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Original Article

Effects of aquatic plants on reducing salinity and cation concentrations in different types of water

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Abstract: The efficiency of some aquatic plants, i.e., *Azolla filicoides*, *Ceratophyllum demersum*, and *Lemna minor*, in reducing electrical conductivity (ECs) and some cations were studied in a laboratory experiment with three filter sizes (300, 400, and 500 cm³) for each plant and type of water. Two sources of water samples were collected: Shatt al-Arab (EC 7 dS m^{-1}) and Shatt al-Basrah water, collected on October 5, 2022 (EC 60 dS m^{-1}), and February 20, 2022 (EC 43 dS m^{-1} adjusted to 20 dS m^{-1}), respectively. Filtered water was kept in plastic containers while the EC and cations reduction efficiencies were calculated. Based on the results, *Azolla* had the highest reduction efficiency among the filters, followed by *Ceratophyllum* and duckweed for the filter size equal to 500 cm³. The other filter sizes were less efficient than those with a volume equal to 500 cm³ or greater. The different sizes showed varying abilities in reduction, all less than those of the 500 cm³ size.

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Introduction

The rise in population has resulted in increased water consumption, thus calling for other sources like saline water, wastewater, groundwater, wells, and drainage water to address the shortage in agricultural needs (Malash et al., 2005). As a result, researchers have thus concentrated on several key techniques and practices of agriculture targeted at using alternative water sources and enhancing soil fertility (Henderson et al., 1977), including inexpensive technologies that are easy to use. One such method is the green phytoremediation method, which can filter polluted water using organic plant-based filters like aquatic plants, which absorb pollutants and limit the spread of weeds, which is very economical.

Bioindicators such as aquatic plants are important in pollution detection and can be used as reliable means of removing pollutants from water bodies (Ingole and Bhole, 2003). These bioindicators can help explain the intricate interplay between an organism's response to environmental stressors and its susceptibility to lethal effects caused by chemicals. Due to their wide dispersal, multiplicity, and adaptability to changing habitats, different families of aquatic plants have been exploited as bioindicators of water pollution and are extensively utilized in biotechnology. Aquatic plants are effective in soil and water remediation due to their hereditary, physiological characteristics that enable them to store these pollutants in non-toxic forms within vacuoles (FAO, 1999).

Floating plants like Azolla, Chara, and duckweed develop tolerance towards contamination (Al-Zubaie et al., 2009; Al-Hamdaoui, 2021). To have a sustainable environment, the most preferable approaches to producing safe irrigation water from polluted sources include biological filters prepared from biomass. These filters can absorb pollutants and thus are potential eco-friendly phytoremediation technology that can curb invasive aquatic weeds and algae (Materac and Sobiecka, 2017). Therefore, this study aims to employ treated polluted water as an economically feasible alternative to fresh water in irrigation, thereby mitigating environmental pollution. Additionally, the research explores using aquatic plants of *Azolla filicoides, Ceratophyllum demersum*,

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and *Lemna minor*, as cost-effective solutions for treating saline irrigation water. This dual approach seeks to minimize environmental contamination while preventing these plants from being discarded as waste.

Materials and Methods

Water sampling: The first water source was the Shatt al-Arab River, with an EC 7 dS m^{-1}. The second source was the Shatt al-Basrah River, collected at two intervals: the first on 5/10/2022, with an electrical conductivity of 60 ds m^{-1}, and the second one on 20/2/2022, with an electrical conductivity of 43 ds m^{-1}. The conductivity was adjusted to 20 dS m^{-1} by mixing with desalinated water, the use of the dilution ratio equation as described by Ayers and Wested (1985): EC_1= [EC_a*a] + [EC_b (1-a)], where: EC_1 (mixture water) = Electrical conductivity of the desirable mix water (dS m^{-1}), ECa (cont. water) = electrical conductivity of desalinated water used for dilution (dS m^{-1}), a = proportion of the Shatt al-Basra water in the mixture EC_b (river water) = electrical conductivity of Shatt al-Basra water (dS m^{-1}).

