



Involvement of Citizens in the Measurements of Water Salinity Using Test Kits in the Medjerda Watershed (Northern Tunisia)

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Abstract

Citizen science-based (CS) water quality monitoring (WQM) is considered as an innovative approach to enhance the hydrosystems' monitoring. The main objective of this study is to assess the salinity monitoring adopting CS-based WQM for Medjerda watershed, the main hydrosystem of Tunisia, using test kits. The study focused on total dissolved solids (TDS) and electrical conductivity (EC) of water. 96 samples were collected to assess water salinity, from 12 sampling sites located in the Medjerda river or its main tributaries. Water salinity monitoring tests, for wet (January–March 2020) and dry (June–July 2020) periods, were performed by test kits. Regression analysis, determination coefficient (R^2), F test, and Cronbach's alpha (α_C) test were performed to statistically assess the difference between the citizens' dataset and the standard values. Results show that TDS and EC-sensitive test kits were reliable for measuring a wide range of concentrations of 207–6073 ppm and 415–9999 $\mu\text{S}/\text{cm}$, respectively. There was also a good agreement between the citizen-based outcomes and the analytical methods. Nevertheless, the reliability depends on the citizen and the parameter to be tested. Finally, the rapid and simple measurements using the test kits appear suitable to be used as CS-WQM for Medjerda hydrosystem if instructions are strictly followed, and test kits are correctly used. With more consistent training, the test kits should allow for reliable, sensitive, and precise monitoring of water quality.

Keywords

Citizen science • Water quality monitoring • Test kits • Medjerda • Tunisia

1 Introduction

Water resources in MENA Region, and particularly in Tunisia, are subjected to many pressures related to urbanization, anthropogenic activities, agricultural expansion, and climate change (Bahri et al. 2016). These pressures reached the UN-Sustainable Development Goal 6 (SDG 6) to support and strengthen the participation of local communities in improving water and sanitation management (<https://www.un.org/sustainabledevelopment/water-and-sanitation/>). This goal was performed within Medjerda watershed (Fehri et al. 2019). The concept of citizen science (CS) is based on the potential social benefits of engaging, collaborating, and actively involving citizens in data collection and knowledge generation. CS is nowadays considered as an innovative approach to strengthen the water quality monitoring (WQM) capacity (Fehri et al. 2020; Jollymore et al. 2017). Test kits are considered as rapid testing tools to provide on-site water quality information for effective WQM. Water test kits have been used to analyze various chemical species of free chlorine, hydrogen sulfide, and formaldehyde (Arsawiset and Teepoo 2020), Hg (II) ions (Lan et al. 2018), dissolved oxygen @, Zn (II) ions (Takahashi 2014), hypochlorite (Ballesta Claver et al. 2004), and hardness (Capitán-Vallvey et al. 2003). Since data for water quality are limited in time as well as in space, often because of poor capacity building in hydrosystems' monitoring in Tunisia, CS-WQM in the measurement of salinity need therefore to be thoroughly used in Medjerda watershed. The main objective of this study is to assess the salinity measurements of a CS-WQM in Medjerda watershed using test kits.

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2 Materials and Methods

The study focused on total dissolved solids (TDSs) and electrical conductivity (EC) of water. A short training was organized for three citizens to ensure good reliability of the test kits' readings. Overall, 96 samples were collected for water salinity measurements, monitored in 12 sampling sites from the Medjerda river and some of its tributaries (Fig. 1).

Surface water salinity monitoring tests, for wet (January–March 2020) and dry (June–July 2020) periods, were performed by TDS/EC Meter 35,672 TE and laboratory conductimeter CD-4317SD. Water sampling sites, destined for irrigation purposes, were chosen based on the volunteers' facilities and the availability of reference WQM stations. The meter kits were immersed in the sampled water, after the numerical display was steady; the HOLD button was pressed and took it out of the sample water for checking the result. Regression analysis, based on Pearson correlation coefficient (PCC), determination coefficient (R^2), F test, and Cronbach's alpha (α_C) test were performed to assess the difference between the citizens' dataset and the standard values.

3 Results

3.1 Reliability of Test Kits

The results showed that TDS and EC-sensitive test kits were reliable for measuring a wide range of concentrations of 207–6073 ppm and 415–9999 $\mu\text{S}/\text{cm}$, respectively. The highest agreement between test kits and the laboratory conductometer, as indicated by PCC (0.989) and R^2 (0.982), was obtained for measuring TDS, while α_C (0.962) was obtained for measuring EC (Table 1). These observations indicate the suitability to use test kits to monitor water salinity.

3.2 Citizen-Based Outcomes for Test Kits Measurements

As mentioned in Table 2, results showed a good agreement between the citizen-based outcomes and the analytical methods for the three citizens. Nevertheless, the reliability depends on the citizen, the parameter to be tested, and its magnitude.

