

Development of a Computer Application for the Calculation of Water Quality Index in Morocco

Kanga Idé Soumaila, Naimi Mustapha, Chikhaoui Mohamed, Ada Aya Laouali



Abstract: *Water quality indices are generally a combination of biological, chemical, physical parameters to form a numerical composite index that can be easily interpreted and shared. Their efficiency and usefulness in managing and monitoring water quality have been appreciated by management organizations around the world. The integration of these tools into computer applications can be a major asset. The main purpose of this article is to present a computer application that integrates a water quality index developed in Morocco to facilitate its use and avoid manual errors related to users. The application entirely developed in python language under PyCharm (Integrated Development Environment) is executable on a computer and is presented as a GUI (Graphical User Interface) containing two sub-interfaces to calculate the surface and groundwater quality index according to the type of water analyzed.*

Keywords: *Computer application, Water quality index, Water quality parameters, Development, Morocco.*

I. INTRODUCTION

A water quality index represents the combination of biological, chemical and physical parameters to form a numerical composite index that can be easily interpreted and communicated to a target audience [1-4]. The assessment of water resources management and water quality policies to determine variations in water quality over time and space by water resource managers can be done using water quality indices [5]. Several water quality indices have been developed worldwide, including the Canadian Council of Ministers of the Environment's Index [6], Brown's Index [4], Dinius's Index [7], Said's Index [8], Oregon water quality Index [9], Walski and Parker [10], Smith's [11], Sargoankar and Deshpande [12], Swamee and Tyagi [3], etc. All these indices are now used to assess water quality, each with its advantages and disadvantages [13], commonly related to their development. Some indices use several water quality parameters to develop the index, while the cost of developing a water quality index can be very high, particularly in developing countries.

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* Correspondence Author

Kanga Idé Soumaila*, Soil and Water Conservation Laboratory, Department of Natural Resources and Environment, Hassan II Institute of Agronomy & Veterinary Medicine, PO. Box 6202 - Madinat Al Irfane - Rabat, Morocco.

Naimi Mustapha, Soil and Water Conservation Laboratory, Department of Natural Resources and Environment, Hassan II Institute of Agronomy & Veterinary Medicine, PO. Box 6202 - Madinat Al Irfane - Rabat, Morocco.

Chikhaoui Mohamed, Soil and Water Conservation Laboratory, Department of Natural Resources and Environment, Hassan II Institute of Agronomy & Veterinary Medicine, PO. Box 6202 - Madinat Al Irfane - Rabat, Morocco.

Ada Aya Laouali, Global Navigation Satellite System Laboratory, Hassan II Institute of Agronomy & Veterinary Medicine, PO. Box 6202 - Madinat Al Irfane - Rabat, Morocco.

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For this reason, some researchers [3, 13, 8, 2] suggest that reducing water quality parameters to a relevant set of parameters represents a significant gain in conceptualizing water quality indices.

It should also be noted that the use of a water quality index requires an expert in water quality assessment since these indices use, in most cases, mathematical formulas to normalize and aggregate the water quality parameters that compose them. This use, even for an expert, can be very time-consuming, especially if it involves assessing water quality at several quality monitoring stations or over several years. Thus, the development of computer applications to automate calculations is necessary more than ever. To our knowledge, very few computer applications or software using water quality indices are available in the literature. Sakar and Abbasi [14] proposed for the first time, a water quality index software (QUALIDEX) containing several water quality index modules that include two indices developed in the USA and three indices developed in India. Other software such as SWQAT [15], MTSI [16], IWQG V.1 [17], QUAL2K or the latest version QUAL2Kw developed by the United States Environment Protection Agency [18], are available in the literature. Nabizideh et al [5] have integrated Iran's water quality index into software to ease calculations and still be able to use the index if certain water quality parameters are missing. Kanga et al [19] proposed a water quality index in accordance with the laws governing water quality in Morocco. The purpose of this article is to present a computer application that integrates this index to ease its use and prevent user-related errors.