The pH was measured using a pH-Metter (AMTAST-3) and the electrical conductivity (EC) using an EC-Metter (AMTAST-3) at 25°C. Calcium ions were determined by titration with a 0.01N Na2-EDTA solution, using Murxide as an indicator. Magnesium ions were calculated after determining total hardness and calcium hardness using the equation of Mg^{+2} mg L^{-1} = (general hardness - calcium hardness) * 0.224.

Na^+ and K^+ were measured using a flame photometer (JENWAY PFP7). Ammonium was assessed using the initial distillation method with a Microkjrldal apparatus, followed by titration with a diluted sulfuric acid solution (0.02N). Dissolved phosphorus was determined using the ascorbic acid method on a UVD3200 Spectrophotometer at a wavelength of 880 nm. The total hardness of the water was estimated by titration with a solution of Na2-EDTA (0.01M) using buffer solution and Erichrome Black-T as an indicator (EPT).

The filters used in the examination were (1) *Ceratophyllum demersum* filter: Samples of *C. demersum* were gathered from the marshes of Jubayish. They were cleaned to remove impurities and dirt, rinsed with tap water, and then distilled water. After air-drying, they were dried in an oven at 70°C. The dried samples were ground and stored in plastic containers until used for laboratory experiments. (2) *Azolla filicoides* Lam. (*Azolla*) filter: Samples of *A. filicoides* Lam. were collected from cultivated fields in Baghdad governorate. They were stored in tightly sealed plastic boxes until transported to the laboratory. The samples were cleaned to remove impurities and dirt, rinsed with tap water followed by distilled water, air-dried, and then dried in an oven at 70°C. They were stored in clean plastic containers until used for laboratory experiments to prevent contamination. (3) Filter plant of *Lemna* minor: Samples of *Lemna* L. were collected from Karmat Ali and stored in plastic containers till they reached the laboratory. They were then cleaned to remove impurities and dust, washed with tap water followed by distilled water, air-dried, and dried in an oven at 70°C. The samples were ground and stored in plastic containers to prevent contamination until laboratory experiments were performed.

Plastic tubes with a diameter of 7.5 cm and a height of 20 cm, ending in a conical shape, were used and attached to a valve to control the quantity and speed of water flowing from the filter. Glass wool was placed at the valve outlet to prevent the filtration material from leaking. The plastic tubes were secured on a wooden stand to stabilize them, according to Liu et al. (2000), for filter preparation and setup. The filters were used at three volumes, 300, 400, and 500 cm^3 for each aquatic plant. Then, the following types of water were passed through the stated filters at their respective salinity tiers: Shatt al-Arab water with an electric conductivity (EC) of 7 dS m^{-1}, Shatt al-Basrah water: First collection on 2022/10/five with EC of 60 dS m^{-1}, and second collection on 2022/02/20 with EC of 43 dS m^{-1}, adjusted to 20 dS m^{-1} by diluting with desalinated water.

The filtered water was collected immediately into sealed plastic bins and stored at 4°C until further analysis. This experiment was repeated four times

