SPOTLIGHT

The IAEA Ocean Acidification International Coordination Centre Capacity Building Program: Empowering Member States to Address and Minimize the Impacts of Ocean Acidification

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INTRODUCTION

Ocean acidification (OA) is broadly recognized as a major problem for marine ecosystems worldwide, with follow-on effects to the economies of ocean-dependent communities. The urgent need to mitigate and minimize the impacts of OA is a scientific and political priority, as highlighted by the latest Intergovernmental Panel on Climate Change report (IPCC, 2022) and by the inclusion of OA as a target in the United Nations Sustainable Development Goals (SDG). In addition, over 20 years of strong scientific evidence on the impacts of OA provides compelling arguments for urgent CO_2 mitigation. Reducing CO_2 emissions will require ambitious regulatory and economic instruments, as well as effective systemic changes across governments and societies. It is critical to implement adaptation measures to minimize the impact of OA, among other key environmental stressors, as the mitigation process takes time, and the impacts of OA are already felt globally. Assessing the impacts of solutions and their potential implementations requires information at local scales, considering the variabilities in marine ecosystem responses to OA (e.g., local adaptation, species redundancies).

One of the main challenges for designing OA mitigation and adaptation strategies is the lack of data on chemical changes and biological impacts from developing countries. A minority of scientific publications on OA stems from research undertaken in the Global South. For example, only 14% of publications describing OA studies in the Atlantic Ocean have a first author from the Global South (OA-ICC bibliographic database 2024; https://www.iaea.org/services/oa-icc/science-and-collaboration/data-access-and-management). This highlights the lesser involvement of researchers from the Global South in the field of OA and the need for further training to develop local leadership. Studying OA requires implementation of specific and complex best practice methodology, for example, for the measurement of seawater carbonate chemistry (e.g., Feely et al., 2023). The successful execution of sustained measurements and experimentation in developing countries is hindered by a general lack of basic OA literacy and exacerbated by a lack of infrastructure, instrumentation, and financial support.

PROJECT DESCRIPTION

A need for coordination of OA research and synthesis activities led to the creation of the SOLAS (Surface Ocean Lower Atmosphere Study) and IMBeR (Integrated Marine Biosphere Research) OA (SIOA) working group in 2009. This group facilitated the establishment of the International Atomic Energy Agency's (IAEA) Ocean Acidification International Coordination Centre (OA-ICC) to coordinate, promote, and facilitate global OA activities. The OA-ICC is an IAEA Peaceful Uses Initiative project launched at the UN Rio+20 conference in 2012 following increasing concern from IAEA Member States about OA. Organized around three pillars—science, capacity building, and communication—it brings together experts to discuss issues of relevance to the global OA community, compiles and centralizes information, provides online resources (https://www.iaea.org/services/oa-icc), and organizes training courses.

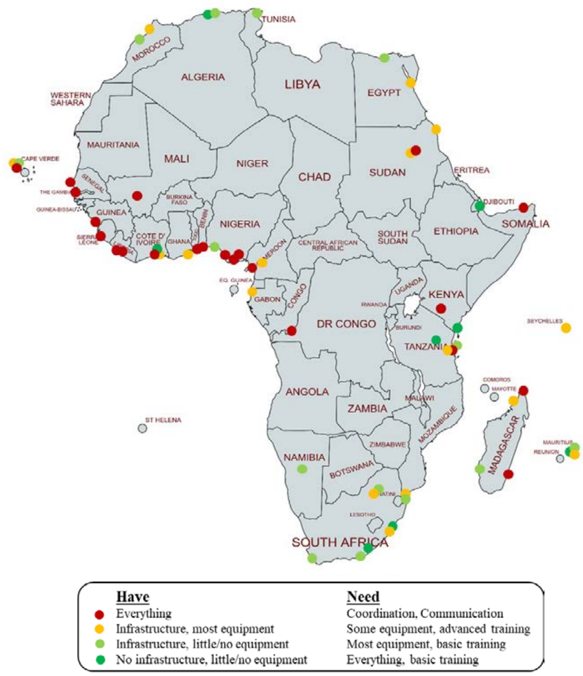
To optimize financial resources and increase the chances of successful implementation of the knowledge transferred through its initiatives, the OA-ICC developed an OA capacity building program. Analysis of past course performance, as evaluated by pre- and post-course evaluations, has enabled improved format, content, and teaching methods, and refined the identification of the most effective participants and course locations based on existing capacities and needs.

Experts designed a questionnaire to identify priorities for trainings, potential hosts, or experts, tailoring the level, content of the training, and capacity for OA research. This questionnaire also provided useful information on the expertise and motivation of participants, infrastructure quality, available equipment, and regional strengths and barriers. It was also used over time to document national and regional progress. The information gathered is also a resource for the community to promote collaborations within regions (e.g., share equipment, infrastructure, or expertise). For example, a capacity evaluation for Africa was performed in 2021 with data from 101 respondents from 69 institutions and 30 countries (**Figure 1a**). Each institution's capacity is reflected by a number between 1 (full capacity for OA research) and 4 (lack basic infrastructure).