II. MATERIAL AND METHODS

The development of a water quality index involves four steps: the choice of parameters, the normalization of parameter values, the weighting of the different parameters, and the aggregation of sub-indices [4, 10, 13, 20, 21, 22]. This does not mean that all the indices used the 4 steps since many indices needed only 3 steps, it depends only on the objectives targeted. Kanga et al [19] proposed a water quality index that complies with the legislation governing water resource quality management in Morocco. The index was developed in three steps, because no weighting step was needed: the choice of water quality parameters, the normalization of parameters into sub-indices and the aggregation of sub-indices into a final index. This index has been integrated into a computer application to automate and simplify calculations, and avoid misinterpretation of the water quality assessment. Figure 1 shows the processes from the development of the water quality index to its integration into the computer application.



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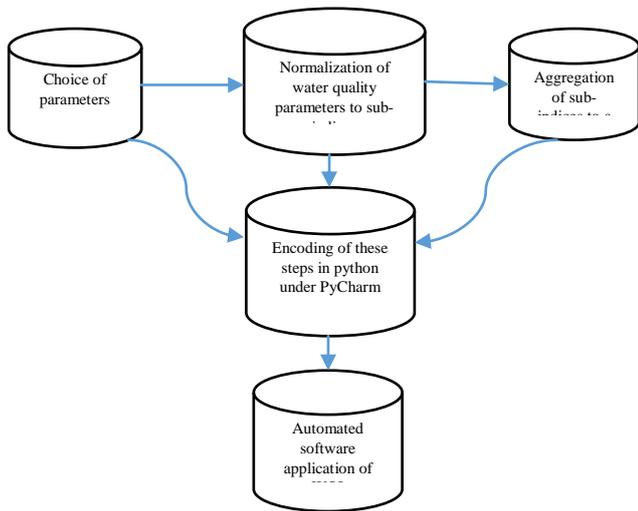


Figure 1: Main processes of developing the water quality index and its integration into a computer application

A. Methods for developing the water quality index

Generally, if X water quality parameters are analyzed in the laboratory of a water sample and only n parameters are considered to assess water quality at this measurement point, the raw values of these selected parameters are normalized into sub-indices and then aggregated into a final index that indicates the overall water quality.

B. Choice of parameters

The choice of parameters is a very important step in the development of a water quality index, since the relevance of the index can be judged by the choice of these parameters. The choice of parameters must be judicious to avoid redundancies and must focus on parameters related to the precise use of water. In general, the water resources management bodies in a locality define this choice. All water basin agencies in Morocco have a water quality assessment method in accordance with 10-95 Law of August 16, 1995, 36-15 Law of October 6, 2016 and 1275-02 Decree of October 17, 2002. The parameters used by water basin agencies to assess overall water quality are the same as those used to develop this quality index. Several water quality parameters are measured in a water sample; however, the water basin agencies in Morocco and, in particular, the Sebou agency, uses six parameters for surface water and five parameters for groundwater quality assessment. These parameters are, for surface water: dissolved oxygen (O_2), biochemical oxygen demand for 5 days (BOD_5), chemical oxygen demand (COD), ammonium ion (NH_4^+), total phosphorus (P), and fecal coliforms (CF). For groundwater, these parameters are used: Electrical conductivity (EC), Chloride (Cl), Nitrate (NO_3^-), Ammonium (NH_4^+), fecal Coliforms (CF).

C. Normalization of parameters

Parameter normalization is the transformation of variables, which are in different units and dimensions, into a common scale [1-3]. Water quality parameters are not expressed in the same unit. For example, chemical parameters are expressed in milligrams per liter (mg/L); physical parameters all have different units: temperature in degrees Celsius or Fahrenheit, conductivity in micro or milli-Siemens per cm ($\mu S/cm$ or mS/cm), bacteriological parameters, such as fecal coliforms, is measured in count per milliliter (Count/mL). In other words, variables such as dissolved oxygen go in the same direction as water quality,

the higher the value, the better the water quality; unlike fecal coliforms, which have the reverse effect. It is, therefore, necessary to normalize these values so that the final water index represents all the parameters selected with the relative contribution of the strength of each parameter. The normalization of parameter values into sub-indices was based on Moroccan water quality standards (1275-02 decree) and segmented linear functions. The general equation for normalizing a parameter [1] is described as follows:

$$I_i = (x - a_i) \left(\frac{b_{i+1} - b_i}{a_{i+1} - a_i} \right) + b_i, \quad a_i \leq x \leq a_{i+1} \text{ and } b_i \leq \text{Classe } I \leq b_{i+1}$$