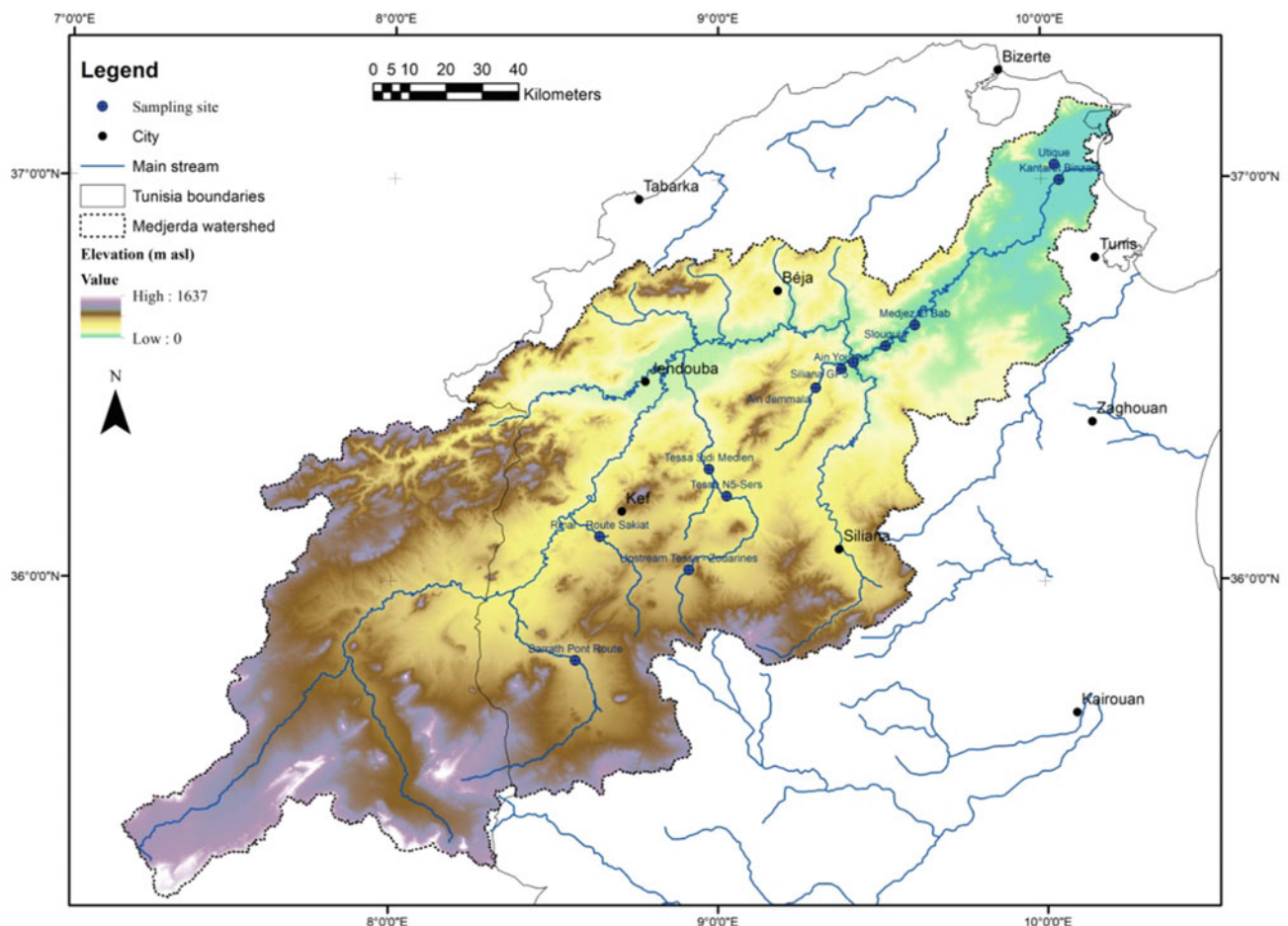


Fig. 1 Study area indicating sampling sites in the main stream of Medjerda watershed

Table 1 Results of statistical analyses testing reliability of test kits

Parameter	Cronbach's alpha	F test	Prob	R ²	PCC	Equation
TDS	0.915	5360.37	0.000	0.982	0.989	$X = 0.635 \times Y$
EC	0.962	4377.68	0.000	0.979	0.989	$X = 0.811 \times Y$

Table 2 Comparison of the average and standard deviation of TDS and EC among three citizens

Parameter		Citizen 1 (33) ^a		Citizen 2 (31) ^a		Citizen 3 (32) ^a	
		Test kits	Standard	Test kits	Standard	Test kits	Standard
TDS	Average	1525.7	1956.8	2710.6	4095.5	2728.4	4065.5
	Standard deviation	764.4	1135.0	1496.9	2873.8	1854.2	3248.6
EC	Average	3051.8	2948.1	5418.0	6155.9	3646.7	6264.8
	Standard deviation	1528.7	1693.3	2974.6	4313.8	2149.9	5011.3

