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Assess the environmental health status of macrophyte ecosystems using an oxidative stress biomarker. Case studies: The Gulf of Aqaba and the Lagoon of Venice

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Abstract

The aim of this work was to evaluate the implementation of the oxidative stress biomarker (LPO) for the assessment and monitoring of the ecological status of macrophyte in relation to potentially toxic elements (PTEs) in the Gulf of Aqaba (Jordan) and the Lagoon of Venice (Italy). Results showed that the anthropic influences related to PTEs of the examined areas are evident. Moreover, changes in the LPO levels can precede significant changes in ecological health status of macrophyte ecosystems that can be used in the future as an early warning tool for the assessment and monitoring of polluted ecosystems worldwide.

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Keywords: Ulva; oxidative stress; macrophytes; malondialdehyde.

1. Introduction

Marine macrophytes (macroalgae and angiosperms) are important biotic components in aquatic environments. They have a vital role in productivity and nutrient cycling in aquatic ecosystems [1]. Macrophytes can be used to assess and monitor the ecological status of coastal and transitional water bodies, because of their structural and

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functional key role in the marine ecosystems [2]. They are sensitive to anthropogenic stressors, modifying their structure and function accordingly [3]. Thus, the importance of these aquatic plants to provide information on the health of ecosystem, and consequently used as early warning signals for general or particular stress is highlighted [4].

Anthropogenic pollutants have been known to possess adverse effects capable of degrading the ecological integrity and functionality of marine environments [5]. Nowadays, several types of PTEs reaching the marine environment threaten macrophytes and consequently deteriorate the ecosystem health. Sewage sludge, fertilizers and pesticides, persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), polychlorobiphenils (PCBs) as well as heavy metals are examples of PTEs released into marine environments because of the overuse of agrochemicals, mismanagement of industrial activities and waste disposal [6].

In the intertidal zones of the marine environment, macrophytes can be exposed to several PTEs resulting in intermittent intracellular oxidative stress conditions by the accumulation of reactive oxygen species (ROS) [7,8]. There is evidence indicating that different types of PTEs can stimulate the production of ROS, which correspond to oxidative stress damage causing toxic effects in aquatic organisms [9].

On the other hand, chemical analytical methods may detect and quantify specific concentrations of the PTEs, but these do not provide direct information on the potentially adverse effects on the ecosystem [10,11]. Therefore, recently, growing interests arise on the use of molecular biomarkers to determine the oxidative damage produced by PTEs on the biotic components that inhabit the aquatic environments. These methods can be useful, quick and cost effective tools to provide an early warning signal on ecosystem health conditions and disturbance [12,13].

Oxidative stress deteriorates the structure and functionality of the cells. Fatty acid rich structures such as the cell membranes may be oxidized by excess production of ROS, causing a loss of rigidity [14] and permeability resulting ultimately in cell death [15,16]. In the oxidation process known as lipid peroxidation, the lipid peroxide Malondialdehyde (MDA) is one of the major end products of this process [17]. The determination of MDA content is a widely-used method to estimate the oxidative stress level by estimating the formation of lipid peroxides in biological material [18]. The estimation of lipid peroxidation (LPO) is considered as a highly predictive value as a biomarker of pollution effects [19].

The present study aims to describe the development of an innovative early warning tool, based on the implementation of the lipid peroxidation oxidative stress biomarker, for the assessment and monitoring of ecological status in response to PTEs in different marine environments. For this purpose, two macroalgal species of the genus Ulva have been proposed as good biosentinels [20,21]. These macroalgae have a widespread distribution, are sedentary, widely studied, readily available, sensitive to environmental changes and can be easily maintained in laboratory conditions [22,23]. Their high surface/volume ratio, provided by a laminar structure and a structurally uniform and physiologically active thallus [20] are other favorable characteristics.

The Jordanian coastline of the Gulf of Aqaba (GA) is the only marine access of Jordan. Several activities developed on the coastal area includes tourism, industrial constructions of new ports and resorts accompanied by intensive shipping and terrestrial transportation, which increased the pressures on the marine ecosystem of the gulf [24]. Several PTEs have been discharged into the coastal areas as a result of the lack of environmental awareness, fishing activities, shipping processes, oil and hazardous material spills and the phosphate industry [25].

In the Lagoon of Venice (LV) the ecological conditions are affected by the past industrial activity of Porto-Marghera, agricultural drainage, urban sewage [26], waste incineration, and boat engines [27,28]. Different PTEs have been discharged in the lagoon and accumulated into the sediments [29] and into the macroalgal tissues [30]. Both these locations, the GA and the LV, may contain concentrations of PTEs which can generate oxidative stress in the macrophytes that live in these environments.

2. Materials and methods

2.1 Sites description

Ulva species were collected from two regions: The Lagoon of Venice (LV) in Italy and the Gulf of Aqaba (GA) in Jordan during November 2016 (Fig. 1). In the LV three sites were selected: Santa Maria del Mare (SMM) was chosen as an uncontaminated site with high ecological status as reported by [31]; San Giuliano (SG) influenced by