With I_i , the sub-index of the i th parameter, a_i the measured value of the parameter, b_i the i th corresponding class according to the simplified grid of the 1275-02 decree in this context. Five (5) classes are used to classify water quality in Morocco: Excellent, good, medium, bad, very bad. For each value of a water quality parameter, the sub-index transformation is performed using the linear equation above and has a value between 0 (Very Poor) and 100 (Excellent). Table 1 shows the distribution of classes with numerical values as follows:

Table 1: Classification of water based on the WQI proposed

Value	Description
90-100	Excellent
63-90	Good
50-63	Medium
38-50	Bad
0-38	Very Bad

For example, BOD_5 measurements that are strictly less than 3 mg/l are considered "Excellent" in terms of water quality description, and correspond to the range of numerical values {90 to 100}. To normalize this class, simply do:

$$\begin{cases} 0 \leq x \leq 3 \text{ mg/l} \\ 100 \geq I_{DBO_5} \geq 90, I_{DBO_5} = (x - 0) \left(\frac{90-100}{3-0} \right) + 100; \\ I_{BOD_5} = -3.33x + 100 \\ \forall x, 0 \leq x \leq 3 \end{cases}$$

Table 2 shows the sub-indices of the water quality parameters. For each class, a linear equation was developed to quantitatively estimate water quality.

Table 2: Normalization equations of water quality parameters

DO (mg/l)	DBO ₅ (mg/l)	DCO (mg/l)
$I_{OD} = 11.366x$ $\forall 0 < x \leq 8.8$ $I_{OD} = 100, si x > 8.8$	$I_{BOD_5} = -3.33x + 100$ $\forall x, 0 \leq x \leq 3$ $I_{BOD_5} = -13.5x + 130.5$ $\forall x, 3 < x \leq 5$ $I_{BOD_5} = -1.85x + 72.28$ $\forall x, 5 < x \leq 10$ $I_{BOD_5} = -0.8x + 58$ $\forall x, 10 < x \leq 25$ $I_{BOD_5} = 0, \forall x > 25$	$I_{COD} = -0.5x + 100,$ $0 < x \leq 20$ $I_{COD} = -5.4x + 198$ $20 < x \leq 25$ $I_{COD} = -0.86x + 84.66$ $25 < x \leq 40$ $I_{COD} = -0.3x + 62$ $40 < x \leq 80$ $I_{COD} = 0, \forall x \geq 80$
NH ₄ ⁺ (mg/l)	TP (mg/l)	CF (numbers / 100 ml)
$I_{NH_4^+} = -100x + 100$ $\forall 0 \leq x < 0.1$ $I_{NH_4^+} = -67.5x + 96.75$ $\forall 0.1 \leq x \leq 0.5$ $I_{NH_4^+} = -8.67x + 67.33$ $\forall 0.5 \leq x \leq 2$ $I_{NH_4^+} = -2x + 54$ $\forall 2 \leq x \leq 8$ $I_{NH_4^+} = 0, \forall x > 8$	$I_{TP} = 100 - 100x$ $\forall 0 \leq x < 0.1$ $I_{TP} = -135x + 103.5$ $\forall 0.1 \leq x \leq 0.3$ $I_{TP} = -65x + 82.5$ $\forall 0.3 \leq x \leq 0.5$ $I_{TP} = -4.8x + 52.4$ $\forall 0.5 \leq x \leq 3$ $I_{TP} = 0, \forall x > 3$	$I_{FC} = -0.5x + 100$ $0 \leq x < 20$ $I_{FC} = -0.005x + 90.1$ $20 \leq x \leq 2000$ $I_{FC} = -0.0007x + 64.44$ $2000 \leq x \leq 20000$ $I_{FC} = 0, \forall x > 20000$
NO ₃ ⁻ (mg/l)	Cl (mg/l)	CE (µS/cm)
$I_{NO_3^-} = -x + 100$ $\forall 0 \leq x < 10$ $I_{NO_3^-} = -1.8x + 108$ $\forall 10 \leq x \leq 25$ $I_{NO_3^-} = -0.52x + 76$ $\forall 25 \leq x \leq 50$ $I_{NO_3^-} = 0, \forall x > 50$	$I_{Cl} = -0.05x + 100$ $0 \leq x \leq 200$ $I_{Cl} = -0.27x + 144$ $200 < x \leq 300$ $I_{Cl} = -0.028x + 71.67$ $300 < x \leq 750$ $I_{Cl} = -0.48x + 86$ $750 < x \leq 1000$ $I_{Cl} = 0, \forall x \geq 1000$	$I_{CE} = -0.013x + 100$ $0 \leq x < 750$ $I_{CE} = -0.049x + 126.81$ $750 \leq x < 1300$ $I_{CE} = -0.0093x + 75.07$ $1300 \leq x < 2700$ $I_{CE} = -0.04x + 158$ $2700 \leq x < 3000$ $I_{CE} = 0, \forall x \geq 3000$

