WATER QUALITY INDEX: A NEW AUTOMATED WAY OF MEASURING THE QUALITY

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Abstract: Water is an essential environmental constituent and its quality is an issue of primary interest for the residents. The quality of water is a crucial factor for human health. The assessment of water quality is done in various ways. A very powerful tool for this purpose is the Water Quality Index (WQI). The objective of this paper is to propose and implement a platform that provides a solution enabling users to directly reach to the calculated result of the water quality, by simply uploading the file (containing collected information about water quality measurements in different periods of time) and places from device's internal memory or cloud service provider.

Key words: Water quality, Water quality index, measurement, information technologies.

1. INTRODUCTION

Environmental pollution and especially the contamination of water sources is a problem facing society today. The increasing urbanization, industrialization, the modernization of agriculture, the increase in traffic contribute to global pollution, which requires accurate monitoring and information about the quality of water resources [1]. During the past decade, widespread reports of ground water contamination have increased public concern about drinking water quality [2].

Drinking water quality directly affects human health. The impacts reflect the level of contamination of the whole drinking water supply system (raw water, treatment facilities and the distribution network to consumers) [3]. Drinking water is an essential environmental constituent and the quality of drinking water is an issue of primary interest for the residents of the European Union [4]. Monitoring of drinking water quality is an important component of water management, while data analysis is necessary for the identification and characterization of water quality problems. Assessment is the process by which water quality data is transformed into information. The information gained from monitoring is essential for assessing water quality. Monitoring can also verify water pollution following it with corrective action. Public water supply systems are required to perform microbiological, chemical, physical and radiological monitoring of their drinking water to determine the presence of any regulated contaminants.

The quality of drinking water has a powerful impact on public health. Therefore effective monitoring and comprehensive assessment of public drinking water supply systems are crucial to protect the wellbeing of the public and to allow implementation of a preventive approach to manage drinking water quality [5]. The consumption of unsafe water has been implicated as one of the major causes of this disease [6].

The assessment of water quality is done in various ways. A very powerful tool for this purpose is the Water Quality Index (WQI). A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good, bad) for reporting to management and the public in a consistent manner. Researchers use different types of indices. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public [7]. In 1965, Horton for the first time formulated a water quality index and then it was used by many researchers for different types of water. The WQI represents a simple number from 0-100 where a highest value indicates the best quality water and vice versa [5, 8, 9, 10, 11]. According to studies by several authors different statistical approaches have been followed for analysing water quality data based on rank order of observations and factor analysis and WQI was applied to river water and coastal water. In 2006, [12] has developed a new index called the ‘‘Universal Water Quality Index (UWQI)’‘, by studying the supranational standard, i.e., the European Community Standard [12]. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with a number. The objective of this study is to propose and implement a platform that provides a solution enabling users to directly reach to the calculated result of the water quality, by simply uploading the file (containing collected information about water quality measurements in different periods of time) and places from device’s internal memory or cloud service provider, validating the files. A valid file is considered valid if it has the following structure in Table 1.

Table 1. Sample matrix for a valid file

Legend: MU – Measurement unit; MV – Measured value; OV – Objective value

	MU 1	MU 2	...	MU *m-1*	MU *m*
Measurement time 1	MV	MV	MV	MV	MV
Measurement time 2	MV	MV	MV	MV	MV
...	MV	MV	MV	MV	MV
Measurement time n	MV	MV	MV	MV	MV
OBJECTIVES	OV for unit 1	OV for unit 2	...	OV for unit *m-1*	OV for unit *m*

Regarding the required file structure, there is no limitation about the amount of measurement units or times. The information in the first row and column of the matrix are for representational purposes, and they do not affect the calculation of WQI. The *objectives* row is an important row that the file should contain, and it will not process the calculation if the file does not contain the same. Its purpose is to set the values that define if the measured value is inside the expected scope or out of it. The format of the objective values should be as follows: if the objective is a *bottom limit*, meaning that every value below that limit is dangerous, the objective value should have *greater than* sign (>) in front of the value; if the objective is a *top limit*, meaning that values above that limit are dangerous, the objective value should have *less than* sign (<) in front of the value; if the objective is in a fixed range, its value should be in the following format: *bottom limit – top limit*. A sample file is represented later on this paper.

In case of valid, it calculates the results, and those results are represented in a bar-type chart representing water quality for each selected file. Otherwise, the user will be prompted to select valid files, or edit the same in a manner that the platform is able to read.

The paper is organized as follows: the first section is the introduction. The second section deals with materials and methods used. The third section explains the proposed architecture and the last section relates to the platform implementation.

