimicas - UMSA
Type (public/privé)	Public
Discipline scientifique	Geochemistry of metals and metalloids in aquifers and surfaces ecosystems
Thématiques de recherche	Biogeochemistry
Nationalité	Bolivian
Adresse professionnelle	IIQ, Calle 27 s/n Campus Universitario Cota Cota
Tél.	
Tél. portable (facultatif)	
Courriel	maurormache@gmail.com

■ **Partenariat avec l'IRD** *(soutien éventuel dont a déjà bénéficié le membre de l'équipe)*
Since 2015, I am working closely with an IRD researchers (Stéphane Guédron) in expatriation at the UMSA. We work mostly on the polymetallic and metalloidic contamination of the surface and ground- waters of the Milluni mining region.

■ **Résumé du parcours professionnel** *(une demi-page maximum, corps 10)*
I obtained my Bachelor of Science degree in Chemistry at Universidad Mayor de San Andrés, La Paz, Bolivia in 1999, since then I have been working as Technician – Researcher supporting many research projects in the area of environmental chemistry. During these years I have worked in Chemical Analytical Laboratory and I have gained skills in analytical instrumentations i.e. atomic absorption spectrometry, Infrared spectrometry, Ultraviolet - visible spectrophotometry and others. Since year 2000, I have been working in Hydrochemistry Laboratory and participating of field work, including the collection of environmental samples (water, soils, sediments, rocks, others), measuring field parameters and conducting laboratory analyses. In 2010 I obtained my Licence degree and started my PhD studies in the Royal Institute of Technology in Stockholm, Sweden. I obtained my PhD degree in Land and Water Resources Engineering in 2015. During my PhD studies, my research was focused in the hydrogeochemistry of arsenic and other trace elements where the main objectives were to determine the main geologic sources and the principal mechanisms for arsenic mobilization into the surface water and groundwater. Currently I am still working in the Chemical Research Institute at UMSA as a researcher and I am responsible of the environmental laboratory.

■ **Publications significatives** *(une demi-page maximum, corps 10)*

1. **M. Ormachea Muñoz**, J. L. Garcia Aróstegui, P. Bhattacharya, O. Sracek, M. E. Garcia Moreno, C. Kohfahl, J. Quintanilla Aguirre, J. Hornero Diaz, J. Bundschuh " *Geochemistry of naturally occurring arsenic in groundwater and surface-water in the southern part of the Poopó Lake basin, Bolivian Altiplano*", Journal of Groundwater for Sustainable Development, vol. 2-3, pp. 104–116, **2016**.
2. **M. Ormachea Muñoz**, P. Bhattacharya, O. Sracek, O. Ramos Ramos, J. Quintanilla Aguirre, J. Bundschuh, J. Prakash Maity. "*Arsenic and other trace elements in thermal springs and in cold waters from drinking water wells on the Bolivian Altiplano*", Journal of South American Earth Sciences, vol. 60, pp. 10-20, **2015**.
3. **M. Ormachea Muñoz**, H. Wern, F. Johnsson, P. Bhattacharya, O. Sracek, R. Thunvik, J. Quintanilla, and J. Bundschuh, "*Geogenic arsenic and other trace elements in the shallow hydrogeologic system of Southern Poopó Basin, Bolivian Altiplano",* Journal of Hazardous Materials, vol. 262, pp. 924–940, **2013**.
4. **M. Ormachea**, L. Huallpara, J. Quintanilla, **O. Ormachea**, **R. Escalera**, P. Bhattacharya "*Natural arsenic occurrence and its removal from drinking water using a tubular photo-reactor enhanced with a solar concentrator in Cochabamba, Bolivia*". In: Ng, Noller, Naidu, Bundschuh & Bhattacharya (eds.) "Understanding the Geological and Medical Interface of Arsenic, As2012". Interdisciplinary Book Series: "Arsenic in the Environment—Proceedings". Series Editors: Jochen Bundschuh and Prosun Bhattacharya, CRC Press/Taylor & Francis, (ISBN 978-0-415-63763-3), pp. 305-306, **2012**.
5. Oswaldo Eduardo Ramos Ramos, Luis Fernando Cáceres, **Mauricio Rodolfo Ormachea Muñoz**, Prosun Bhattacharya, Israel Quino, Jorge Quintanilla, Ondra Sracek, Roger Thunvik, Jochen Bundschuh, Maria Eugenia García, Sources and behavior of arsenic and trace elements; in groundwater and surface water in the Poopó Lake Basin, Bolivian Altiplano, Environmental Earth Sciences, 66 (2012) 793-807
6. Dina L. López, Jochen Bundschuh, Peter Birkle, Maria Aurora Armienta, Luis Cumbal, Ondra Sracek, Lorena Cornejo, **Mauricio Ormachea**, Arsenic in volcanic geothermal fluids of Latin America, Science of the Total Environment, 429 (2012) 55-75.