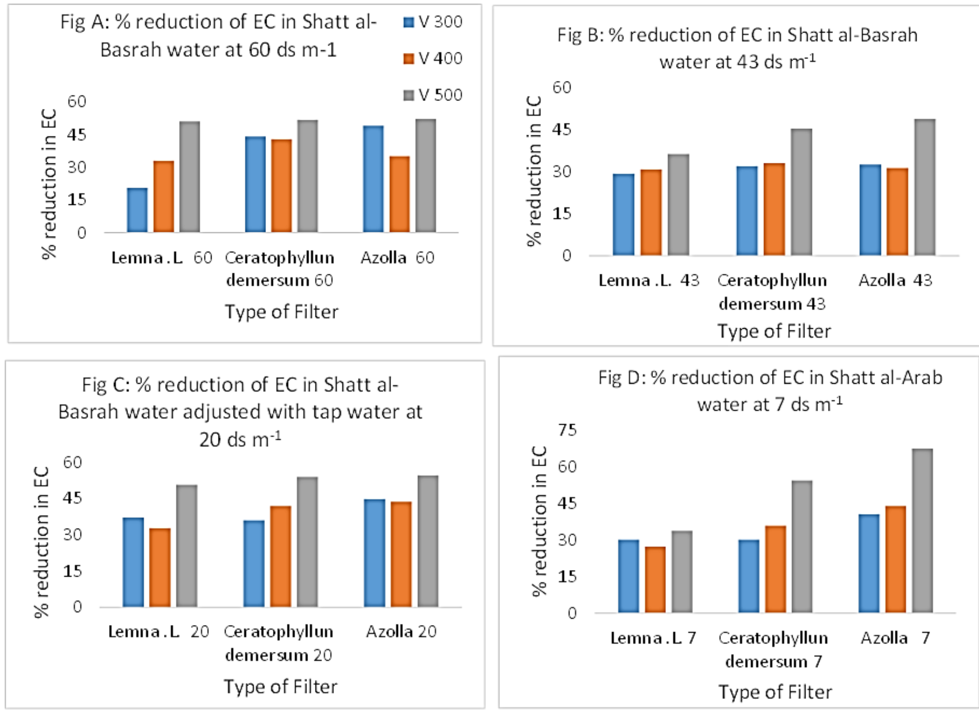

Figure 1. Percentage of reduction in EC values for Shatt al-Basrah water.

based on the water type and their electrical conductivity. The reduction efficiency of the concentration of the constituent elements of salinity was calculated using the following equation: Reducing efficiency (%) = (concentration before filtration - concentration after filtration) / (concentration before filtration) * 100.

Results and Discussions

The electrical conductivity (EC): The results confirmed the efficiency of filter types in reducing the EC values of water samples (Shatt al-Arab and Shatt al-Basrah with EC of 60, 43, and 20 dS m^{-1}). The 500 cm^3 filter volume exhibited the best reduction performance for all studied chemicals. Figure 1 (A, B, C, D) illustrates that the *Azolla* had the highest EC reduction using a volume of 500 cm^3, with reductions of 67.37, 52.16, 48.86, and 54.45% for Shatt al-Arab and Shatt al-Basrah waters with EC values of 20, 43, and 60 dS m^{-1}, respectively. The *Ceratophyllum* filter at 500 cm^3 volume ranked second, attaining reductions of 54.28, 51.82, 45.41, and 53.95% for the above-mentioned water types. In contrast, the *Lemna* filter showed the lowest reduction values for EC, reducing 33.66, 51.00, 36.26, and 50.60% for the studied water types in sequence.

These findings agree with Buffle (1988) and Senesi (1992), who confirmed the ability of natural materials to bind with metals to form natural-metal complexes. Similarly, Al-Haddad (2011) confirmed the reduction of EC in saline waters when passed through organic substances. Based on the results, the 400 cm^3 filter volume outperformed the 300 cm^3 volume in decreasing EC percentages for all water and filtration types. The increase in the extent of filters results in a thicker layer in contact with water and more pores, thereby enhancing the ion retention capability (Salman, 2001).

Cation reduction rate:

A: Calcium: According to the results, the *Lemna* (duckweed) had the highest performance in reducing calcium ions (Fig. 2A, B, C, D). The reduction rates were 51.17, 50.56, and 47.43% for Shatt al-Basrah water with electric conductivity values of 60, 43, and 20 dS m^{-1}, respectively, at a filter volume of 500 cm^3. Following this, the *Azolla* filter recorded calcium ion reduction rates of 50.78, 47.49, and 38.02% for Shatt al-Basrah water with electric conductivity values of 60, 43, and 20 dS m^{-1}, respectively.