Based on these evaluations, the OA-ICC developed a multi-level capacity building program from basic training (level 1) to collaborative research (level 4), tailored to the countries' needs (**Figure 1b**). Trainers are selected based on their expertise and the specific focus of each course. Originally, these experts primarily originated from well-resourced countries, but when available, local experts are always prioritized. Participants from previous training courses were engaged as trainers in the most recent editions. The training courses are based on active learning with clear deliverables (e.g., a country-specific action plan or a scientific publication) and have varied focus (e.g., chemistry, biology, data management, communication), depending on regional needs and the evolution of the scientific field. The courses also have been adjusted based on feedback of prior participants.

Following OA best practices can be challenging for some institutions, as it requires expensive equipment, infrastructure, and trainings. These limitations are partly overcome by promoting collaboration with scientists from well-resourced countries; however, the trainings are also developed around simplified best practices adapted to the participants' current capabilities (as evaluated through a pre-evaluation, e.g., **Figure 1a**) that allow meaningful observations to be made (e.g., Edworthy et al., 2022) and that test relevant hypotheses. Some Level 3 and 4 courses have been organized around a

(a) Capacity Evaluation for OA Research in African Institutions



(b) Location of OA-ICC Training

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
	Basic Training *Theory, co-design, strategic plan*	**Advanced Training** *Practicals, e.g., chemistry, biology, monitoring, multiple stressors*	**Advanced Training** *Practicals, e.g., communication, experimental design, meta-analysis, data reporting*	**Coordinated and Collaborative Research, and Joint Experiments**
2014	Chile			
2015	New Zealand, China, South Africa			
2016	Mauritius*, Mexico, Saudi Arabia	Mozambique, Mexico		
2017	Senegal, Fiji*	Mauritius*, Chile		
2018	Jordan, Ecuador	Chile	Hawaiʻi*, Monaco, Kuwait	Sweden
2019	Colombia*, Iran	Monaco (2x), Kenya		
2020–2021 (covid)				
2022	Sweden	Peru	Monaco	
2023			Monaco, Costa Rica	Monaco
2024	Liberia		Monaco	

*Trainings organized by The Ocean Foundation (lead organization), with funding from the US Department of State and/or the Government of Sweden.

(c) Origin and Number of Participants Involved in OA-ICC Training

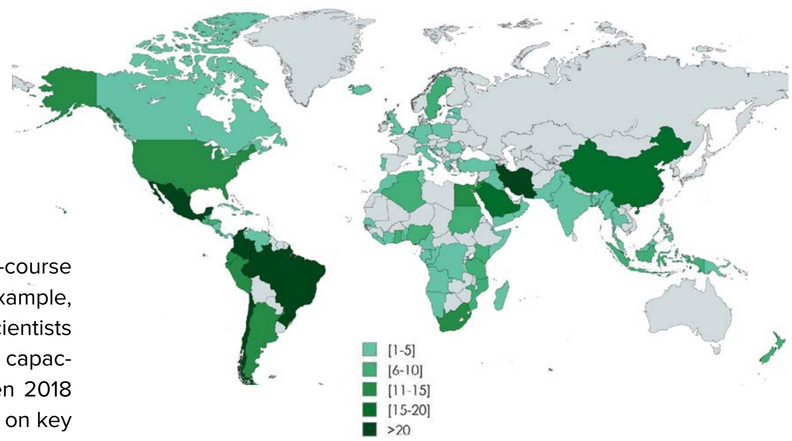


FIGURE 1. (a) Results from a gap analysis survey of in-country researchers to assess African institutions' ability to study ocean acidification (OA). (b) Host countries of the Ocean Acidification International Coordination Centre (OA-ICC) training since 2014. (c) Locations and numbers of participants involved in OA-ICC training workshops from 2014 to 2024.

joint OA experiment over two to three weeks, spurring post-course scientific collaboration and joint publication of results. For example, in the context of an IAEA Coordinated Research program, scientists from 13 countries who were previously trained by the OA-ICC capacity building program designed a global experiment. Between 2018 and 2023, they collected data on the long-term impact of OA on key local seafood species. These high-level training courses take a holistic approach that includes concepts from both chemistry and biology to answer the scientific questions trainees seek to investigate (e.g., What is the impact of OA on my local seafood species?).

Several indicators (Figure 2a) are collected both directly after the training (self-evaluation, learning outcome) and two years later (self-evaluation, bibliographic analysis) to answer practical questions (e.g., Was the course extensive enough? Was it well organized?). Learning outcomes are evaluated through pre- and post-course tests that evaluate the use of key scientific concepts and implementation of knowledge about the training subject (e.g., Did the participants start to work on OA after the course? Are they publishing on the topic?). In addition to course quality metrics, impacts on a global scale are also considered. For example, the OA-ICC capacity building program aims to increase the number of IAEA Member States reporting OA data toward SDG 14.3.1.

