BioTechnology
ISSN: 0974-7435

BioTechnology: An Indian Journal

Review|Vol18Iss02

Mediterranean Hydrothermal Vent Systems' Ecological and Biotechnological Importance

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Received date: February 12, 2022; **Accepted date:** February 15, 2022; **Published date:** February 28, 2022

Abstract

The Marine hydrothermal systems are a type of extreme environment associated with subsurface volcanic activity, and they are characterised by harsh chemo-physical conditions, such as high CO2 and H2S concentrations, and low pH. Such environments have a significant impact on living creatures, forcing them to develop adaptive techniques in order to live. Researchers have been drawn to hydrothermal systems because of their vast ecological and biological significance. These acidified ecosystems are important natural laboratories for predicting the effects of global environmental changes, such as ocean acidification, at the ecosystem level, by observing the responses of marine organisms to environmental extremes. Hydrothermal vents are also renowned for being excellent sources for isolating thermophilic and hyperthermophilic microorganisms with biotechnology potential. This review, which tries to provide a picture of the ecological properties of the principal Mediterranean hydrothermal vents, focuses on this dual aspect. The physiological responses, quantity, and distribution of biotic components are investigated by focusing on necto-benthic fauna and prokaryotic communities, which are known to play an important role in the dynamics of marine ecosystems and serve as indicator species. The importance of hydrothermal vents as a source of bioactive chemicals will be discussed, as well as the scientific interest in them.

***Keywords:** Hydrothermal vents; Benthos; Prokaryotic; Environmental change; Bioactive molecules*

Introduction

Extreme conditions have characterised our planet since the beginning of time, and they have been preserved over time in a number of unique locations, including extremely cold and hot regions, anoxic basins, deep sea, hydrothermal vents, and areas with harsh pressure, salinity, nutrient concentration, and oxygen availability. All of these factors contribute to a perpetual questioning of life's boundaries. The interest that these settings have on the scientific world is multifaceted, because a better understanding of them allows for both a look back and a look forward, as a valuable resource for predictive studies on future scenarios and the prospect of new discoveries. Hydrothermal vent systems (HVSs) are tectonically active ecosystems that are classed as terrestrial, deep-sea (DHV), or shallow-sea (SHV) depending on location and water depth [1]. Marine hydrothermal systems (HSs) have received less attention than their terrestrial counterparts, despite the fact that they are widespread and new ones are discovered on a regular basis. SHVs and DHVs exhibit considerable ecological distinctions, despite the fact that their cut distances are only 200 metres. Submarine volcanoes, island and intra-oceanic arcs, ridge habitats, intraplate oceanic volcanoes, continental edges, and rift basins are just a few of the diverse active settings where SHVs can be found [1]. They could be considered intermediate between terrestrial and off-shore geologic systems because their water source is a mixture of meteoric, magmatic, groundwater, and/or seawater. SHVs are complicated and dynamic for these reasons, as well as their location in the euphotic zone. DHVs, on the other hand, are distinguished by a complete lack of light, severe temperatures (up to 400 °C), and large thermal gradients between vent fluids and the surrounding saltwater [2]. HSs were once thought to be inhospitable to all forms of life, but new study has revealed that at the heart of these systems, there is a thriving microbial community capable of supporting an active trophic web despite the harsh environmental circumstances. Microorganisms that endure severe physical and chemical gradients, as well as dietary requirements and total metabolic pathways best adapted to such habitats; have a negligible impact on hydrothermal conditions [3]. Microbial communities perform a critical ecological supporting role in both types of settings (DHVs and SHVs) by converting inorganic chemicals produced from vent emissions into biomass. Microorganisms are thus involved in processes such as the synthesis of organic matter, its breakdown or mineralization, metal cycles, and interactions with fauna (Figure 1). Unlike DHVs, where the ecosystem's functioning is mostly dependent on chemosynthesis, SHVs' primary production is based on both photosynthesis and chemosynthesis processes, which are enabled by sunlight and reduced chemical oxidation as energy sources. Free-living microorganisms connected with discarded vent fluids, free-living microorganisms on the surface of flowing vent waters, or symbiotic forms associated with invertebrates are all involved in these microbial processes at the base of the hydrothermal trophic food chain [8]. Indeed, the outflowing fluids enriched in iron, sulphides, and gases, which are used by the symbiotrophic invertebrate, control the occurrence and distribution of benthic organisms in DHV; in SHV, it is influenced by the distribution of free-living microbial communities. The unexpected discovery of life in these seemingly unfriendly habitats has piqued researchers' attention, but the problem extends far beyond examining the diversity they contain. This review focuses on the biodiversity of Mediterranean marine hydrothermal vents, with a special emphasis on necto-benthic and microbial communities. Furthermore, the scientific significance of such settings as natural laboratories and ecological models for studying future scenarios, understanding how their conditions formed past living groups, and as a valuable source in the bioprospecting sector will be investigated. It is undoubtedly geared at exposing the major gaps that now exist for these yet-to-be-discovered habitats and their incredible biotechnology potential.