B: Magnesium: The results showed that the

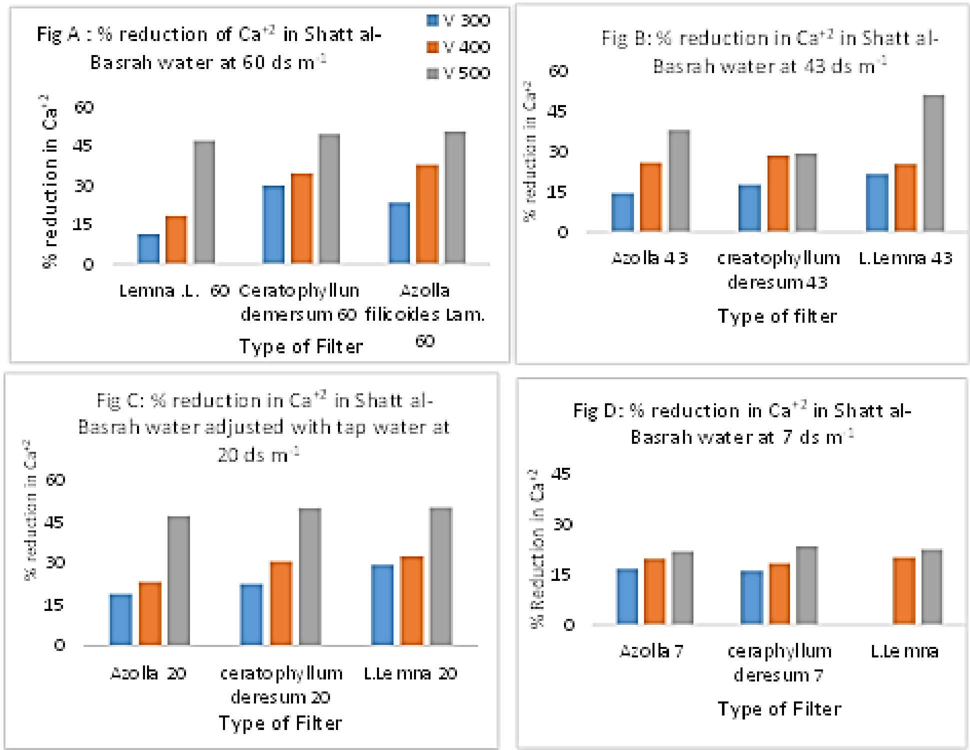

Figure 2. Percentage of reduction in Ca+2 values for Shatt al-Basrah water.

efficiency of magnesium ion reduction by filters increased with higher EC (Fig. 3A, B, C, D). *Azolla* filter has a high magnesium ion-reducing efficiency when water from Shatt al-Basra with an EC of 43 dS m^{-1}. Its best reduction efficiency in water was 66.01% with a filter volume of 500 cm³. Conversely, the reduction rates for other types of water reached 56.20, 60.49, and 55.03% for Shatt al-Arab and Shatt al-Basra waters with different EC (60-20) dS m^{-1}, respectively. The results suggest that the filter, at a volume of 500 cm³, decreases EC at percentages ranging from 63.29-60.76-57.61-55.31%. In particular, Shatt Al-Basra waters with an EC of 43 dS m^{-1} and Shatt al-Arab and Shatt al-Basra waters with an EC of 60 dS m^{-1}, respectively. Meanwhile, the Lemna filter decreased magnesium ion at percentages starting from 68.92-61.51-54.02-44.82% for a size of 500 cm³, Shatt Al-Basra water with EC of 60, 43, and 20 dS m^{-1} and Shatt al-Arab water.

Based on the results, the performance of reducing magnesium increases proportionally with the size and type of the filter. Increasing the dimensions of the filter increases the range of interstitial distances, thereby increasing the opportunity for contact with the passing water. EL-Baz et al. (2020) pointed out that the decrease in ion concentration is attributed to the phenomenon of physical adsorption because of van der Waals forces or hydrogen bonding while ions move from the solution to the surface of the filter material.