D. Aggregation

The normalized sub-indices are aggregated to form a composite water quality index. Researchers use several methods for aggregating sub-indices. For instance, Abbasi and Abbasi [1] report four forms of aggregation: linear, segmented linear, non-linear and segmented non-linear. The methods for aggregating sub-indices are diverse: additive (linear sum index, weighted linear sum index, sum index at root power), multiplicative (weighted product), logic (maximum operator, minimum operator) [1]. The following equation is the form used to aggregate the different values of water quality parameters.

$$WQI = \prod_{i=1}^n (I_i)^{\frac{1}{n}}$$

Where I_i , represents the sub-index of the first parameter, and n, the number of parameters, WQI, the global water quality index.

E. Encoding the index in a computer application

The application was programmed under "Pycharm Community Edition", a development environment widely used among developers because of its lightness and ease of use. The entire encoding process was done in Python, a language with many modules, easy to learn because of its syntactic clarity. The program is carried out sequentially in two main steps divided into several sub-steps [23]: Design of the application and its graphic interface (sizing of buttons, display windows, creation of python files, etc.), and programming of event managers defining the application's

behavior (import modules, Tkinter, implementation of normalization and aggregation equations, logic, etc.). Figure 3 briefly presents the pycharm encoding process.

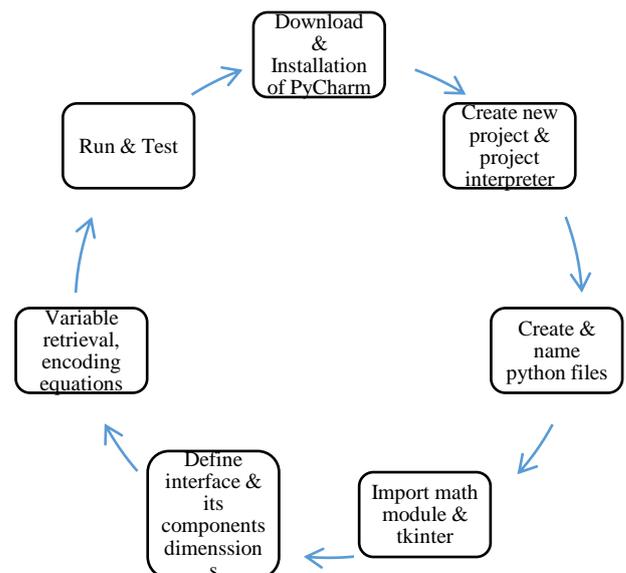


Figure 3: Process of encoding water quality index in python.