■ Fiche individuelle membre 4

Civilité, nom, prénom	Dr Ramos Ramos Oswaldo
Profession	Professeur
Etablissement de rattachement	Instituto de Investigaciones quimicas - UMSA
Type (public/privé)	Public
Discipline scientifique	Geochemistry of metals and metalloids in soils and surfaces waters
Thématiques de recherche	Biogeochemistry
Nationalité	Bolivian
Adresse professionnelle	IIQ, Calle 27 s/n Campus Universitario Cota Cota
Tél.	
Tél. portable (facultatif)	
Courriel	oswalram2@hotmail.com

■ **Partenariat avec l'IRD** *(soutien éventuel dont a déjà bénéficié le membre de l'équipe)*

Since 2013, I am working closely with two IRD researchers (Stéphane Guédron and Céline Duwig) in expatriation at the UMSA. We work mostly on the polymetallic and metalloidic contamination of the urban waters of the Katari watershed.

■ **Résumé du parcours professionnel** *(une demi-page maximum, corps 10)*

I got my PhD degree in geochemistry at Real Institute of Technology KTH (Stockholm, Sweden) in the subject area of Land and Water Resources Engineering in 2014. I have worked in the mining areas in Bolivian Altiplano and my thesis was focused at Arsenic geochemistry in groundwater and surface water; the title of my thesis was "Geochemistry of Trace element in the Bolivian Altiplano – Effects of the natural processes and anthropogenic activities".
After the PhD studies, my research was focused in occurrence of natural arsenic and their geochemistry in drinking water in rural areas, groundwater, surface water from Katari basin and fish from Titicaca lake. The projects are supported by funds from ASDI cooperation and IDH (universities research fund) as PI: i) Titicaca lake, Bolivia: Organic arsenic speciation in biotic and abiotic systems (2014-2015); ii) Katari head basin, Water and soil resources management at Colquencha municipals studies (2014-2016).
From 2001 -2007, I was included as researcher and technician at international project with ASDI fund; these projects were focused in heavy metals and metalloids in surface water in mining areas; and also I worked as a researcher at Catchment management and mining impacts in arid and semi-arid South America (CAMINAR)" project with UE funds.
Actually, I am working as researcher at Chemistry Department and Chemistry Research Institute at Universidad Mayor de San Andrés (UMSA). I am co- PI with my colleagues of two new projects with Swiss cooperation fund, both are focusing in climate change and resilience at Colquencha comuninity located in the Katari head basin.

■ **Publications significatives** *(une demi-page maximum, corps 10)*

Archundia D., Duwig C., Spadini L., Uzu G., Guédron S., Morel M.C., Cortez R., Ramos Ramos O., Chincheros J., and Martins J.M.F., (2017). How uncontrolled urban expansion increases the contamination of the Titicaca lake basin (El Alto - La Paz, Bolivia). In press in Water, Air and Soil Pollution. DOI: 10.1007/s11270-016-3217-0.

Mauricio Ormachea Muñoz, Prosun Bhattacharya, Ondra Sracek, Oswaldo E. Ramos Ramos, Jorge Quintanilla Aguirre, Jochen Bundschuh, Jyoti Prakash Maity. Arsenic and other trace elements in thermal springs and in cold waters from drinking water wells on the Bolivian Altiplano. Journal of South American Earth Sciences 60: 10-20.

Oswaldo E. Ramos Ramos, Tobias S. Rötting, Megan French, Ondra Sracek, Jochen Bundschuh, Jorge Quintanilla, Prosun Bhattacharya. Geochemical processes controlling mobilization of asenic and trace elements in shallow and surface waters in the Antequera and Poopó mining regions, Bolivian Altiplano. Journal of Hydrology 518: 421-433.

Luis Fernando Cáceres C., Oswaldo E. Ramos Ramos, Sulema N. Valdez Castro, Rigoberto R. Choque Aspiazu, Rocío G. Choque Mamani, Samuel G. Fernández Alcazar, Ondra Sracek, Prosun Bhattacharya. 2013. Fractionation of Heavy Metals and Assessment of Contamination of the Titicaca Lake Sediments. Environmental Monitoring and Assessment Journal. Accepted June 2013.