C: Sodium: The *Azolla* filter with a size of 500 cm³ performed well in sodium ion reduction, reaching 87.17% in filtering Shatt al-Arab water (Fig. 4A, B, C, D). Following this, the *Ceratophyllum* and Duckweed filters with the same size were reduced by 74. 80 and 74.69%, respectively, for Shatt al-Arab water. For the mixed water with an EC of 20 dS m^{-1}, the sodium concentration decreased by 53.68% with the *Azolla* filter, 53.57% with the *Ceratophyllum* filter, and 49.79% with the duckweed filter.

The results suggest that sodium ion reduction efficiency increased as the water EC increased, as seen in the Shatt Al-Basra water with EC of 60 and 43 dS m^{-1}. This finding aligns with Hashem et al. (1997), who determined that natural residues play a role in reducing EC and the concentrations of sodium and chloride.

D: Potassium: The type and size of the filter channel

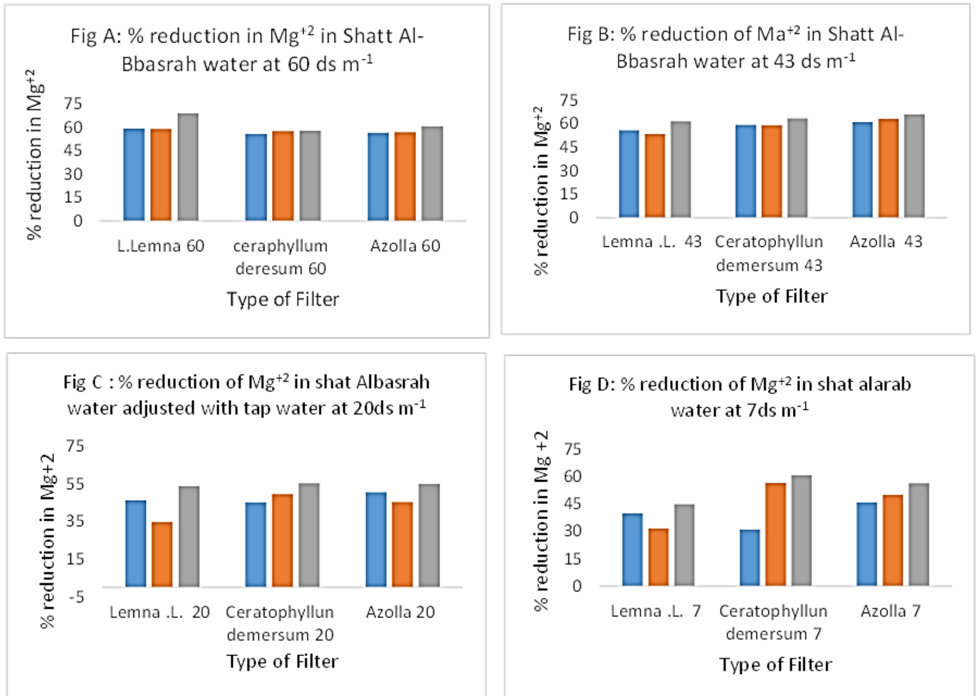

Figure 3. Percentage of reduction in Mg+2 values for Shatt al-Basrah water.

