Assessment of citizen's measurements using test strips for water quality in the Medjerda watershed (Northern Tunisia)

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i. Introduction

Water resources in Africa are subjected to many pressures related to urban growth, agricultural expansion, and climate change (Bahri et al., 2016). These pressures jeopardise reaching the UN-Sustainable Development Goal 6 (SDG6). Efficient monitoring of water systems is pivotal for designing efficient water management strategies that alleviates aforementioned pressures (Mutambara et al., 2016). Yet, the water monitoring capacity in Africa is often very poor, in particular for Water Quality Monitoring (WQM). Citizen Science (CS) based WQM is nowadays proposed as an innovative approach to strengthen the WQM capacity (Fehri et al., 2020; Njue et al., 2019; Jollymore et al., 2017). The concept of CS is based on the potential social benefits of engaging, collaborating and actively involving citizens in data collection and knowledge generation. Yet, the quality of CS-based WQM is different as compared to reference WQM. CS-based WQM programmes need therefore to be thoroughly validated. The main objective of this study is to assess the quality of a CS-based WQM program for the Medjerda river in Tunisia.

ii. Literature Review

Over the last decade, numerous analytical methods have been successfully developed for WQM. Besides measurements made gravimetrically and by titrimetry, advanced instrumental methods including high performance liquid chromatography, atomic absorption spectrometry, and electrochemistry have been used for water quality analysis. These analytical techniques showed advantages of high sensitivity and accuracy, but they showed also limitations such as the need for expensive and complex pre-treatment process and highly qualified technical personnel (Cummings, 2010). Water quality test strips for on-site water quality monitoring have been widely used as an alternative in assessing water quality. Water strip WQM programs have short response time, are easy operational, have a low bio-toxicity, and a low cost (Forest et al., 2006). Water test strips have been used to analyse various species of free chlorine, hydrogen sulfide and formaldehyde (Arsawiset and Teepoo, 2020), tetracycline antibiotics (Li et al., 2019), Hg (II) ions (Lan et al., 2018), Zn (II) ions (Takahashi, 2014), microcystins (Humpage et al., 2012), hypochlorite (Ballesta Claver et al., 2004), hardness (Capitán-Vallvey et al., 2003) and microorganisms (Martins et al., 1997). The reliability of water quality test strips and kits for WQM were assessed against laboratory-based standard methods (Naigaga et al., 2016, Mosley and Donald, 2005, Bischoff et al., 1996). However, test strips lack selectivity for detection due to the random diffusion of chromogenic reagents on the detection zone in the presence of common interfering agents (Evans et al., 2014). Given the stability and highly portable format of water test strips, test strips could be easily used by everyday citizens in the framework of CS based WQM (Gagnon et al., 2007). Yet, Capdevila et al. (2020) identified attributes of citizens, attributes of institutions and the interactions between citizens and institutions as additional factors determining the success of a CS-based WQM program.

iii. Methodology

The quality of a CS-based WQM program based on water strips for the Medjerda river (Tunisia) was assessed. The study focused on total alkalinity, nitrate content and chlorine content. Three citizens participated to the program. A short training was organized to ensure a good reliability of the test strips readings. Overall 96 samples were collected for water quality monitoring along 12 sampling sites on the Medjerda river. The locations were based on the location of the volunteers and the availability of reference WQM stations (Fig.

1). The main characteristics of the sampling sites are summarized in Table 1. Water quality monitoring tests for wet (January-March 2020) and dry (June-July 2020) periods were performed by standard laboratory techniques (titration, molecular adsorption spectrometry) (Rodier et al., 2009) and by test strips. The test strips were immersed for 1-second in the sampled water then shacked- to remove the excess water. After waiting for 1 minute, the colors of the strips were compared with the color scale (Fig. 2). Regression analysis, based on Pearson Correlation Coefficient (PCC), 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.