Oswaldo E. Ramos Ramos, Jorge Quintanilla, Lourdes Chambi, Gunnar Jacks, Prosun Bhattacharya, Rigoberto Choque, Sulema Valdez, Israel Quino. 2012. Arsenic fractionation in soils in mining region of the Bolivian Altiplano. In: Ng, Noller, Naidu, Bundschuh & Bhattacharya (Eds) "Understanding the geological and medical interface of Arsenic", CRC Press/ Taylor and Francis (ISBN-978-0-415-63763-3) PP. 335-336.

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■ **Activités récentes de formation, d'animation, de valorisation de la recherche (participation à des colloques, des expertises...) et de transfert à la société** *(une demi-page maximum, corps 10)*

I am teaching at graduate and postgraduate Master program from Chemistry Department at UMSA from 2016. In graduate program I teach the course Analytical Chemistry I, Analytical Chemistry Laboratories II; and in mater program Water Resources, Geochemistry. I organized the first International course of X-Ray Diffractions in Bolivia, with five international experts from Colombia, Venezuela, Mexico, Brazil, and Japan. I was supervisor of many students from graduate and postgraduate program.

■ Fiche individuelle membre 4

Civilité, nom, prénom	Dr Alanoca Lucia
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Etablissement de rattachement	Instituto de Investigaciones quimicas - UMSA
Type (public/privé)	Public
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■ **Partenariat avec l'IRD** *(soutien éventuel dont a déjà bénéficié le membre de l'équipe)*

All along my training in the field of research (1998-2016), I was under the supervision of IRD researchers. I started my licence studying the Hg contamination in the inundation plain of Beni followed by my Master II (2008) at the University Paul Sabatier on the role of the inundation plain of the Beni watershed through the transportation, deposition and speciation of Hg in the Bolivian amazon. Both my Master and PhD were realized thanks to IRD DFS (Département Soutienet formation) grants.

■ **Résumé du parcours professionnel** *(une demi-page maximum, corps 10)*

I obtained my PhD in earth and planetary sciences at the University Paul Sabatier (Toulouse III- France) in December 2016. My PhD thesis called "biogeochemical cycle of mercury in Lake Uru-Uru – Bolivian Altiplano" focused on the net methylmercury production capacity through a balance between methylation and demethylation in various compartments of the lake. The study was performed using methodology at the cutting edge of technology using enriched isotopes 199iHg and MM201Hg. In addition, I determined the sources and emission fluxes of Hg (inorganic and methylated Hg; iHgandMMHg) from the sediment to the water column in various season (i.e., dry and wet seasons). Before I finished my thesis I was contracted by the Ministry of environment and water (MMyA: Ministerio de Medio Ambiente y Aguas) and by the UMSA (Universidad Mayor de San Andrés). The MMyA contracted me to realize the evaluation of the Hg contamination in the watershed of Rio Madre de Dios (Bolivian Amazonia) and the UMSA (IIQ) to develop and optimize the THg analysis at the picomolar level in waters and other environmental matrix through the project hydrological contamination and implications for the drinking water quality in the mining region of Milluni ("Contaminación Hídrica e Implicaciones sobre la Calidad del Agua de Consumo, Milluni, La Paz").
Currently, I'm working as contractual engineer at the IIQ-UMSA, studying the biogeochemistry of Hg in the Milluni watershed which is contaminated by extractive activities and which is a source of drinking water for La Paz city.

■ **Publications significatives** *(une demi-page maximum, corps 10)*

Alanoca L., Guédron S., Amouroux D., Audry S., Monperrus M., Tessier E., Goix S., Acha D., Seyler P. and Point D., 2016. Synergistic effects of mining and urban effluents on the level and distribution of methylmercury in a shallow aquatic ecosystem of the Bolivian Altiplano. Environmental Science: Processes & Impacts. 18, 1550 - 1560.
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Maurice-Bourgoin L., Quiroga I., Alanoca L., Chincheros J., and Quintanilla J., 2001. Distribución del mercurio en la cuenca amazónica boliviana (Rio Beni) - Impacto sobre las poblaciones ribereñas. Revista Boliviana de Química, Vol.18 (1):16-27.

