The Fate Of Water Quality Sector In Developing Countries

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Abstract: The aspect of water quality is gaining attention in domestic water uses on a global scale. Irrigation, livestock, ecosystem, recreation and construction sectors are also oriented on the same merit. The accuracy and precision of water quality analytical findings become critical. Method to preserve water sample for laboratory analysis are available, the limited maximum holding time is realized for microbial and anionic parameters. In situ analyses are made possible with portable devices, good practices during in-situ and in-house procedures are essential. The need for extensive water quality analysis of new and developed water sources is challenged, major natural water mineral contents being central to this case. The relationship between major dissolved minerals and Electric Conductivity (EC) is utilized. Treatment of polluted water sources follows the same water quality monitoring concept; issues of free Chlorine and Microbes assessment are clearly addressed. The concept will equip water laboratory managers with sound reasoning on deciding parameters to be analyzed, individuals at household scale as well as professionals in other related sectors will serve time and cost for unnecessary water quality analyses.

Keywords: Portable photometers; Qualified and unqualified analytical personnel; Water quality analysis; Water quality monitoring; Water treatment.

1. Introduction

Water quality is an essential sector of domestic water consumption [12]. Nowadays it is not satisfactory to secure water sources alone and supply to communities in demand, water quality is a requirement during planning and budgeting for developing relevant water source [19]. If water sources are found to be polluted by certain contaminants, relevant treatment facilities are proposed to alleviate the problem [3,30]. Information regarding the suitability of a particular water source must be accurate for facilitating effective decisions. Assessing the quality of such new water sources is usually challenging, the full and impartial water quality analysis is advocated for precise contaminant elucidation [34]. This process presents a cost to many individuals owning private wells, but it becomes a mandatory stage when community-based water project investments are realized [23]. When treatment practices are suggested, monitoring of such water sources and their distribution network becomes inevitable [29]. Since water quality treatment of public utilities is a continuous process, monitoring parameters at a given frequency are suggested by respective state regulatory authorities [4]. Inspection and compliance requirements are also accomplished on the same basis. Water research is another area where water quality finds its significance. Many academic and project-based proposals intend to fill gaps based on relevant available scientific communications [18]. Hence, individuals and groups of researchers tend to employ various water quality analytical methods to achieve this; it may include subcontracting research designed water samples to a competent testing laboratory or performing analysis on their own by using available equipment and consumables. It should be noted that all researchers in different dimensions are not necessarily appropriate analyst; thus findings obtained from these groups may be of different quality due to different experimental analytical capabilities [25]. However, since data obtained are used for recommending the status of a particular scientific gap, it is critical that results be precise and accurate. The idea of a qualified analytical scientist arises from several observed non-reproducible findings under similar or identical experimental conditions [20]. This communication intends to address the need for qualified analyst in research-based activities, roles of researchers are also declared. It also provides guidance for water quality managers in developing countries on what samples to take, what analyses to perform, and how to determine if more detailed data are needed. Criteria are presented for simple qualification of such water sources with respect to available state guidelines and intended uses.

2. Water Quality Analytical Issues

This section considers methodologies employed by water quality testing laboratories; the main focus being how accurate and precise water quality results are generated for academic, research, society, Inspection and or business compliance.

3.1   2.1 In-house analysis

Water quality analysis is realized at a fixed, controlled and usually full analytical furnished place, the Laboratory. At this level, it is possible to characterize all unknown water and wastewater contaminants and pollutants. Equipment used here may range from simple to complex, depending on the laboratory technical and analytical scope, financial capacity, Accreditation requirements, State requirements, and analytical sensitivity and simplicity issues. The laboratory can be assessed on its analytical competency by using proficiency testing schemes from third-party competent bodies [11]. Generally, at this scale, water quality analysis is at its best treatment.

2.2 In situ analysis

Laboratory analysis and subsequent findings are based on a representative water sample delivered. Almost all cationic water quality parameters can be preserved to a maximum of six months prior laboratory analysis [8]. A challenge is noted on most anionic and microbial water quality parameters; they usually require a combination of preservation methods but presents limited maximum sample holding time, hence on-site assessments are recommended [35].

2.3 Simplified analytical techniques

Based on scientific developments, water quality parameters have been well studied [15]. In this regard, a recent achievement on minimization and elimination of analytical errors has been accomplished [5]. The advantageous use of colour reaction in visible spectrum has made this possible. Portable photometers capable of rapid and in situ analysis are now available [35]. Simplified analytical techniques are widely known for onsite analysis. They are generally potential for anionic parameters due to their limited maximum holding time, thus field trials can be accomplished and monitored confidently over long off-laboratory sessions [35]. However, such techniques are also extensively used at the in-house analysis scale. Issues have been spotted with respect to the application of portable instruments. Their simplicity of application has attracted even unqualified analytical personnel, as the use of portable photometer meets their intended analytical purpose [13,35]. This has been possible due to dry chemistry involvement, as one need only to follow procedure and mix the respective powder pillows for a given reaction time before final result readout. In the analysis, quality control and hence assurance needs to be followed before the acceptance of final results, a challenge to unqualified personnel.