III. RESULTS AND DISCUSSION

Developed entirely under PyCharm, an integrated development environment, the computer application was developed in Python language. Compared to other computer applications such as Qualidex [14], which includes five water quality indices and other modules allowing the user to develop his own quality index, this computer application is very simple and integrates only the index developed by Kanga et al [13]. The programming of the different equations and logics above has resulted in an application that can be easily used and executed on a computer. The application is presented as a GUI (Graphical User Interface) containing two sub-interfaces to calculate the surface and groundwater quality index. The two interfaces evolve in the same way for the calculation of WQI, the difference lies only in the quality parameters used for surface and groundwater in Moroccan laws. This computer application has been developed to save time and avoid errors related to manual calculations.

A. Interface for calculating the quality index for surface water

After running the application, the user interface for calculating the quality index pops up. It consists of a menu that offers two options: "Surface water" to calculate the surface water quality index, and "Groundwater" to calculate the groundwater quality index. The user must have raw data on water quality parameters in mg/l for chemical parameters and in counts per 100 ml for fecal coliforms. Once the raw data entered for the parameters, the "Calculate" button allows to immediately calculating the sub-indices on each parameter. "Results", "WQI", and "Class" are dialog boxes that display the numerical values of the parameter sub-indices, the numerical value of overall water quality index after aggregation of sub-indices, and the class matching the interpretation of this numerical value, respectively. The "Reset" button allows the user to clean up the operations previously performed and repeat the data entry. The "Exit" button allows the user to exit the application, after confirming in the dialog box that he/she wants to exit the application. Figure 4 shows the different functionalities of the application.

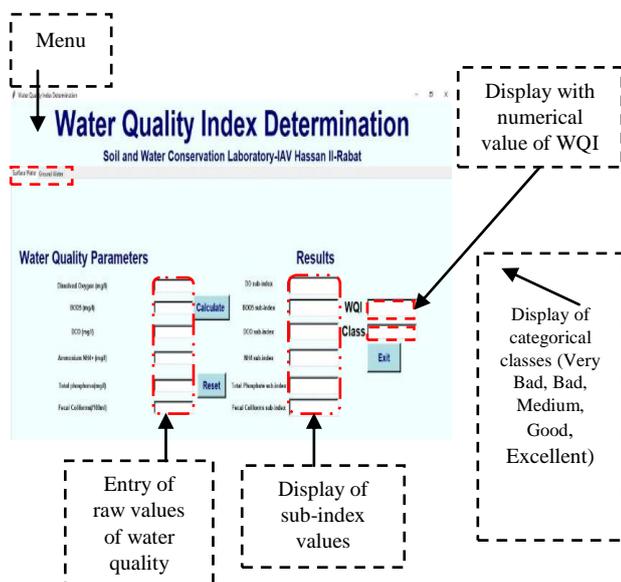


Figure 4: User interface after execution of the application

For example, surface water for which laboratory analyses have given the following values for these quality parameters: Dissolved oxygen: 6 mg/l; Biological oxygen demand: 26 mg/l; Chemical oxygen demand: 12 mg/l; Ammonium ion: 0.003 mg/l; Total phosphorus: 0.05 mg/l; Fecal coliforms: 327/100 ml. The application shows very poor water quality for this measurement point. Figure 4 shows the water quality index calculation results from data of this example.