■ **Activités récentes de formation, d'animation, de valorisation de la recherche (participation à des colloques, des expertises…) et de transfert à la société** *(une demi-page maximum, corps 10)*

Currently, I am part of the research team on mercury biogeochemistry in the Milluni-Bolivia basin with Mauricio Ormachea and Stéphane Guédron. The study will be complemented by an evaluation of the Hg content in drinking water in the city of La Paz. The investigation will allow the national authorities to make decisions that help improve the quality of life, in particular, the population of La Paz.

4. **Partnership with an IRD research unit** *(3 pages maximum, font 10)*

To be filled in by the research unit correspondent

■ **Background of the partnership**

The correspondent will describe here:
- the origins of the relationships with the team or some of the team members.
- the different stages or the different forms it has taken,
- the partnership between the institution of the research unit and the institution(s) where the team members are employed, if any.
Analyse the outcomes and the major achievements that justify this JEAI proposal.

Since 2001, the team of IRD was particularly active in Bolivia in research focusing on water quality and polymetallic mine induced contamination in various watersheds of the Bolivian Altiplano and the Amazonian side. During his assignment in Bolivia (2001-2006), Marc Roulet supported the first research programs hold by IRD after a gap of almost 20 years in the frame of the ANR ToxBol (Polymetallic contamination and impact on the environment, health and society), and developed a research laboratory with Jean-Louis Duprey at the LCA facility specialized on total mercury determination in soil and sediment. His research focused mainly on mercury contamination of the aquatic ecosystem (both of the Altiplano and the Amazonian side of Bolivia) based on pioneer monitoring programs of water, sediment and biota of Bolivian rivers and lakes. These early research programs allowed the identification of the distribution, speciation and dissemination of mining contamination in Bolivia. His research programs were followed by David Point (2010-2015) through the program EC2CO COMIBOL (Processing, transfer and isotopic fractionation of two mineral contaminants - Zn, Sn - in the sediment, water interfaces, trophic structure of a lacustrine ecosystem of the Bolivian highlands) involving a multidisciplinary (Epidemiology, Biology, and social science) scientific group of the IRD (i.e., Jacques Gardon, François-Marie Gibon & Hubert Mazureck) which worked in the southern Altiplano in the mining regions of Oruro. Several PhD or post-doctoral fellows as those of Carlos Molina and Lucia Alanoca were conducted during these programs.
In 2011, D. Point organized an international workshop called "Fonctionnement et Contamination du lac Titicaca: Impact sur l'environnement, la société et la santé" (12-13 Mai 2011) which allowed all the participants to make a point on the knowledge and gaps existing in this emblematic ecosystem. From this workshop resulted many proposition of transdisciplinary project which progressively succeeded. This resulted in the expatriation 4 IRD researchers at the UMSA in La Paz; Xavier Lazzaro (2012-2014), Stéphane Guédron (2013-2017), Céline Duwig (2014-2016) and Gaëlle Uzu (2016-2018) which allowed the reinforcement of the IRD projects and the development of new fields of research including sedimentology, hydro-geochemistry, aerology and paleo-environmental studies.

In the meantime, Dario Acha was hired in 2010 at the IE team as the first biogeochemist and brought a new dynamic with its French partner. He recently hired Carlos Molina as assistant professor (2014) to reinforce his team in the thematic of benthic ecology and genomics in partnership with the Isabelle Morales (IBMB) who works on the interaction between microbial communities and organic contaminants. Besides, the recent (2014 & 2015) hiring of Oswaldo Ramos-Ramos and Mauricio Ormachea at the IIQ also brought new force and capacity in the field of geochemistry of metals and metalloids. After her PhD at the GET/IRD unit, Lucia Alanoca recently joined the IIQ team as a contractual engineer and set up with Stéphane Guédron a laboratory dedicated to picomolar level mercury analysis.
Thus, the combination of these 6 young researchers lead to the creation of the TITICACA team resulting mostly on recent interactions and collaborative projects developed since 2010.