^aNumbers between parentheses indicate the number of collected observations for each citizen

4 Discussion

Results reported in the investigation confirm that test kits can be used for rapid testing on-site water quality monitoring. Despite variability between citizens, CS can be applied to monitor water salinity, mainly used for irrigation, and there is a good agreement between standard methods and test kits. The potential advantages of actively involving citizens in water quality monitoring data collection of Medjerda watershed may be considered as an innovative approach to strengthen the concept of citizen science for effective WQM. However, test kits are often subject to a range of limitations and interferences and should be used with caution. Limitations ways of test kits were related to level of accuracy, limit of detection, detection range, the method used for the testing and water types (Naigaga et al. 2016; Evans et al. 2014).

5 Conclusions

The TDS/EC measurements using test kits appear suitable to be used by citizens for WQM of the Medjerda watershed if they are properly used, the instructions are strictly followed, and test kits are correctly used. There is a high agreement between standard methods and test kits, as indicated by statistic indicators for measuring TDS and EC. With more consistent training, the test kits should allow for a reliable, sensitive, and precise WQM.

References

Arsawiset, S., Teepoo, S.: Ready-to-use, functionalized paper test strip used with a smartphone for the simultaneous on-site detection of

- free chlorine, hydrogen sulfide and formaldehyde in wastewater. *Anal. Chim. Acta* (2020). <https://doi.org/10.1016/j.aca.2020.04.041>
- Bahri, A., Brikké, F., Vairavamoorthy, K.: Managing change to implement integrated urban water management in African cities world water week 2015, WWW 2015. *Aquatic Proc.* **6**, 3–14 (2016). <https://doi.org/10.1016/j.aqpro.2016.06.002>
- Ballesta Claver, J., Valencia Miron, M.C., Capitan-Vallvey, L.F.: Determination of hypochlorite in water using a chemiluminescent test strip. *Anal. Chim. Acta* **522**(2), 267–273 (2004). <https://doi.org/10.1016/j.aca.2004.06.051>
- Capitán-Vallvey, L.F., Fernández-Ramos, M.D., Alvarez de Cienfuegos Gálvez, P., Santoyo-González, F.: Characterisation of a transparent optical test strip for quantification of water hardness. *Analytica Chimica Acta* **481**(1), 139–148 (2003). [https://doi.org/10.1016/S0003-2670\(03\)00073-4](https://doi.org/10.1016/S0003-2670(03)00073-4)
- Evans, E., Gabriel, E.F.M., Benavidez, T.E., Coltro, W.K.T., Garcia, C. D.: Modification of microfluidic paper-based devices with silica nanoparticles. *Analyst* **139**(21), 5560–5567 (2014). <https://doi.org/10.1039/c4an01147c>
- Fehri, R., Khelifi, S., Vanclooster, M.: Desaggregating SDG-6 water stress indicator at different spatial and temporal scales in Tunisia. *Sci. Total Environ.* **694**, 133766 (2019). <https://doi.org/10.1016/j.scitotenv.2019.133766>
- Fehri, R., Khelifi, S., Vanclooster, M.: Testing a citizen science water monitoring approach in Tunisia. *Environ. Sci. Policy* **104**, 67–72 (2020). <https://doi.org/10.1016/j.envsci.2019.11.009>
- <https://www.un.org/sustainabledevelopment/water-and-sanitation/>
- Jollymore, A., Haines, M.J., Satterfield, T., Johnson, M.S.: Citizen science for water quality monitoring: data implications of citizen perspectives. *J. Environ. Manage.* **200**, 456–467 (2017). <https://doi.org/10.1016/j.jenvman.2017.05.083>
- Lan, L., Niu, Q., Li, T.: A highly selective colorimetric and ratiometric fluorescent probe for instantaneous sensing of Hg²⁺ in water, soil and seafood and its application on test strips. *Anal. Chim. Acta* **1023**, 105–114 (2018). <https://doi.org/10.1016/j.aca.2018.03.023>
- Naigaga, S., Boyd, C.E., Gaillard, P., Abdelrahman, H.A., Molnar, J.J.: Assessing the reliability of water-test kits for use in pond aquaculture. *J. World Aquaculture Soc.* **48**(4), 555–562 (2016). <https://doi.org/10.1111/jwas.12377>
- Takahashi, Y.: Dye nanoparticle-coated test strips for detection of ppb-level ions in water. In: *Nanotechnology Applications for Clean Water*, 2nd edn, pp. 63–72 (2014). <https://doi.org/10.1016/B978-1-4557-3116-9.00004-4>