2.3.1 The use of Chemicals

Dry packages are commercially available for in situ analysis; they are usually packed in powder pillows [9] but liquid forms that require prescribed number of drops during analysis exist. Most anionic parameters for analysis require special treatment such as water filtration and acid rinse of sample cell before use in portable devices [35]. pH adjustments are key in reaction feasibility and kinetics, but this is mostly corrected from dry chemical combination used under the procedure. Preparation and testing of standards covering the expected concentration range of water sample for a given parameter are crucial [1]. Unqualified analytical personnel have a chance of missing any of these requirements towards accurate and precise result generation.

2.3.2 The use of Sample cells

Different companies are available on offering competitive devices with excellent analytical capabilities. Their instruments have similar operating principles of science [14]. During analysis, a sample is placed in a sample cell where chemical will be added for reaction or colour development. In most procedures, two sample cells are required, one for the blank and the other for the sample. Such portable photometers are programmed to collect baseline colour information from the blank and correct it after sample readout for final results. Application of different sample cells have been noticed to provide tolerable errors due to non-unique optical properties they actually present [35]; however, such tolerance is questionable with low-level concentrations

and wear/ ageing of sample cells following their routine application. Thus, the use of one sample cell for the same purpose is encouraged. On the other hand, sample cells are of different shapes, the common being round and square or angle based. Round sample cells have fill line or mark for orientations that matches with that of the photometer device; however, since the application of one sample cell is suggested here, precise replacement after mixing procedures of the same sample cell may not be practical. Errors due to round sample cells are excellently removed if square or angle based sample cells are used, also other devices have a fixed flow-through cell feature for this purpose [7].

3. Comprehensive Water Quality Analysis

When deciding the suitability of water source for intended uses, full water analysis is commonly advocated for proper identification of any water pollutant and identifying its remediation practice. Here, Microbial, physical and chemical parameters are assessed [24]; an exception is made to unnecessary parameters based on the intended use e.g water pH on cement based constructions. In developing countries, this is becoming cost due to analytical reagents requirements. Science has proved the existence of parametric correlation in water analysis, it is commonly known as water quality analysis balance which also serves as an accuracy check of analytical results [16]. Major natural water minerals component has been identified to be Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+), Sodium (Na^+), Bicarbonates (HCO_3^-), Carbonates (CO_3^{2-}), Chloride (Cl^-), Nitrate (NO_3^-) and Sulphate (SO_4^{2-}) ions [16]. An exception arises from site-specific issues such as fluoride areas that have higher fluoride content. EC of water is the function of these minerals at an appreciable level; it also depends on the water temperature and ions nature. When wastewater is considered, dissociated organic contents also play a key role in determining the EC. EC of natural water can simply be computed by major ions composition using equation 1 and Table 1 [32].

$$EC = \sum_i (C_i f_i) \qquad (1)$$

Where C_i and f_i are the concentration and conductivity factor of i species in water respectively.

***Table 1:** EC factors for ions commonly found in water*

Ion	EC factor (µS/cm per mg/L)
Ca^{2+}	2.60
Mg^{2+}	3.82
K^+	1.84
$Na+$	2.13
HCO_3^-	0.715
CO_3^{2-}	2.82
Cl^-	2.14
NO_3^-	1.15
SO_4^{2-}	1.54

The essence of equation 1 is that, once EC has been determined, one can have the best decision on whether full water analysis should be done or not. Table 2 presents East African potable water quality guidelines for domestic uses; domestic requirement has been used as an example here due to their global applicability for all drinking waters. Water

quality guidelines such as irrigation, construction, recreation and others can be applied on the same basis.

Table 2: East African Potable water standards [33]

Parameter	Formula	Natural Potable Water (mg/L)
Bicarbonate*	HCO_3^-	Not Specific
Carbonate*	CO_3^{2-}	Not Specific
Chloride	Cl^-	250
Sodium	Na^+	200
Potassium	K^+	50
Sulphate	SO_4^{2-}	400
Magnesium	Mg^{2+}	100
Calcium	Ca^{2+}	150
Nitrate	NO_3^-	45

* as $CaCO_3$

By using EC of a water sample, it is easier to address whether major water quality minerals exceed maximum limits for intended used; thus opting not to waste resources on their chemical analysis. With respect to the East African potable water standard, Table 3 shows possible EC as a result of individual major water minerals content computed from equation 2.

$$EC = \frac{1}{2}\left[\sum_i (C_i f_i) \right] \qquad (2)$$

Where C_i and f_i are the concentration and conductivity factor of i cationic or anionic major water minerals in water respectively.