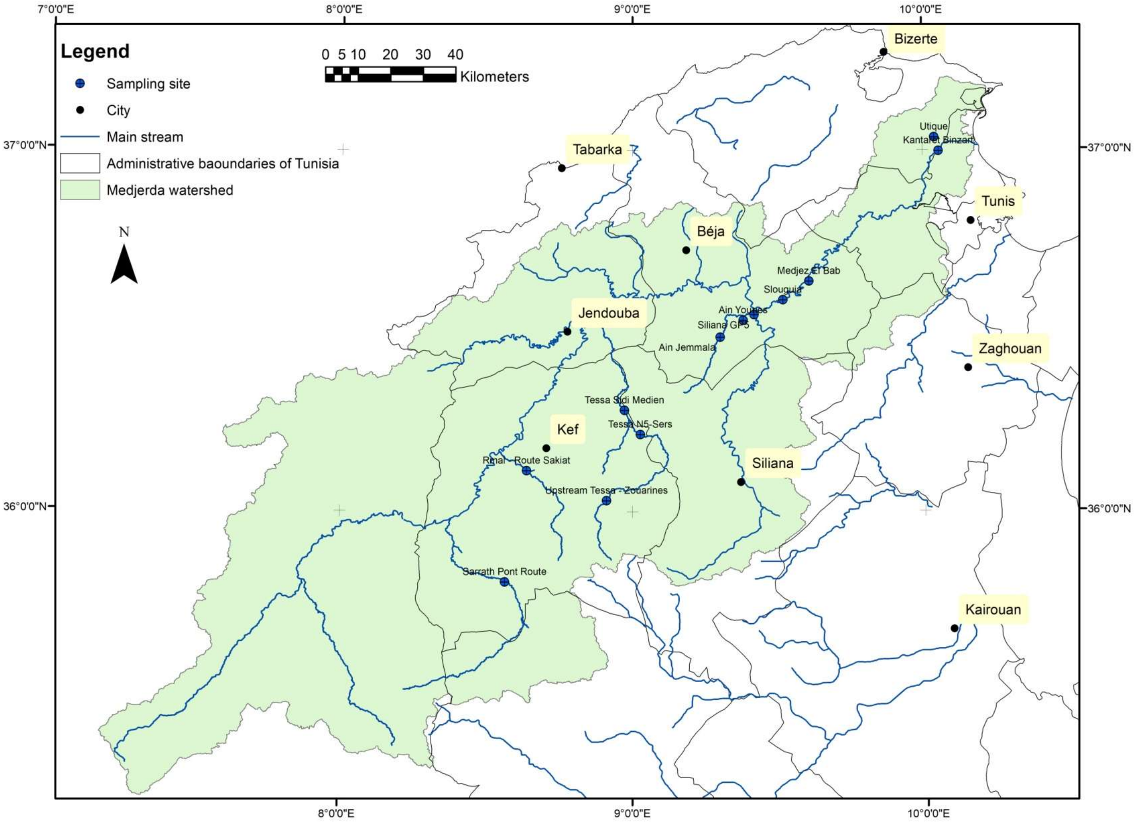

Fig 1. The study area indicating sampling sites in the main stream of Medjerda watershed

Table 1. Main characteristics of the sampling sites

Name	Geographic coordinates		Altitude (m asl)	Sub-watershed
	Latitude	Longitude		
Utique	37°2'8.16"	10°2'29.52"	28	Medjerda downstream
Kantaret Binzart	36°59'50.54"	10°3'22.16"	21	Medjerda downstream
Medjez El Bab	36°38'19.32"	9°36'26.13"	46	Medjerda Mid Valley
Slouguia	36°38'19.32"	9°31'26.14"	55	Medjerda Mid Valley
Siliana GP5	36°32'45.96"	9°25'4.45"	75	Siliana
Ain Younes	36°31'14.28"	9°31'0.76"	133	Khalled (spring)
Ain Jemmala	36°29'3.12"	9°18'4.86"	239	Khalled
Tessa Sidi Medien	36°16'54.12"	8°58'22.42"	299	Tessa
Tessa N5-Sers	36°12'52.92"	9°1'38.94"	567	Tessa
Upstream Tessa -Zouarines	36°1'53.04"	8°54'41.99"	657	Tessa
Rmal - Route Sakiat	36°38'19.73"	8°38'19.73"	357	Mellegue
Sarrath Pont Route	35°48'20.16"	8°33'55.65"	576	Mellegue