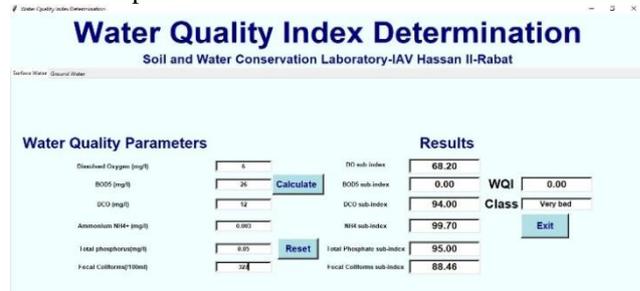


Figure 5: Calculation of the surface water quality index

With regard to the numerical values of the sub-indices, it can be observed that this poor water quality is mainly due to biological oxygen demand, which presented an abnormally high value exceeding the permissible limit of quality in accordance with Moroccan laws on the quality of water resources. The sub-index of the BOD₅ has a numerical value of 0.00, which corresponds to the "very poor" class; this is because the value 26 mg/l has exceeded the acceptable water quality limit (25mg/l). This leads the overall quality of water to be very poor at this point of measurement. Therefore, water treatment at this measuring point must be carried out in the direction of biological oxygen demand. Indeed, as soon as a parameter exceeds the permissible limit of quality, the final water quality index is expected to be zero, i.e. of very poor quality.

B. Interface for calculating groundwater index

The functionalities of the interface for calculating groundwater quality index are the same as those for surface water. The difference lies only in the water quality parameters used. Parameters such as dissolved oxygen can only be measured for surface water. Parameters such as the amount of fecal coliforms can be measured for both groundwater and surface water. For example, a well water sample whose laboratory analysis shows the following values for these parameters: Electrical conductivity: 150 µS/Cm; Nitrate: 23 mg/l; Ammonium: 0.01 mg/l; Fecal coliforms: 362/100 ml; Chloride: 231 mg/l. The calculation shows that the groundwater quality is good for this measurement point. Figure 6 displays the results of calculation from data of the above example.

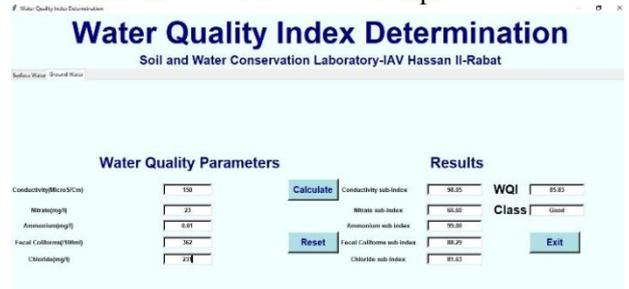


Figure 6: Calculation of the quality index for groundwater

IV. CONCLUSION

Although the development of a water quality index based on Moroccan legislation is of great help to water resource managers, its use seems very difficult for simple user. This computer application made it possible to meet this specific need and thus represents a key tool for public and private water resource managers, in order to determine the overall status of water intended for consumption.

From a technical point of view, this computer application allows to:

1. Know the parameters at the basis of the global variation of the quality variation of water at a measuring point.
2. Share and disseminate results easily thanks to the automation of calculations.
3. Avoid errors related to manual calculations by the user.

The application can only be used in Morocco since it is the Moroccan water quality standards that have been used for the standardization of quality parameters. Improvements are planned to increase the functionality of the application to allow the display of time evolution curves.

