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Water Quality and Risk Assessment in Rainwater Harvesting Ponds †

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Abstract: The aim of this study was to investigate the water quality of rainwater harvesting ponds of Istanbul which are used for irrigation. For this purpose, samples were collected from 17 rainwater harvesting ponds during the summer of 2022 and selected physicochemical and biological characterization of these samples was carried out. Cyanobacterial bloom was observed in 2 ponds out of 17 and the dominant species were potentially cyanotoxin producers (*Microcystis*, *Aphanizomenon*, *Dolichospermum*, *Planktothrix*, and *Cuspidothrix*). It is found that one of these ponds was not proper for irrigation purposes due to microcystin presence. To increase the water quality in these reservoirs, onsite management strategies should be taken into consideration.

Keywords: irrigation; rainwater harvesting; rainwater quality; water security; cyanotoxins; climate change

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1. Introduction

Environmental, economic, and climatic changes in many parts of the world put serious pressure on water resources, making a reliable alternative water supply a critical global concern [1]. Rainwater harvesting is a sustainable water management practice that involves collecting and storing rainwater for later use. The collected rainwater can then be used for a variety of purposes, including irrigation, landscaping, and even household uses [1]. Since rainwater harvesting is an off-grid water supply [2], it contributes to reduce the pressure on the central systems decreasing the reliance on freshwater abstraction [3] particularly in areas where water is in short supply or where the demand for water exceeds the available supply.

While determining the suitability of the water resource, water quality becomes a prominent issue. The harvested rainwater is generally of sufficient quality for non-drinking purposes [4]. However, due to various reasons (e.g., nutrient inputs, temperature increase, draught, etc.), cyanobacteria proliferation can occur in rainwater harvesting ponds and damage the water quality. Furthermore, some species can excrete cyanotoxins that may enter the agricultural fields by irrigation and cause environmental and public health problems. Thus, it is important to evaluate the potential contaminants of harvested rainwaters.

The goal of this research was to evaluate the water quality of rainwater harvesting ponds in Istanbul used for irrigation and assess their potential risks for non-potable usage.

2. Materials and Methods

The samples were collected from 17 rainwater harvesting ponds located in Istanbul (Türkiye) during the summer of 2022 (Figure 1). These ponds were built between 1965–

1989 in Istanbul and used for irrigation purposes in the neighboring agricultural fields. The active water volumes of the ponds varied in the range of 11.000–7.000.000 m^3 in which S11 has the highest volume followed by S16, (1.406.405 m^3) and S15 (1.103.386 m^3).

The water samples collected from the surface were kept under dark and cold conditions and brought to the laboratory immediately. Water temperature, pH, Dissolved Oxygen (DO), and conductivity were measured in situ via a portable multiparameter (650 MDS, YSI, Yellow Springs, OH, USA) at each sampling site. Total Nitrogen (TN) and Total Phosphorus (TP) were analyzed according to the methods outlined by the American Public Health Association [5]. The chlorophyll-*a* concentration was determined using the method described in ISO 10260 [6]. Phytoplankton samples were fixed by Lugol's iodine solution, and the phytoplankton enumeration was performed according to Utermöhl (1958) [7]. The microcystin concentrations were measured using liquid chromatography-high-resolution mass spectrometry (LC-HRMS) [8].