Environmental Parameters

HSs were previously referred as as ecosystems that were difficult to access, poorly investigated, characterised by a lack of life-forms, and, most importantly, as regions located at extremely deep depths. The finding of SHVs has shown that hydrothermal sites can be found at shallow depths over the years. SHVs are systems that are found up to 212 m deep, whereas DHVs are those that are found deeper than 212 m [13]. Temperature and depth, which affect light radiation and pressure, are thus the two fundamental environmental variations between SHVs and DHVs. Furthermore, the two HSs could differ due to the presence or absence of reduced chemicals and metals, as well as different concentrations of these compounds and metals.

Temperature

Because just a few eukaryotes are well suited to high temperatures, temperature has a significant impact on biota distribution. In both oxy and anoxic settings, it regulates the dispersion of phototrophic organisms [14]. The temperature of the fluids in SHVs ranges from 10 to 119 °C, with temperatures reaching 95.8 °C in the sediments. The temperature of the fluids in DHVs can reach 400 degrees Celsius, while seawater seeping deep into the earth's crust can produce fluids with a temperature of 1200 degrees Celsius [20]. Low temperature (up to 50 °C), medium temperature (up to 200 °C), and high temperature (up to 400 °C and higher) are the most common classifications for venting fluids [21]. Despite the harsh conditions, it has been discovered that the majority of the biota linked with vents lives at temperatures between 10 and 25 °C. Shallow and deep Mediterranean HVs are equally represented, with temperatures exceeding the boiling point of water (see Vulcano and Panarea Islands), but never exceeding 135 °C, owing to their proximity to 1200 m. Unlike DHVs, which rely solely on chemosynthesis for primary production, SHVs rely on photosynthesis as well, thanks to the availability of light radiation. The SHVs are model sites for studying global environmental changes such as ocean warming and acidification due to the cohabitation of these two metabolisms, high CO2 concentrations, and better accessibility.

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pH

SHV hydrothermal fluids are typically high in CO2 (95–98 percent of total fluid composition), present as gas bubbling, with little sulphide and methane coemission. The active emissions of these CO2-dominated fluids change the carbonate chemistry of the saltwater around the HVs, leading in pH values lower than ambient seawater (acidification), having consequences for the entire ecosystem. Furthermore, HVs have a broad variety of inorganic chemical compounds generated by hydrothermal activity, which contributes to their mineralogical richness and complexity. Minerals like these could operate as inorganic surfaces that encourage the synthesis of organic molecules, but they could also create chemical gradients that encourage the interaction of electron donors and acceptors. Because HVs expose entire communities to a lifetime of increased CO2 levels, they serve as natural laboratories for measuring the effects of ocean acidification on the structure of marine ecosystems. The chemical characterization of extreme compounds is the most difficult phase, but it is also the most important for understanding their properties and determining the best application for them. The significant difficulty of determining EPS necessitates the creation of new purification protocols, microscopic examination, and sensitive spectroscopy approaches. Furthermore, carboxylesterases, lipases, and cellulases have been demonstrated to be particularly appealing enzymes for a variety of chemical sectors, including food, laundry, and pharmaceuticals. The major issue in enzyme research is finding compounds with new enzymatic activity and increased stability, and deep hydrothermal vents, as recently reviewed by Jin et al., provide an excellent paradigm for this type of research.

Conclusion

The importance of marine hydrothermal vent systems as ecological and bioprospecting models is highlighted in this paper, which focuses on the Mediterranean region. We demonstrated here that most studies focus on shallow systems, whereas knowledge of deep systems is more fragmented, both in terms of bacterial diversity and isolation of new physiologically active compounds. In terms of microbial communities, archaeal populations are understudied in both shallow and deep settings. Other inventive techniques to filling the existing gaps in the topic could also be beneficial. This is the case with new generation robotics and census actions based on Citizen Science and Local Ecological Knowledge, which are appropriate tools for involving not only researchers but also the general public. By following these tactics, it will be feasible to continue exploring the seafloor and find additional shallow places and hydrothermal emissions that are easier to reach for divers.

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