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REFERENCES

1. Abbasi T and Abbasi SA, 2012. Water Quality Indices. Elsevier. Amsterdam, Netherlands.
2. Gitau MW, Chen J and Ma Z, 2016. "Water Quality Indices as Tools for Decision Making and Management" Water Resour. Manag. 30 (8): 2591-610
3. Swamee P K and Tyagi A, 2007. "Improved Method for Aggregation of Water Quality Subindices." J. Environ Eng-ASCE. 133:220-225.
4. Brown RM, McClelland NI, Deininger RA and Tozer RG, 1970. "A Water Quality Index- Do We Dare?" Water & Sew. Works. 117:339-343.
5. Nabizadeh R, Amin MV, Alimohammadi M, Naddafi K, Mahvi AH and Yousefzadeh S, 2013. Development of innovative computer software to facilitate the setup and computation of water quality index. J. Environ. Health. Sci. Eng.11:1
6. (CCME) Canadian Council of Ministers of the Environment, 2001. CCME Water Quality Index. 1.0 Technical Report. CCME, Winnipeg, MB.
7. Dinius SH, 1987. "Design of an Index of Water Quality." Water Resour. Bull. 23(5):833-843.
8. Said A, Stevens DK and Sehlke G, 2004. "An Innovative Index for Evaluating Water Quality in Streams." Environ. Manage. 34:406-414.
9. Cude CG, 2001. "Oregon Water Quality Index: A Tool for Evaluating Water Quality Management Effectiveness." J. Am. Water Resour. As. 37(1):125-137.
10. Walski TM and Parker FL, 1974. "Consumers Water Quality Index" J. Environ. Eng-ASCE 100(3):593-611.
11. Smith D, 1990. "A Better Water Quality Indexing System for Rivers and Streams." Water Res. 24(10):1237-1244.
12. Sargoankar A and Deshpande V, 2003. "Development of an Overall Index of Pollution for Surface Water Based on a General Classification Scheme in Indian Context." Environ. Monit. Assess.
13. Kanga IS, Niandou AS, Naimi M, Chikhaoui M, Schimmel K and Luster-Teasley S, 2019a. A Systematic Review and Meta-Analysis of Water Quality Indices. JAST-B. 9 (2):1-14.89(1):43-67.
14. Sarkar C and Abbasi S A, 2006. Qualidex – a new software for generating water quality indice. Environ. Monit. Assess. (2006) 119: 201-231
15. Sharma A, Naidu M and Sargaonkar A, 2013. Development of computer automated decision support system for surface water quality assessment. Comput. Geosci-UK. 51 (2013):129-134
16. Moeseneder C, Dutra M, Thebaud O, Ellis N, Boschetti F, Tickell S, Dichmont C, Mare W, Pascual R and Cannard T, 2015. A simulation

interface designed for improved user interaction and learning in water quality modelling software. Environ. Modell. Softw. 70(2015):86-96.

17. Ewaid SH, Kadhum SA, Abed AS and Salih RM, 2018. Development and evaluation of irrigation water quality guide using IWQGV.1 software: A case study of Al-Gharraf Canal, Southern Iraq. Environ. Technol. Inno.13:224-232.
18. Brown LC and Barnwell TO, 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS (EPA/600/3-87-007). US Environmental Protection Agency, Athens.
19. Kanga IS, Chikhaoui M and Naimi M, 2019b. Water Quality Assessment Using a New Proposed Water Quality Index: A Case Study from Morocco. J. Environ. Agric. Biotech. 4(4):957-792.
20. Horton RK, 1965. "An Index Number System for Rating Water Quality." J. Water Pollu. Cont. Fed. 37:300-306.
21. Lumb A, Sharma TC and Bibeault JF, 2011. "A Review of Genesis and Evolution of Water Quality Index (WQI) and Some Future Directions." Water Qual. Expos. Hea.3:11-24.
22. Terrado M, Borrell E, de Campos S, Barcelo D and Tauler R, 2010. Surface-water-quality indices for the analysis of data generated by automated sampling networks. Trends Anal. Chem. 29(1):40-52.
23. Kravev VS and Kraveva RS, 2017. Methods and tools for rapid application development. In Proceedings, 3th International Scientific and Practical Conference "Methodology of Modern Research", 21-24. March 2017. Abu-Dhabi, UAE. World Science, Vancouver, Canada.

AUTHORS PROFILE

Kanga Idé Soumaila, MSc in Natural Resources & Environment. PhD. Student, Soil & Water Conservation. Hassan II Institute of Agronomy & Veterinary Medicine, Rabat, Morocco.

Naimi Mustapha, Professor at Department of Natural Resources and Environment, Watershed Management, Land Evaluation and Soil Management specialist. Hassan II Institute of Agronomy & Veterinary Medicine, Rabat, Morocco.

Chikhaoui Mohamed, Professor at Department of Natural Resources and Environment, water and soil conservation specialist. Hassan II Institute of Agronomy & Veterinary Medicine, Rabat, Morocco.

Ada Aya Laouali, Bachelor's degree in Distributed Computer Systems, MSc in Global Navigation Satellite System Laboratory, Hassan II Institute of Agronomy & Veterinary Medicine, Rabat,