



PhD in SCIENCE, TECHNOLOGY AND POLICY FOR SUSTAINABLE CHANGE - 40th cycle

PNRR 630 Research Field: CO2 SEQUESTRATION IN OCEAN: NUMERICAL SIMULATIONS AND EXPERIMENTS

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0
In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	<p>Anthropogenic greenhouse emissions and the consequent global warming are leading to disastrous consequences for the planet, involving a serious risk for the living species that inhabit it, including humans. In this general frame, the greenhouse effect and the acidification of the oceans are particular problems resulting of the exponential increment of carbon dioxide in the atmosphere. The Paris Agreement requires signatory states the commitment to take actions to limit the increase in global average temperature below 2 degrees Celsius. To reduce carbon dioxide emissions quickly and significantly is not sufficient to achieve this ambitious temperature target, but the removal of the CO₂ already present in the atmosphere is required. To this aim several ad hoc methodologies should be developed and are object of interest of the scientific and technological community. Among them the industrialisation of the geological carbon cycle by capturing CO₂ in the atmosphere through a process that produces calcium bicarbonate marine solution to be discharged into the sea. Several discharge way are taken into consideration such as exhausting pipe in deep sea or in coastal zones from lime production plants, or discharging from ships. This methodology presents the double advantage to sequester CO₂ from atmosphere and, at the same time, to enhance ocean alkalisation and restore its capability to adsorbe carbon dioxid. This technique is promising and interesting but its efficiency and harmless effects on the marine biota must be deeply</p>



	<p>investigated. Aim of the present work is to investigate the efficiency, the benefits and the impact on the marine environment of the calcium bicarbonate discharge. The study will be carried out using the Computational Fluid Dynamics (CFD) approach, in comparison and taking into account the informations and data furnished by the experimental facilities set up by Limenet.</p> <p>The proposal perfectly fits the mission M2 of PNRR, green revolution and ecological transition, in the C4 restoration and protection of the seabed and marine habitats, adoption of national air pollution control programmes. It also fits the mission M4, reinforcing fundamental and applied research, support processes for innovation and technology transfer.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>The efficiency, the benefits and the impact on the marine environment of the calcium bicarbonate discharge will be studied using both experimental approach and numerical simulations.</p> <p>The computational fluid dynamics (CFD) approach will be applied to numerically simulate the discharge process and the calcium bicarbonate diffusion. In particular the calcium carbonate precipitation, the reaction rate in sea water, the concentration diffusion and the pH variation will be analysed. To this aim a multiphase flow approach will be considered. Close to the discharge site, the turbulent mixing plays a fundamental role in the reaction and diffusion process, while in the far region transport by sea current are dominant. To afford numerical simulations of turbulent flows in such a wide range of scales, from the local turbulent scales near the discharge site, until large scales in coastal regions or in the deep sea, zonal approach will be applied. Starting from home-made numerical code, the ad hoc numerical zonal models will be implemented. Due to the large number of degrees of freedom involved in the problem, the use of high performance computational (HPC) platform is required. The numerical and physical model will be assessed on the basis of comparison with data and informations obtained by experimental facilities set up by Limenet. All the</p>



	<p>phases of model design will be applied in an iterative way from conceptualization to validation through calibration. Then, the obtained model will be applied in real cases in coast zones or open sea for Limenet process design. The chemical stability of calcium bicarbonate, the alkalinity, the pH and the conductivity of sea water will be measured first of all in steady tank. Moreover measures of the discharge processes will be taken in a pilot plant. The PhD candidate will spend 6 months, distributed along the three years, at the Limenet society to collaborate in the experimental facilities.</p>
Educational objectives	<p>The research project presents an interdisciplinary character, and requires to develop expertise in several fields, in closed collaboration with chemists, biologists and environmental engineers. Numerical and HPC skills, knowledge of turbulence theory and of fluid dynamics of multiphase flows are necessary to manage the research and will be aquired. The PhD candidate will also aquire expertises in managing experimental facilities.</p>
Job opportunities	<p>The project aims to train a PhD researcher in the multidisciplinary and international environment that will enable a successful career in the academy or research centers, where he could pursue the fundamental research, or in the industrial sector where experts in CO₂ sequestration will be increasingly in demand.</p>
Composition of the research group	<p>0 Full Professors 0 Associated Professors 1 Assistant Professors 0 PhD Students</p>
Name of the research directors	<p>Prof. Antonella Abbà</p>

Contacts	
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Limenet Srl Società Benefit
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Hamburg University - Center for Earth System Research an Sustainability (CEN)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>The Ph.D. candidate will be provided with office space and a personal computer if needed. Apart from the compulsory ones, the Ph.D. candidate will have the opportunity to follow additional courses, receive economic support to attend summer schools, and participate in conferences. There will be the possibility of paid teaching assistantship.</p>