2. MATERIALS AND METHODS

Water Quality Index: To assess the quality of drinking water we used the Water Quality Index (WQI) developed by the Canadian Council of Ministers of the Environment, which is widely used. The WQI includes three measures of variance from the selected drinking water quality objectives-scope (F1), frequency (F2) and amplitude (F3). [13]

The *scope* represents the water quality of the legal norm of non-compliance during the period of interest and it express Eq. 1:

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) \cdot 100$$

The *frequency* characterizes the percentage of individual tests that do not meet objectives Eq. 2:

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \cdot 100$$

The *amplitude* represents the amount by which failed tests do not meet their objectives Eq. 3:

$$F_3 = \left(\frac{nse}{0.01 \cdot nse + 0.01}\right)$$

where, *nse* indicates the *normalized sum of excursions* that is the collective amount by which individual tests are out of compliance. The WQI is then calculated as Eq. 4:

$$WQI = 100 - \left(\frac{\sqrt{{F_1}^2 + {F_2}^2 + {F_3}^2}}{1.732} \right)$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality. This score is then ranked into one of the following five categories [13]:

Excellent: (WQI Value 95-100).Water Quality is protected with a virtual absence of impairment; conditions are very close to pristine levels; these index values can only be obtained if all measurements meet recommended guidelines virtually all of the time.

Very good: (WQI Value 89-94). Water Quality is protected with a slight presence of impairment; conditions are close to pristine levels.

Good: (WQI Value 80-88). Water Quality is protected with only a minor degree of impairment; conditions rarely depart from desirable levels.

Fair: (DWQI Value 65-79). Water Quality is usually protected but occasionally impaired; conditions sometimes depart from desirable levels.

Marginal: (WQI Value 45-64). Water Quality is frequently impaired; conditions often depart from desirable levels. Poor: (WQI Value 0-44)-Water Quality is almost always impaired; conditions usually depart from desirable levels.

Poor: (WQI Value 0-44). Water Quality is almost always impaired; conditions usually depart from desirable levels.

3. PROPOSED ARCHITECTURE

We are all aware of the popularity of mobile devices lately. They are very handful, useful and almost every one of us possesses one such. Based on these facts, our platform is implemented in Android.

Smartphone came onto the consumer market in the late 90s, but only gained mainstream popularity with the introduction of Apple's iPhone in 2007. The iPhone revolutionized the industry by offering customer friendly features such as a touch screen interface and a virtual keyboard. The first smartphone running on Android was introduced to the consumer market in late 2008. The smartphone industry has been steadily developing and growing since then, both in market size, as well as in models and suppliers. By 2017, over a third of the world's population is projected to own a smartphone, an estimated total of almost 2.6 billion smartphone users in the world. [14]

The proposed platform in this paper aims to provide a solution that will enable the users to directly reach to the calculated result of the water quality, by simply uploading the file from device's internal memory or cloud service provider, as shown in Figure 1.

