Radiotracers for the study of Marine and Oceanic Ecosystems

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Abstract. Acidification of the oceans influences the physiology of aquatic organisms and, in general, the ecology of marine ecosystems. Here we report on the first stage of the REMO project, focused on the study of marine species especially affected by acidification of waters, using radiotracers and nuclear instrumentation techniques.

1 Motivation

Since the beginning of the industrial revolution, humans have produced CO_2 levels well above the natural level which stayed between 170 ppm and 280 ppm (parts per million) for the last 800000 years. The change started at the end of the XIX century when the levels started to increase reaching a value of more than 418 ppm in 2023 [1]. The oceans have adsorbed about one third of the carbon dioxide released to the atmosphere in the form of carbonic acid H_2CO_3 resulting from the combination of H_2O and CO_2. This has led to a continuous increase in acidification of the oceans, often called the other CO_2 problem, that adds to the well known global warming problem. It is estimated that if CO_2 continues to be released at the same rate as today, ocean acidity will increase by 170% compared to pre-industrial levels. Water acidification influences the physiology of aquatic organisms and, in general, the ecology of marine ecosystems. This anthropogenic effect affects ecosystems at remote places such as the coral reefs due to the oceanic currents. While it is of utmost importance to stop and if possible decrease the anthropogenic production of CO_2, it is also important to make a realistic diagnosis of how these changes affect marine organisms. This is important not only as part of the general health and integrity of the global ecosystem but also because it can affect food security. It is in the diagnosis of the problem that nuclear techniques can help and is the main purpose of the REMO (Radiotrazadores para el estudio de Ecosistemas Marinos y Oceánicos) project. The main idea is to monitor the influence of water acidity in the growth of marine and oceanic ecosystems, in a controlled and stable laboratory environment.

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2 Radiotracers for the study of Marine and Oceanic Ecosystems, the REMO project

In order to follow the growth of the marine species under different conditions of acidity in water, we want to measure the absorption of calcium using as a radiotracer the radioactive isotope ^{45}Ca. Similar activity has been carried out at the IAEA in Monaco since the beginning of this century [2]. However, their methodology includes the destruction of the individuals (dissolving them in scintillator material) in order to measure the amount of ^{45}Ca that has been incorporated in the organism. This makes impossible to study the same animal along its entire life cycle, furthermore, it sometimes requires the culture of a huge number of individuals. A complete review of this kind of studies, with emphasis on the need for non-destructive studies can be found in Ref. [3]. In fact, we plan to use a non-destructive method, putting the individuals inside a set-up and measuring the amount of ^{45}Ca using ad-hoc nuclear instrumentation. We plan to start with two different water conditions. One with the present PH level of 8.1 and the other with the PH level expected at the end of the present century, 7.8, if the increase in CO_2 production continues at the rate of recent years, see figure 1.

The starting phase of the project will concentrate on two key ecosystems, a Mediterranean aquarium to grow bivalves, and a Tropical aquarium with corals. The first one is very important for the Spanish economy, food supply and export. The second is very important at a global level since the coral reefs contain more than 25% of marine biodiversity, and it is a key place for the reproduction of about a quarter of marine species.

The aquaria are now being installed at the research laboratories of the Oceanogràfic Foundation in Valencia. The team there has ample experience in the growing and maintenance of the most important marine echo-systems that are also presented to the general public in the form of the largest aquarium in Europe. They have an extensive labo-