The collaboration between the Bolivian (IE/IIQ/IBMB) and French (IRD) researchers implicated in this proposal started in 2011 with the project COMIBOL about aquatic metal pollution at Lake Uru Uru. Later in 2012 the collaboration expanded with a Bolivian funded project (EUTITICACA funded by IDH - recursos del Impuesto Directo a los Hidrocarburos, P.I. Dario Acha) about organic pollution at Lake Titicaca. Another Bolivian funded project (LATICO2) and a French funded project (ANR-PACHAMAMA) expanded collaboration even more from 2013 to 2016. Then, the collaboration was reinforced through other projects between 2013 and 2016 (i.e., EC2CO Comibol (P.I. D Point), Project PaleoBol (P.I. S Guédron), project Tracisomer (P.I. S Guédron), EC2CO PhytoBol (P.I. G Sarret), IDH Milluni (P.I.s M. Ormachea, L. Alanoca and S. Guédron), Katari LABEX OSUG@2020 (C. Duwig, S. Guedron, O. Ramos Ramos ...). Currently we have ongoing collaboration in a Bolivian funded project (PIA-ACC UMSA20) at emblematic lakes of Bolivian Altiplano and a French funded project (PHYTOBOL) about phytoremediation at Lake Titicaca. We are also about to start two other projects at Lake Titicaca funded by GEF (Global Environmental Fund).
During all these years of collaboration four researchers belonging to the team were expatriated to Bolivia for at least two years and many more came to Bolivia in short and long missions. We also had several Master II students, two PhD students and three postdocs from France coming to Bolivia to conduct their research in our projects. Two Bolivians travel to France to obtain a Master I (ME Espinoza) and PhD (Lucia Alanoca) respectively and we have two other Bolivian students going to France this year to conduct their Master II (Carlos Heredia & Marizol Flores).
The adequacy and complementarity between the scientific topics and expertise of the UMSA and IRD partners was improved and confirmed along these projects since IE/UMSA brought its knowledge on the ecological functioning of the

Andean Altiplano ecosystem (including microbiology and benthic to pelagic ecology) IIQ/UMSA, their knowledge on surface and groundwater chemistry, and IRD partners brought their biogeochemical knowledge (including isotopical tracing). The combination of both approach allowed a better understanding and characterization of these high altitude ecosystems which has been published jointly (Acha et al., 2017; Alanoca et al., 2016a; Alanoca et al., 2016b; Guédron et al., 2017, Archundia et al., 2017a).
To date, scientific activities and research program presented by the TITICACA JEAI are unique in Bolivia and in the Andes. Without the strong involvement and commitment of the permanent members of TITICACA, this program would not be possible by the European partners. This JEAI TITICACA will be carried out in a context of strong collaboration between Bolivian and French teams and completed and supported by additional balanced international collaboration, working and providing the means for the development of a common project.
The major outcomes of this proposal are:

- To consolidate the functioning of the Titicaca stations in a framework of north-south collaboration.
- To reinforce the local expertise in biogeochemistry issues relevant to the region
- To transfer the acquired knowledge to both the next generation of young scientists and the civil society

■ **Terms of the association**

The correspondent will provide a detailed description of the strategy that the research unit will implement to help structure the team and to support the capacity-building of the team members for the next 3 years.

With the aim of strengthening the TITICACA team, we will act for the next three years on the three pillars of the program: strengthening human resources, structuring observations and partnership in research programs.

Collaboration among team members workout well partly because of the diverse background of the researchers which found a great opportunity to complement their work with different perspectives. Consequently our collaboration has a strong potential to keep growing and expand to our graduate programs at our home institutions, which may benefit from a more multidisciplinary perspective. However, now all French researchers are returning or have returned to France. The potential assignment of Xavier Lazzaro in Bolivia in February 2018, scientific and technical coordinator of the sensor platform observatory for France, will be a definite asset to the development and support of this team, but our ongoing and future projects require further mobility of the Bolivian researchers as well as the return of French researchers to Bolivia in short and long missions. We also want to expand and better balance the student exchange between our institutions and strengthen the Bolivian master programs to eventually generate a local multidisciplinary PhD program. The funding for the GEF projects were obtained thanks to a close collaboration with the Ministry of Environment and Water (MMAyA). We also contributed significantly to the design of the national strategy to deal with ongoing environmental issues at Lake Titicaca. We still serve as technical advisors for policy and decision making at MMAyA and have close collaboration with research groups from Peru, which shares the Lake Titicaca with Bolivia.

The TITICACA team has many years of experience and collaboration with its international partners, including OSUG and ISTerre, IGE, GET and BOREA. Despite the small number of scientists with permanent positions, this structured team aims to grow through the support of its partners, according to their possibilities, helping the training of Bolivian students at Master and Doctorate (Cf project of building a doctoral school in La Paz). An ARTS candidature for the formation of a Bolivian student currently training at ISTerre M1 will be submitted at the IRD in 2018 as part of this program.

Observations at Lake Titicaca and Katari watershed are included in currently running research programs allowing a certain continuity of the observatory. This financial support, however, is necessary and complementary with the human resources coming from JEAI TITICACA.