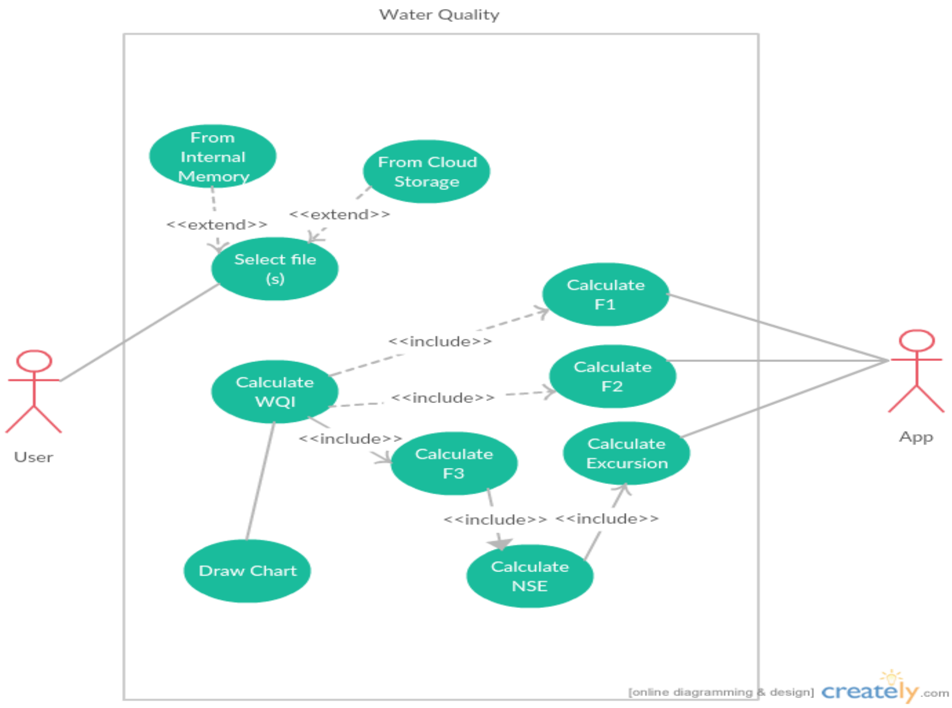

Figure 1. Proposed platform UseCase Diagram

As seen in Figure 1, the platform is developed in such a manner that the user is required to do as less tasks as possible: upload the file(s). As soon as the file(s) are uploaded, a graphical chart is shown containing calculated results for selected files. The chart will represent the results in different colours labelled by file name, trying to provide as much information as possible in the small visual space offered by a mobile device.

The infrastructure of the platform is based on a simple mathematical calculation, using formulas provided in section 2. The user will be able to select files from different sources, such as device's internal memory or different cloud service provider, where he initially has uploaded the files containing collected information about water quality measurements in different periods of time and places. The platform validates the files. In case of the file(s) are valid, it calculates the results, and those results are represented in a bar-type chart representing water quality for each selected file. Otherwise, the user is prompted to select valid files, or edit the same in a manner that the platform is able to read.

In figure 2 is shown the Class diagram, which, in a more detailed way, represents the background tasks that our proposed platform executes in order to provide the information about water quality.

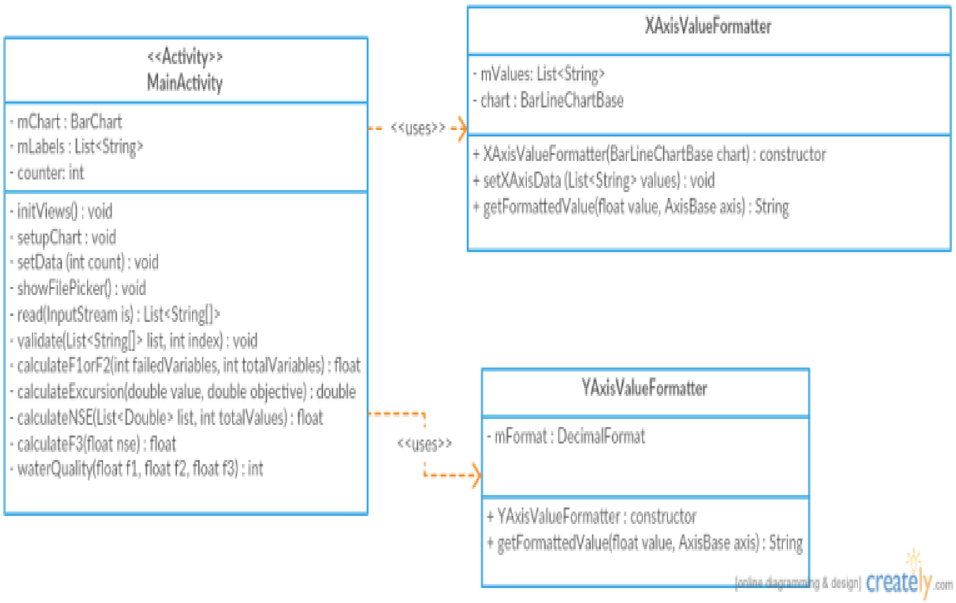

Figure 2. Proposed platform Class Diagram

The class diagram also represents the Data Flow Diagram of the platform that we are proposing. This diagram clearly defines which class interacts with which one and how that interaction occurs. As seen in figure 2, there are two additional classes, which are used to format the information shown in the chart. The *XAxisValueFormatter* class is responsible for preparing the information that will be shown in the *x*-axis of the chart, while the *YaxisValueFormatter* class is responsible for handling the data to be shown in the *y*-axis of the chart.

Starting the application will show the *MainActivity*, which consists of a label telling that there is no data yet to show the chart, and a button, which is placed in the bottom of the screen, through which the user can open the file manager to select the files for calculation. After the selection of files, the *MainActivity* is shown again, but this time consisting of a bar-type chart, representing the calculated information about the water quality of files (most likely, different places) selected. The user can add additional files by repeating the same process.

4. ARCHITECTURE IMPLEMENTATION

The platform's purpose is to automate the calculation of water quality by simply selecting the files user keeps track of different measurements. As we tried to provide a simple working solution, our platform consists of a single activity, where all the tasks are performed. The chart is a third party library, very useful and easy to use [15].

The chart is a two-dimensional chart, where the *y*-axis represents the level of water quality, and the *x*-axis represents the files for which the quality is calculated.

The following figure represents a sample document which is consisted of 10 measured parameters and 12 measured times.