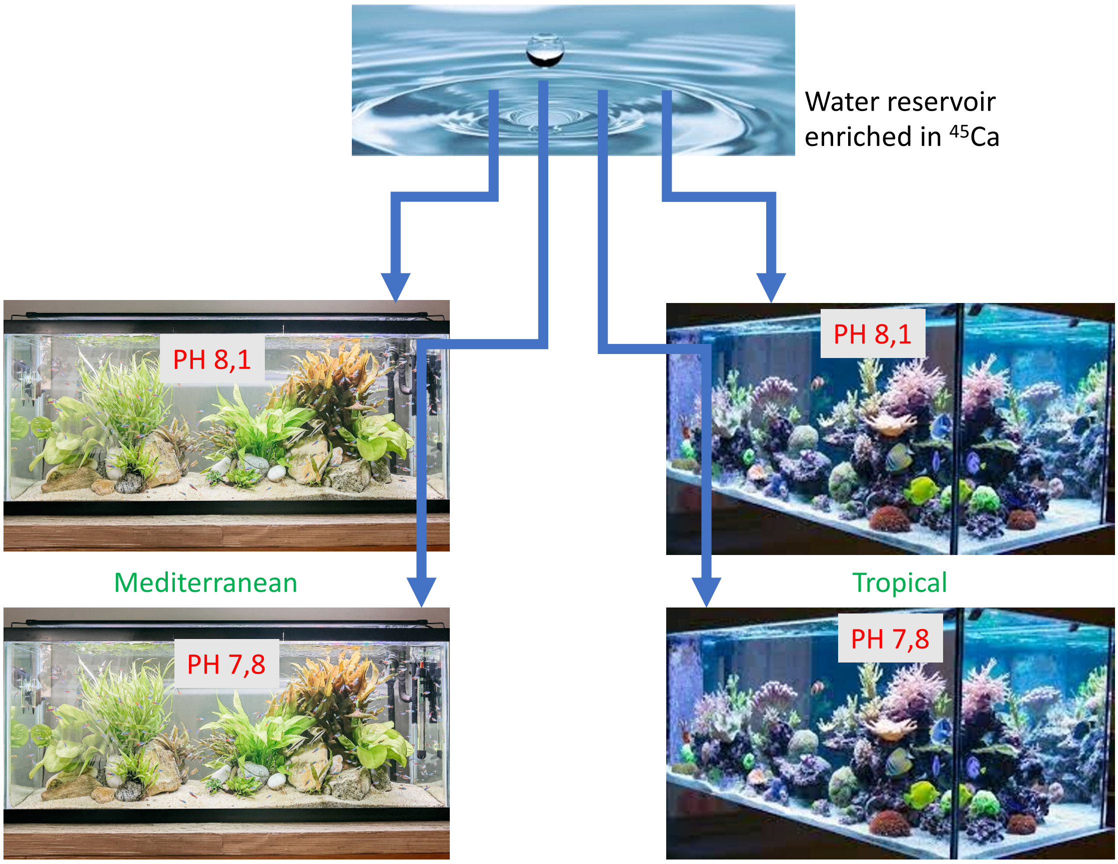

Figure 1. Schematic idea of the distribution of aquaria at the Oceanogràfic. On the left, the two Mediterranean aquaria with the present and end-of-century acidity conditions. On the right, the same acidity conditions, now for two tropical aquaria. For the ^{45}Ca enrichment, a common reservoir will be used.

ratory with the capacity to host the planned aquaria in the best controlled conditions. They also have the best quality natural sea water in the Valencia region. At the moment of writing this article the components of the set-up have already arrived at the Oceanogràfic Foundation and a first mounting with the illumination and filtration plant is ready for a first test with fresh water (see Fig. 2 upper panel).

As mentioned above, our goal is to measure the amount of Ca incorporated by the individual organism in the growing process. This will be done by dissolving a fixed amount of the radioactive isotope of ^{45}Ca into the water, which is chemically identical to the stable "normal" Ca existing in nature and consequently will be incorporated in the body in the same way.

^{45}Ca has a very simple decay scheme, as can be seen in figure 3. Almost 100% of the decays proceed via β^- decay to the ^{45}Sc ground state emitting an electron with an energy that covers a continuous spectrum with a maximum energy of 256 keV. It is this radiation that we want to measure. The half life of this isotope is 163 days.

Several circumstances have to be considered. a) The amount of radioactivity dissolved in the water, of the order of a few kBq, will not affect the physiology of the specimen. There are two reasons for this, firstly the activity is not strong and secondly the range of electrons of this energy in water is only a few mms. b) The growing process in molluscs as well as in corals occurs mainly in the most external part of the animal, hence minimising the self absorption. c) Both kinds of specimen are static. This facilitates the operation of taking them out of the aquatic medium and locating them inside the instrumental setup. d) The half life of ^{45}Ca is of the same order of magnitude as the growing life of the animals. All these considerations are positive and helpful for the proposed methodology. Less advantageous is the fact that corals are very sensitive to external stress and cannot be outside the water for more than 5 or 10 minutes without being affected. In consequence, this is the time scale for the measurements. Molluscs on the contrary are more resilient.