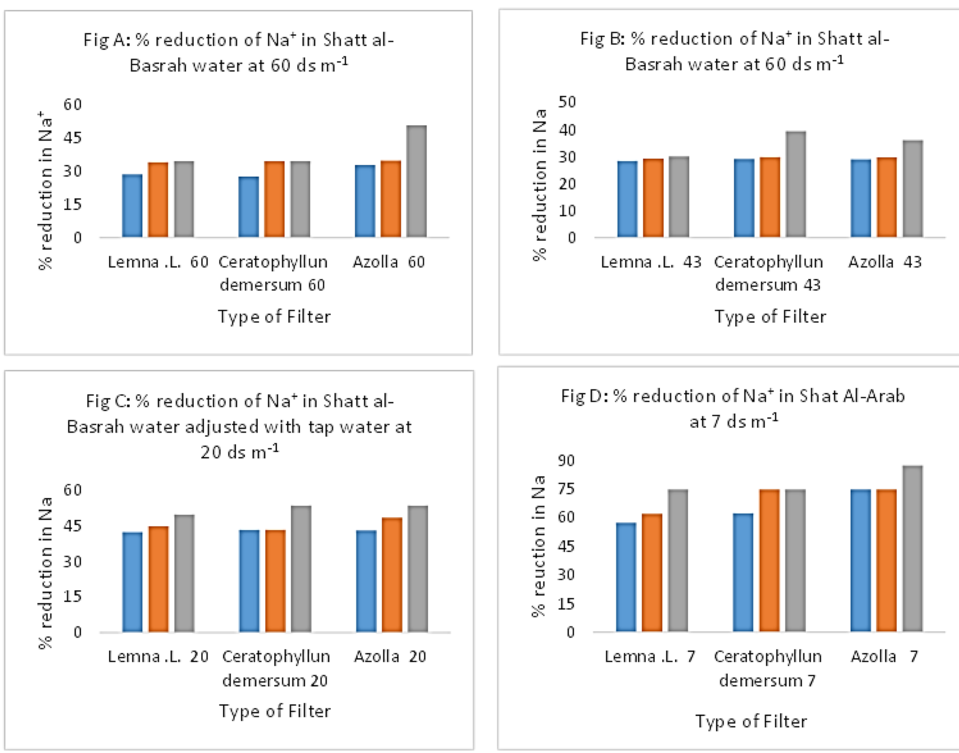

Figure 4. Percentage of reduction in Na+ values for Shatt al-Basrah water.

influence the reduction of potassium concentration in the pipeline over several distances (Fig. 5A, B, C, D). The 500 cm^3 filter decreased K by 50.43, 50.44, and 49.69% in water mixtures with EC up to 20 dS m^{-1} in the same filters. An *Azolla* filter with a 500 cm3 volume reduced the K concentration from 32.87 to 33.94%. This indicates that increasing water salinity decreases the filter's K reduction efficiency.

H: Ammonium: *Ceratophyllum* filter to reduce the ammonium concentration in the water had the highest