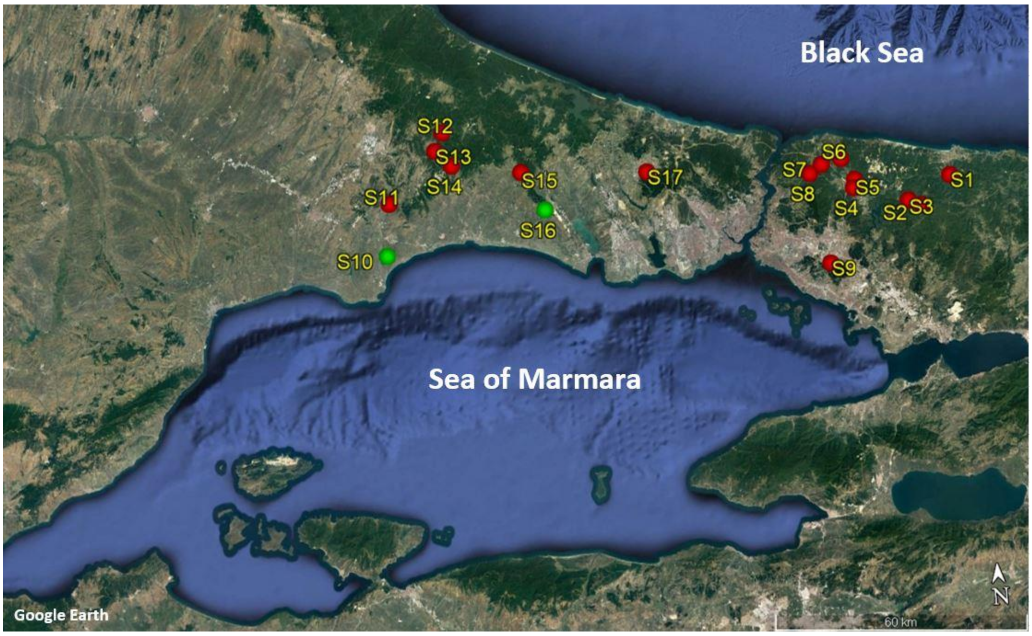

Figure 1. Sampling locations (S): Green dots indicate the rainwater harvesting ponds with cyanobacterial blooms.

3. Results

The physicochemical characteristics of the rainwater harvesting ponds are given in Figure 2. The water temperature ranged between 18–30 °C. The pH was measured between 6.5 and 9.2. A high variation was observed in the conductivity values, in which the highest conductivity was measured in S10 (890 µS/cm) and the lowest was recorded as 112 µS/cm in S14. While TP was measured below 100 µg/L in most of the ponds, the highest value was measured in S11 as 237.5 µg/L. Total Nitrogen was detected in the range of 0.7–1.9 mg/L in which the maximum value was detected in S16 followed by S10 (1.6 mg/L). Furthermore, a high variation was observed in the chlorophyll-*a* concentration in which the highest level was detected in S10 as 82 µg/L. Microcystin was found in S16 as 13.80 µg/L.

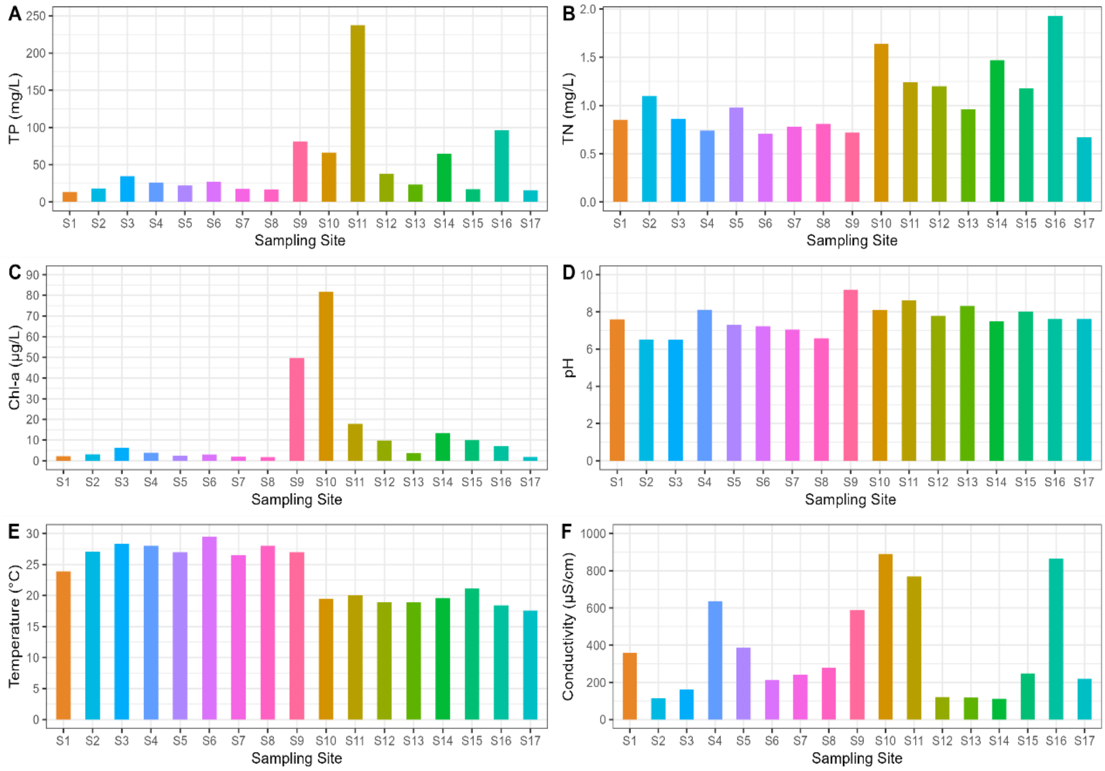

Figure 2. Physicochemical characteristics of the rainwater harvesting ponds during the summer 2022 (**A**) Total Phosphorous, (**B**) Total Nitrogen, (**C**) Chlorophyll-*a*, (**D**) pH, (**E**) Temperature, (**F**) Conductivity.