Table 2. Sample file for measurements of water quality during one year[13]

	DO	PH	TP	TN	FC	As	Pb	Hg	2.4D	Lin-dane
7-Jan	11.4	8.0	0.006	0.160	4	0.0002	0.0004	0.05	0.005	0.005
4-Feb	11.0	7.9	0.005	0.170	4	0.0002	**0.0094**	0.05		
4-Mar	11.5	7.9	0.006	0.132	4	0.0002	0.0003	0.05		
8-Apr	12.5	7.9	**0.058**	0.428	4	0.0002	0.0008	0.05	0.004	0.005
6-May	10.4	8.1	0.042	0.250	4	0.0002	0.0008	0.05		
3-Jun	8.9	8.2	**0.108**	0.707	26	0.0006	0.0013	0.05		
8-Jul	8.5	8.3	0.017	0.153	9	0.0002	0.0004			
5-Aug	7.5	8.2	0.008	0.153	8	0.0002	0.0003	0.05	0.005	0.005
2-Sep	9.2	8.2	0.006	0.130	12	0.0003	0.0018	0.05		
7-Oct	11.0	8.1	0.008	0.093	12	0.0002	0.0011	0.05	0.005	0.005
4-Nov	12.1	8.0	0.006	0.296	8	0.0002	**0.0051**	0.05		
1-Dec	13.3	8.0	0.004	0.054	4	0.0002	0.0003	0.05		
Ob-jec-tive	>5	6.5-9.0	<0.05	<1	<400	<0.05	<0.004	<0.1	<4	<0.01

On Table 2, there can be noticed four bolded values, which represent the values not meeting objective. Based on those values, the quality of water varies. This table represents the data in the file, which represents the first bar on the chart represented later on this paper.

The following code snippet represents the calculation of *excursion* for every value of the matrix, and *NSE* according to the formulas provided earlier in this paper:

```
double:calcExcursion(value, objective)
if(value greater than objective)
return value/objective – 1
else
return objective/value – 1
```

float: calcNSE(list, totalValues)
let S be 0
for each value in list
add value to S
return S/totalValues

After calculating the *excursion* and *NSE*, easily can be calculated *F3* and *WQI*.

After clicking the button in the bottom of the page, a file manager screen appears, listing all the files saved in device's storage. Selecting files from there will lead in the main screen again, but this time, with a chart containing calculated information. Figure 3 represents the main screen with four uploaded files.

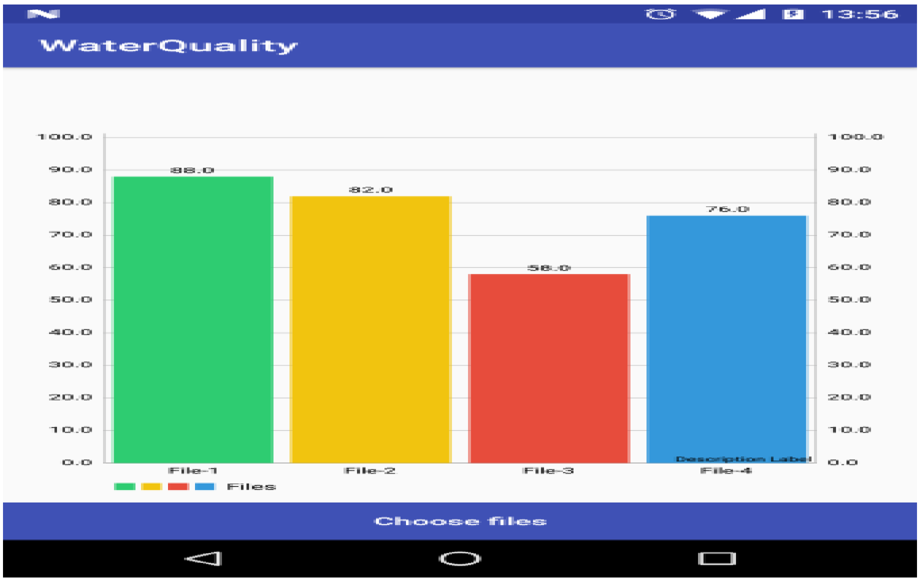

Figure 3: MainActivity User Interface without calculated data.

5. CONCLUSION

In this paper we have presented a proposed architecture that provides a solution enabling users to directly reach to the calculated result of the water quality, as water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with a number. The platform implemented is simple by only uploading the file (containing collected information about water quality measurements in different periods of time) and places from device's internal memory or cloud service provider, validating the files; in case of valid files, it will calculate the results. The platform also manages to have bar-type chart representing water quality for each selected file; otherwise, the user will be prompted to select valid files, or edit the same in a manner that the platform is able to read.

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