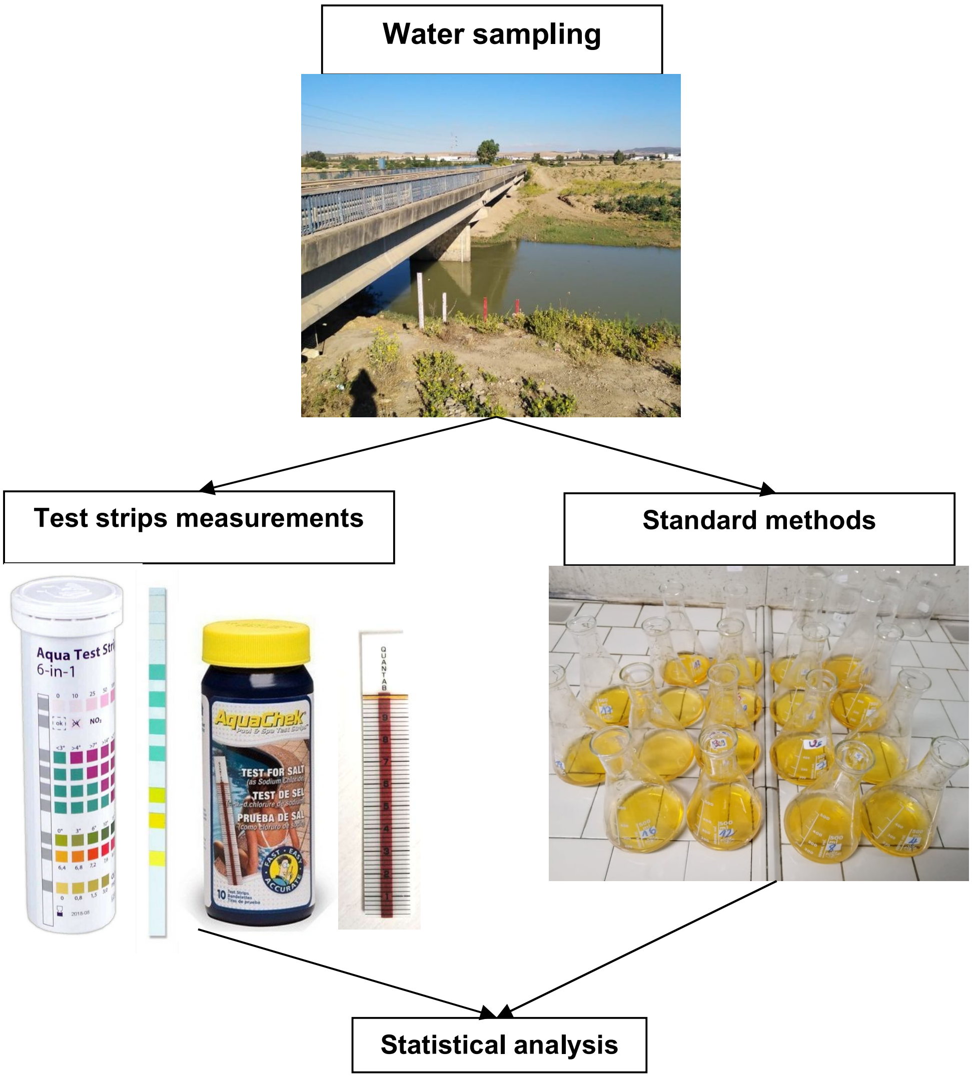

Fig 2. Methodology flowchart for test strips reliability

iv. Findings & Conclusion

The results showed that chloride-sensitive, test strips were the most reliable for measuring a wide range concentrations (0-7510 ppm). Nitrates-sensitive test strips were moderate reliable in the 0-25 ppm range. The total alkalinity-sensitive test strips were less reliable in 3-20°F range concentration measuring. The validity of the test strips may be affected by the relatively low level of nitrate concentrations (0-25 ppm). The highest agreement between test strips and the standard method (PCC (0.962), R^2 (0.926), and α_c (0.982)) was obtained for measuring chloride (Table 2).

Table 2. Results of statistical analyses testing reliability of test strips

Parameter	Cronbach's alpha	F test	Prob	R^2	PCC	Equation
Total Alkalinity	0.918	2292.60	0.000	0.694	0.833	x=0.950y+1.000
Nitrate	0.931	238.49	0.000	0.750	0.866	x=0.940y-1.162
Chloride	0.982	1187.41	0.000	0.926	0.962	x=0.970y+503.834

There was also a good agreement between the citizen-based outcomes and the analytical methods for the three citizens. Nevertheless, the reliability depends on the citizen and the parameter to be tested (Table 3). Less reliability of test strips compared to standard methods may be due to the presence of common interfering agents and instability of color compared to the reference scale. Finally, the rapid and simple measurements using the test strips appear suitable to be used by citizens for surface WQM of the Medjerda river if they are correctly used and the instructions are strictly followed. With a more consistent training, the test strips should allow for a reliable, sensitive and precise monitoring of water quality.

Table 3. Comparison of the average and standard deviation of total alkalinity, nitrates and chlorides among three citizens (numbers between parentheses indicate the number of collected observations for each citizen)

Parameter		Citizen 1 (33)		Citizen 2 (31)		Citizen 3 (32)	
		Test Strips	Standard	Test Strips	Standard	Test Strips	Standard
Total alcalinity (°f)	Average	10.90	11.20	12.88	11.52	12.53	12.13
	Standard deviation	3.35	4.66	2.79	1.94	3.36	3.22
Nitrates (ppm)	Average	7.34	10.40	7.57	8.17	4.49	5.28
	Standard deviation	9.60	9.27	7.62	8.49	7.80	7.44
Chorides (ppm)	Average	1088.67	1263.56	2754.86	3475.07	3767.29	2897.70
	Standard deviation	813.33	912.34	2360.91	3006.36	3511.78	2673.44

v. **References** *(15-30 references)*

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vi. Disclosures

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vii. Keywords: IWRM, CS, WQM, Test Strips, Medjerda river, Tunisia.

viii. Abbreviations:

CS: Citizen Science
IWRM: Integrated Water Resources Management
PCC: Pearson Correlation Coefficient
SDG6: Sustainable Development Goals 6
UN: United Nation
WQM: Water Quality Monitoring