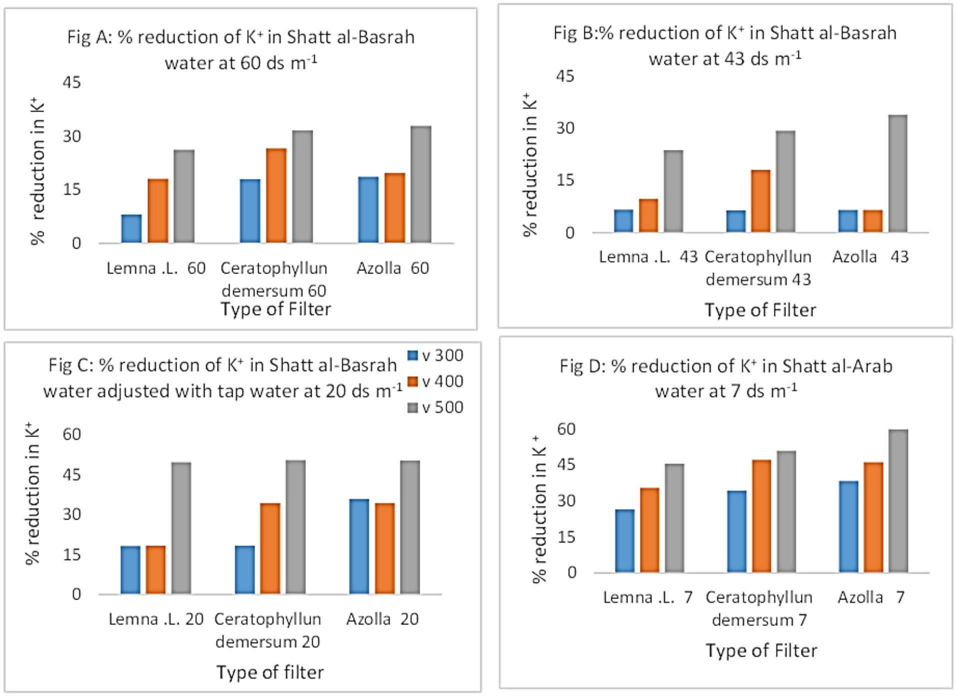

Figure 5. Percentage of reduction in K+ values for Shatt al-Basrah water.

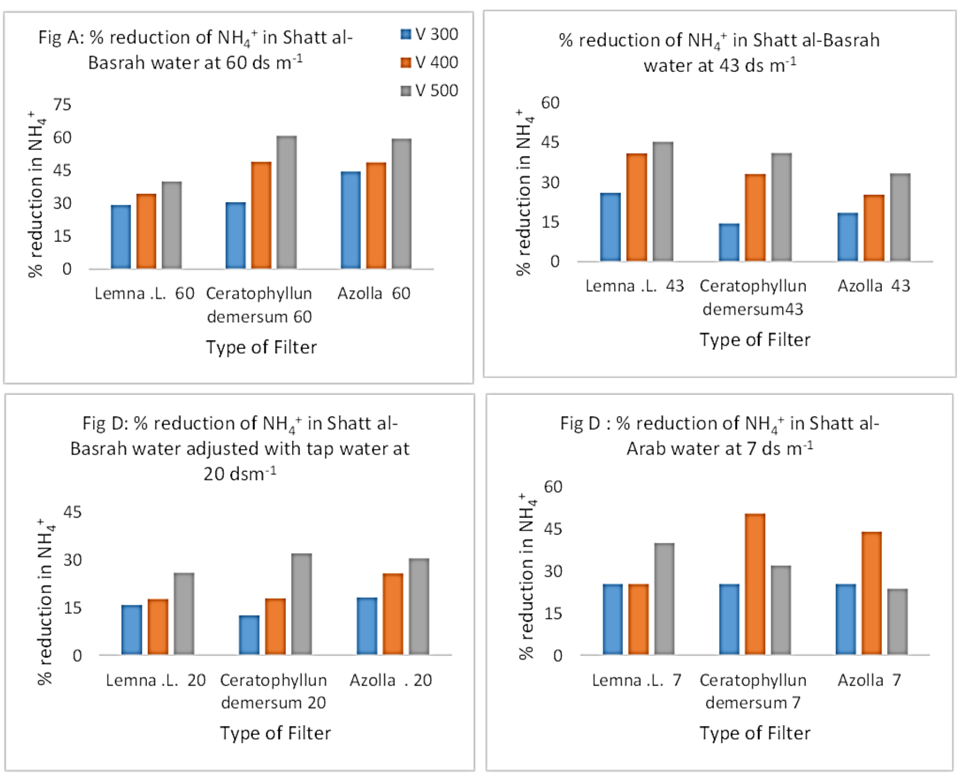

Figure 6. Percentage of reduction in Na+ values for Shatt al-Basrah water.

results in filtering the Shatt al-Arab water (Fig. 6A, B, C, D). The internal width of the *Ceratophyllum* filter was 500 cm^3, and the reduction rate was recorded at 50.33%, compared to 43.9 and 39.99% in equal-sized *Azolla* and Lemna filters, respectively. The performance of the *Ceratophyllum* filter increased with increasing water salinity. The reduction in Shatt al-Basra water with an EC of 60 dS m^{-1} changed to 59. 48%, while the duckweed filter completed a reduction of 40.03% for the same water quality and filter length.

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