5. Budget

a – Financial resources and needs (in euros)

Needs *(3-year period)*		Already available resources *(specify the origin, especially co-funding by host institution)*	Requested from IRD *(€ 50,000 maximum)*
Small equipment	Spare parts & small equipments	Merx System for MeHg speciation, HPLC, chromatography ionic, AAS (funded by various organizations including IDH, IRD and OSUG)	*3000 € (Swagelok, flowmeters, electro-valves and spare parts and 2000 € (consumables; ultraclean acids, argon & helium, teflon tubing …)*
Local missions/ field work expenses	Fieldwork	36000 € (vehicle of the university going on a 2 week basis to lake Titicaca)	*3000 € for bi-monthly field missions at lake Titicaca*
International missions	Missions between Europe and Bolivie	none	*10000 € (for young scientists to go abroad)* *12000 € (for inviting speakers and summer school)* *4000 € (for data management training)*
Costs for the preparation of symposium/ workshops	Final workshop & conference	University infrastructure	6000 € for remote lectures (1/ year) 4000 € for final conference
Other expenses (management fees, publications, etc.)	Consumables and other running costs	500 € (minimum provided by the IE/IIQ-UMSA & IIQ - UMSA) 3800 € /year (Stipends for 3 undergrad students)	*3000 € mainly for calibration, maintenance and other* *1000 € (Consultancy work for helping in the preparation of the final academic proposal)* *2000 € for open access publications and local taxes & fees*
Total	**50,000 €**	**41,500 €**	**50,000 €**

b – Budget Breakdown per period

Items	2019	2020	2021	Total
Small equipment				
Maintenance probe/sensors	1000	1000	1000	**3000**
Maintenance chemistry lab	1000	1000	1000	**3000**
Spare parts	700	700	600	**2000**
Local missions/field work expenses				
Fieldwork	1000	1000	1000	**3000**
Production of a formal proposal for an A.S.P.*			1000	**1000**
International missions				
Invited speakers	3500	3500	5000	**12000**
Scientific Exchange	3000	3000	4000	**10000**
Costs for the preparation of symposium/ workshops				
Workshops & summerschool	3000	3000		**6000**
Data management training courses	1500	1500	1000	**4000**
Conference			4000	**4000**
Other expenses (management fees, publications, etc.)				
Local taxes and fees	200	200	100	**500**
Publications (open access costs)	500	500	500	**1500**
Total	2019 (between 30 and 40%)[1]	2020 (between 30 and 40%)[2]	2021 (remaining balance)[3]	Total
	15400	**15400**	**19200**	**50,000**

1. First instalment (between 30 and 40% of the total amount) following signature of the financial support decision.
2. Second instalment (between 30 and 40% of the total amount) at the beginning of Year 2.
3. Third instalment (remaining balance) at the beginning of Year 3, following the assessment of the mid-term report.

c – Budget request justification *(2 pages maximum, font 10)*

Most of the funding accessible from the projects funded by PNUD are only usable for scientific purpose including the purchase of large equipment (e.g., sensor platform and phytoremediation pilote systems). Thus requested fundings will be centered in field campaigns to follow and develop the project "Propuesta de monitoreo y restauración del Lago Menor Titicaca" (accepted and funded by PNUD/GEF, P.I. D. Acha), exchange between the two institutions for the new interdisciplinary Master. Details of the requested funds are given in the main project (i.e., financial request to reach each objective)

To maintain the following plateforms, phytoremediation system and knowledge transfer the following items ate necessary:

- Field campaign to follow and maintain the monitoring platform
- Missions for the permanent members between France and Bolivia
- Following of the students and exchanges between the 2 countries
- Missions for the permanent members of France for the participation in courses of the Bolivian master
- Missions for the permanent members of Bolivia for the promotion of science out of Bolivia
- Organization of workshops and conference in Bolivia to follow the dynamic initiated by the partners

In addition, technical training in data management is considered as well.

Finally, in terms of capacity building, funding for organizing two Part of the consolidation of the long-term sustainability model consists in ensuring the operation and providing a fast troubleshooting response at the Titicaca observation and monitoring station. For this, TITICACA needs to have available funds for spare parts, specific consumables and calibration that are not covered by UMSA.

Consumables and spare parts are considered in this regard.

The instruments needed for biogeochemistry are already available at the IE/IIQ-UMSA and therefore we only need to cover the transport and expenses on the field.

Finally, a proposal for implementing a program in environmental biogeochemistry at UMSA will be delivered by the JEAI TITICACA to UMSA. The team will only need of monetary support for the production of the final report for which a consultant will be hired.

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