Table 3. EC values and their major parameters to asses: EC values are due to individual major ion concentration contribution as per maximum East African natural potable water standard values.

Ion	E.C (µS/cm)	Major Parameters to Assess	
		Groundwater	Surface water
Ca^{2+}	195	K^+, NO_3^-	K^+, NO_3^-
Mg^{2+}	191	K^+, NO_3^-, Ca^{2+}	K^+, NO_3^-
K^+	46	NO_3^-	NO_3^-
Na^+	213	K^+, NO_3^-, Ca^{2+}, Mg^{2+}	K^+, NO_3^-
HCO_3^-	-	-	-
CO_3^{2-}	-	-	-
Cl^-	267.5	Na^+, K^+, NO_3^-, Ca^{2+}, Mg^{2+}	K^+, NO_3^-
NO_3^-	25.88	None	None
SO_4^{2-}	308	Na^+, K^+, NO_3^-, Ca^{2+},Cl^-	K^+, NO_3^-

In the East African region, it is meaningless to assess bicarbonates and carbonates in potable water as per local standard. Table 3 depicts that, a maximum EC value of a given water sample has an implication on major water parameters to be analyzed. Parameters corresponding to lower EC value than samples are meaningless to analyze as they automatically conform to the standard. Surface water major parameters are rather limited due to the poor dominance of certain minerals; nevertheless, groundwater has certain minerals that usually dominate the water type.

4. Treated Water Analysis
The discovery of domestic water pollution brought treatment practices that render water fit for drinking purposes [17,6,2]. Treatment practices involving Chlorination are constantly established and encouraged to communities [27], regardless of poor microbial detected pollution level for safeguarding

any emerging issue. When chemical pollution exists, conventional filters and or simple water mixing techniques are suggested [22]. The efficiency of treatment practice is assured by regular water quality monitoring; this begins from the treatment plants to various selected water domestic points. Different states have different water quality parameters to monitor.

4.1 Residual Chlorine
Chlorine Disinfectants have been used to inactivate pathogenic microbes in drinking water supplies [28]. Efficient treatment is assessed by means of residual chlorine levels after demand is satisfied; this indicates the excess chlorine responsible for safeguarding water against any possible re-contamination in the supply network after treatment [21]. Recent scientific advances have proposed the possible relation between chlorine disinfection by-products (DBP) and cancer in human being; however, the concept is discouraged by a statement which says "In attempting to control DBP concentrations, it is of paramount importance that the efficiency of disinfection is not compromised and that a suitable residual level of disinfectant is maintained throughout the distribution system" [31]. This statement seems to provide confidence in most developing countries that otherwise could not sustainably afford pre-treatment practices prior to chlorination. Hence, DPB monitoring in treated water is of no priority, this could threaten a future possibility of sound scientific conclusion on global DPB reality issues.

4.2 Microbes
One of the common and excellent indicators of water quality acceptance is the absence of microbes [31]. Microbes of E. Coli and Fecal Coliforms are widely used to present possibilities on the existence of other pathogenic microbes in the East African region. Microbial samples can be preserved by several tricks that are limited to maximum holding times [35]; however in situ analyses are encouraged due to time loss during transportation to the laboratory, and room temperature equilibration prior analysis. A number of regulatory authority exhibits different choice of indicator organism, E. Coli is gaining acceptance in natural water for portraying human based faecal contamination, and widely used as an indicator in treated water supplies [10]. The fact that E. Coli is easily destroyed in water treatments than pathogens such as Cryptosporidium parvum, renders its exclusive suitability as a sole indicator [37]. Such an indicator is relatively suitable in natural waters as other Coliform organisms are obvious from the wildlife activities on surface waters [26]. The use of Total Coliforms seems to lose its significance; in fact, this group of indicator organism better assess the efficiency of water treatment facility on microbial basis. If Total Coliforms are below detection level, then one can be confident on the suitability of treatment means and procedure employed.

5. Concluding Remarks
Accurate and precise water quality findings require competent analyst who is furnished with necessary analytical facilities. With such good practices, results published across the scientific community are likely to be reproducible under similar or identical conditions. Thus, propagation of scientific gaps will be genuine and worth. Unqualified individuals need to consult qualified analyst for the same

analytical assistance. Researchers with limited analytical skills only require working concurrently with the qualified analyst; when this is not practical, subcontracted water samples should be accompanied by relevant commercial certified matrices of known concentration for tracing result validity. Water quality managers can omit the burden of extensive water quality parameters to be analyzed; this is possible when EC values are preliminarily assessed. Hence, time and financial resources can be served; focus on other parameters of concern (e.g trace elements) can be preferred. National water quality database can simply be constructed in developing countries; characteristics of respective water storages such as aquifers can be identified, and the need for new testing on the same region can be minimized.

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