The instrumentation is currently under development at the Gamma and Neutron laboratories of IFIC in Valencia and at the LNL in Legnaro. Two main ideas are proposed, the first one is based on thin scintillating fibres that can bend and adapt to the shell of molluscs. We have already acquired three types of fibre of different manufacturer, thickness, scintillating material and cladding, and we are performing a comparative study to decide which one is best for measuring the low-energy betas emitted by ^{45}Ca. The lower panel of Fig. 2 shows a small sample of these fibres at our test bench at IFIC. The second detector

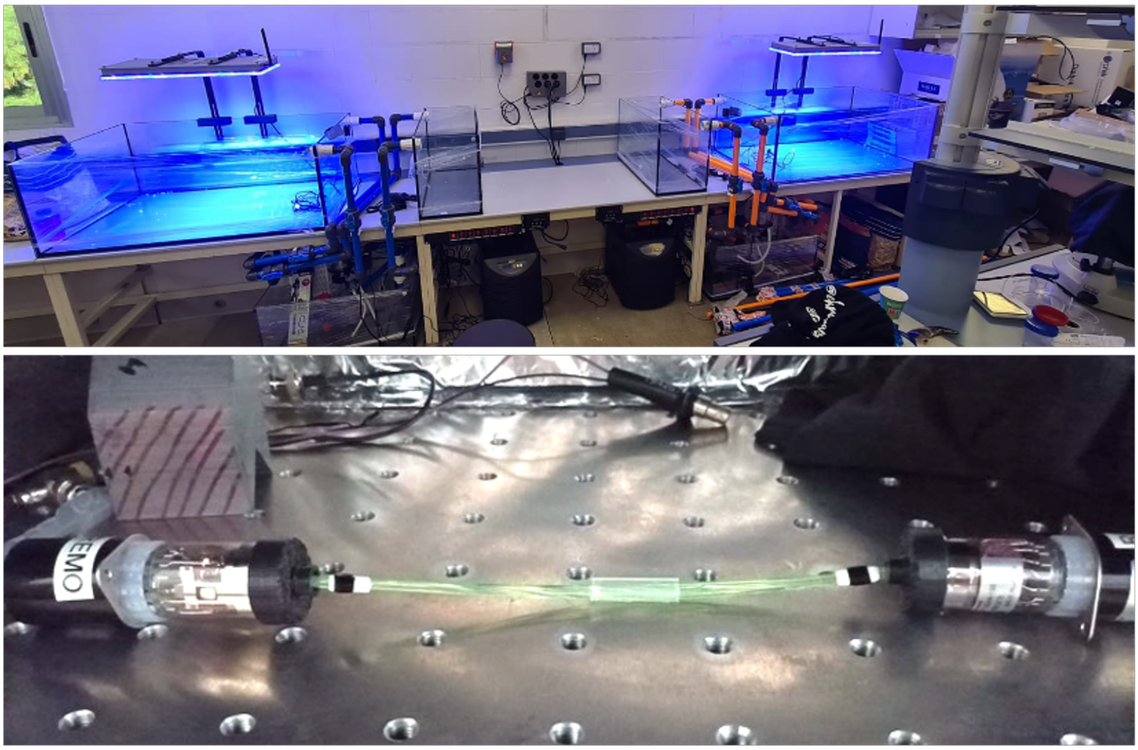

Figure 2. Upper panel: the aquarium system, still dry, as mounted at the Oceanogràfic. Lower Panel, a bundle of green scintillation fibers coupled to two small photomultiplier tubes in our test bench at IFIC.

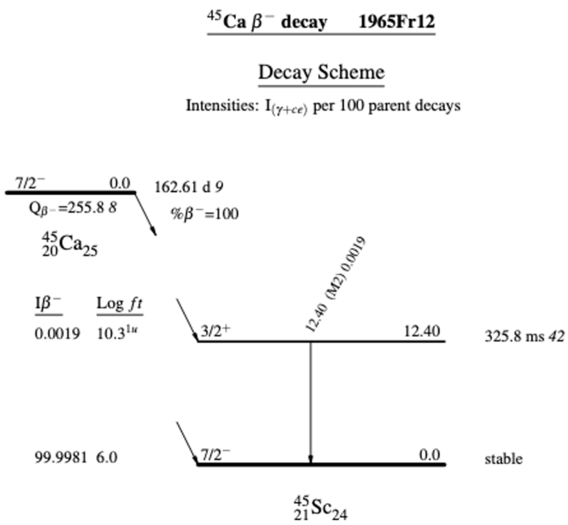

Figure 3. Decay scheme of ^{45}Ca. This radioactive Ca isotope decays by emitting beta particles of up to 256 keV in energy with a half life of 163 days. ^{45}Ca will be used as a radiotracer in the REMO project. Data taken from https://www.nndc.bnl.gov/.

approach is a large volume vessel filled with a commercial liquid scintillator with a special design that protects the mollusc or coral piece from the liquid. The vessel is coupled to a large area photomultiplier tube through an optical Quartz window. This second design is under construction at the time of writing.

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