Cyanobacteria were detected in 3 samples (S10, S11, and S16) out of 17 ponds (Figure 3a). In two of these ponds, cyanobacterial blooms were observed, with Cyanobacteria comprising 82% of the community in S16 and 72% in S10. In detail, *Microcystis* sp. was responsible for the bloom in S16 while *Aphanizomenon* sp. and *Cuspidothrix issatschenkoi* were in S10 (Figure 3b).

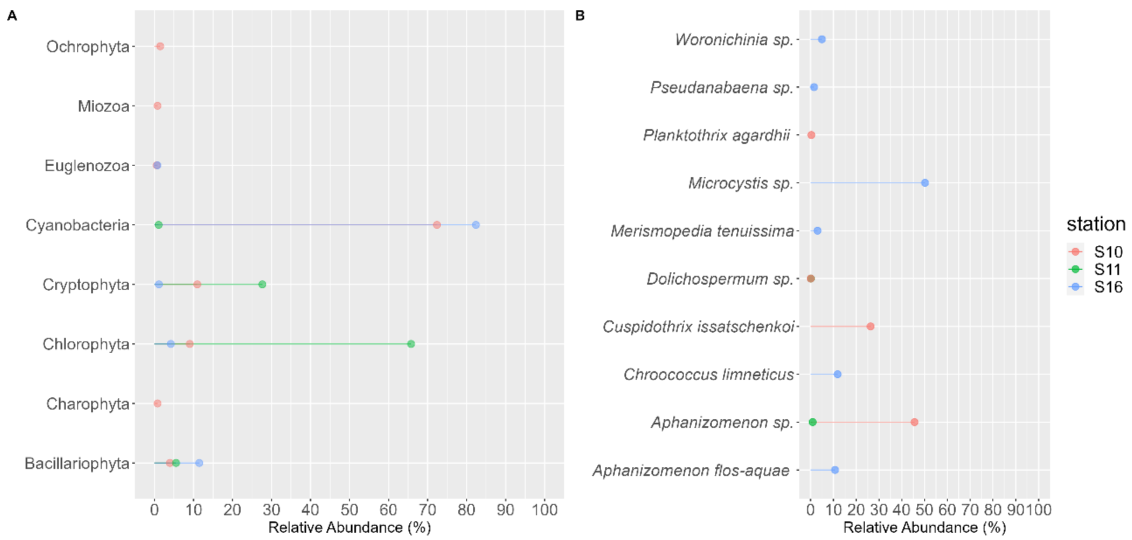

Figure 3. Phytoplankton community composition (**A**) phylum level, (**B**) genus level.

4. Discussion

Rainwater harvesting is a green method of providing water for agricultural practices since having access to adequate and safe irrigation water is crucial for the success of farming operations. Harvesting of rainwater is also known for a being straightforward, economical, and innovative solution contributing sustainability and resilience of water sources. Rainwater is considered a high-quality source of irrigation because it is nearly sodium-free and has a low sodium adsorption ratio, which helps to maintain the physical structure of the soil [2]. On the other hand, there could be some other constituents such as emerging untraditional substances pose a significant challenge to the use of rainwater harvesting for irrigation. Cyanotoxins are one of these components that threaten the ecosystem health.

Certain types of Cyanobacteria can excrete toxins those damages the liver (hepatotoxins), harm the nervous system (neurotoxins), and damage cell integrity (cytotoxins) [9]. *Microcystis*, *Aphanizomenon*, *Dolichospermum*, *Planktothrix*, and *Cuspidothrix* are known genera-producing cyanotoxins [10–12]. Irrigation with water that contains cyanotoxins can have negative impacts on the quality and yield of agricultural plants. Since there is not any treatment for these components, these toxins can bioaccumulate in plant tissues. Then they may enter the food chain with the edible plants and pose environmental and human health risks [9]. Accumulation can vary depending on the type of plant and irrigation method used [13]. Overall, it was found that two ponds were not proper for irrigation purposes. To increase the water quality in these reservoirs, onsite management strategies should be taken into consideration.

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