RESULTS

The OA-ICC has hosted 31 OA trainings for over 500 participants from 108 countries (Figure 1b,c), with the large majority (91%) of trainees coming from the Global South. Most trainings were levels 1 and 2 (59%, Figure 1b), but since 2018, more advanced trainings have been organized, including some focusing on collaborative research (level 4). Several participants have taken multiple trainings at increasing levels (52 participants were involved in more than one training). Some OA-ICC program trainees have become established experts in their home countries and are publishing high quality OA science (e.g., Edworthy et al., 2022).

While the number of training opportunities are typically used as a metric of success, other indicators enable a more complete evaluation of individual (e.g., career), institutional, and national use of the transferred knowledge. For example, pre- and post-course tests showed that the number of OA scientific concepts correctly used by participants increased after the course (Figure 2a). Self-evaluation two years after the training revealed that all surveyed participants report an increase in OA work post-course (Figure 2b). A bibliographic analysis also showed that the probability that trainees published on OA increased 3x within two years after the training (Figure 2a). With these data, future course participants can be selected on the basis of likely future OA science contributions. For example, selecting early career participants with experience in scientific publishing considerably increases their probability of publishing on OA.

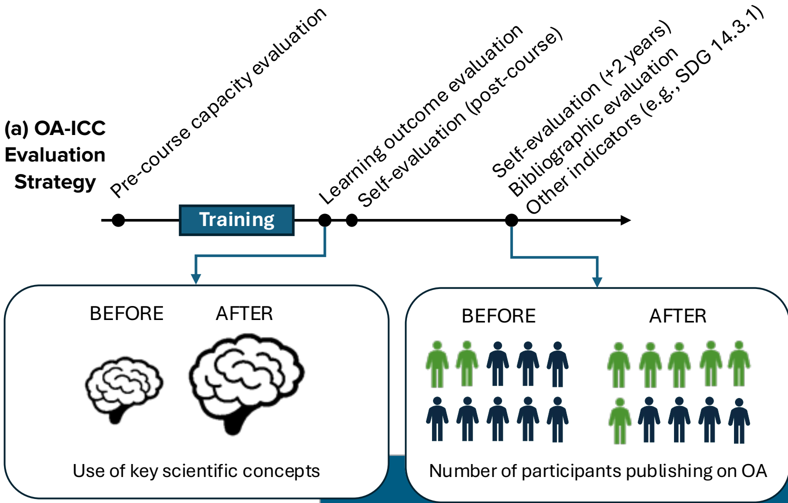


FIGURE 2. (a) OA-ICC evaluation strategy and examples of indicators. (b) Example of self-evaluation conducted two years after the training (% of "yes").

(b) Examples of Self-Evaluation Conducted Two Years After Training

QUESTION	CHINA 2015 (N = 12)	SOUTH AFRICA 2015 (N = 14)
LEARNING OUTCOME	**1 = a little; 5 = a lot**	
The course helped me to have a broad overview of the field of ocean acidification…	4.7±0.1	4.5±0.1
The course helped me to develop my critical scientific thinking…	4.6±0.2	4.4±0.2
The course helped me to better design experiments…	4.3±0.3	4.2±0.3
The course helped me to extend my scientific network…	4.3±0.3	4.8±0.2
APPLICATION OF KNOWLEDGE	**% of "yes" answers**	
Were you working on ocean acidification before the course? [yes/no]	58%	29%
> If YES, did you expand your ocean acidification research after the course? [yes/no]	86%	75%
> If YES, did the course contribute to this expansion? [yes/no]	100%	100%
> If NO, are you working on ocean acidification now? [yes/no]	50%	64%
> If YES, did the course contribute to your starting to work in this field? [yes/no]	100%	93%
NETWORKING	**% of "yes" answers**	
Are you part of any ocean acidification network? [yes/no]	17%	93%

LESSONS LEARNED

After 11 years of the OA-ICC capacity building program, lessons learned include:

- A capacity building program should be goal-oriented and evaluated accordingly using indicators of success beyond just the number of training opportunities, similar to a well-designed experiment. These goals can be set for the participant(s), their institution(s), and/or their country(ies).
- A capacity evaluation should be performed beforehand to prioritize resources and ensure that the training is adapted to local needs.
- A training program should constantly evolve, with varying levels of complexity.
- Data collected through formal and informal evaluations leads to improved procedures (e.g., selection of participants) and teaching methods adapted for different learning environments.
- A long-term strategy should be developed to follow up with and continuously support key participants, institutions, and countries in order to increase the probability for sustainable use of the transferred knowledge.

This model for goal-oriented and evidence-based improvement of capacity building programs can be used by intergovernmental organizations, nongovernmental organizations, and other institutions engaged in capacity development.

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