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Development of a 128-channel multi-water-sampling system for underwater platforms and its application to chemical and biological monitoring

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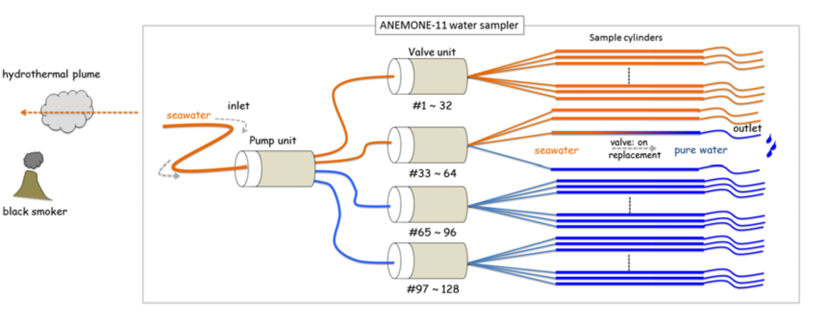
GRAPHICAL ABSTRACT



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H I G H L I G H T S

- A 128-channel water sampler for AUV and ROV exploration was developed.
- The sampling volume and rate were 40 mL and 40 mL min^{-1}, respectively.
- Observations at a hydrothermal area in the Okinawa Trough were discussed.

A R T I C L E I N F O

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A B S T R A C T

We developed a new multi-water-sampling system, ANEMONE-11, for autonomous underwater vehicle and remotely operated underwater vehicle exploration. Water samples are continuously collected by the ANEMONE-11 sampler by an *in situ* water pump at 40 mL/min and are sent to a selection valve unit that consists of 128 valves connected to 40 mL sampling bottles (50 cm in length). Each valve in the unit is selected and opened at preprogrammed intervals. We also discuss the results of observations at a hydrothermal area in the Okinawa Trough.

1. Introduction

Deep-sea hydrothermal activity is an important topic in oceanic mining. It was discovered at the Galapagos Rift in 1978 and is one of the most important sources of heat and chemical flux into the ocean (Corliss et al., 1979). Hydrothermal fluid, which originates from interactions between seawater and hot rock beneath the seafloor, contains large amounts of heavy metals and reduced chemical species, e.g., hydrogen sulfide, methane, Mn^{2+}, and Fe^{2+}. These heavy metals are precipitated as sulfides, sulfates, carbonates, and oxide minerals, and it is expected that rare metals from these seafloor hydrothermal deposits will be applied to industrial activity. As of November 2011, the number of known hydrothermal sites is 593 (InterRidge Vents Database, 2011), and other explorations are still in progress to discover new hydrothermal fields. To investigate a new hydrothermal field, hydrothermal fluid signatures such as ^{3}He, reduced gases, metals, physical conditions [pH, oxygen reduction potential (ORP)], and turbidity anomalies can be used for detection and ranging (Baker, 1990; Kawagucci et al., 2008). In addition to the seawater chemistry, biological constituents produced by life forms in hydrothermal habitats, such as adenosine triphosphate (ATP) and other metabolites, are useful tools in hydrothermal vent surveys (Fukuba et al., 2011). Many institutes worldwide have developed *in situ* analyzers and chemical/biological sensors that measure certain components at the seafloor. Several *in situ* analyzers for iron, manganese, and other chemical elements (Provin et al., 2011; Okamura et al., 2004) and for biological parameters such as ATP (Fukuba et al., 2011) and microbial gene (Fukuba et al., 2011) have been practically used. Other systems use micro total analysis systems (μTAS) to miniaturize the entire system (Fujii and Fukuba, 2007). The chemical sensors include pH, ORP, hydrogen sulfide, and others that use electrodes (Prien, 2007). Although these *in situ* measurements are quite useful in marine research, the measurable components are currently limited. For instance, only a few *in situ* analyzers can measure nutrient salts (nitric acid, nitrous acid, ammonia, phosphoric acid, and silicic acid), which are energy sources for phytoplankton in the photic zone (surface to ∼300 m depth) (Hanson, 2000). Despite the increased interest in dissolved carbon dioxide because of global warming and carbon capture and storage (CCS) projects, currently no *in situ* sensors can directly measure dissolved carbon dioxide.

Generally, chemical components immeasurable by *in situ* sensors are performed in an offshore or onshore laboratory after water sampling and storage. Here we review water sampling systems for oceanic study. Water sampling systems can be broadly divided into four categories on the basis of water sampler container capacity and the sample intake method (Table 1).