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Web-User-Interface System Utilizing rHMEI and Open Data for a Water Quality Analyzer

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Abstract. A clean environment is often taken for granted, but when a river or a lake becomes polluted, it might be hard for the general public to verify the condition. A simple visualization tool for checking the condition of water could help to inform the public and help to increase environmental awareness. With the emergence of Open Data and other openly available data sources, it is possible to create new and innovative applications. In this paper we present a web-based tool for reviewing the quality of water by applying the River Heavy Metal Evaluation Index (rHMEI) method together with open data on water quality in Finland.

Keywords. Visualization, Open Data, rHMEI, User Interface

1. Introduction

There is a saying that Finland is the land of a thousand lakes, although in fact there are 187 888 lakes larger than 500 square meters [1]. The value given to the protection of clean water is reflected by being a national concern in Finland [22], and continues to hold great interest for the Finnish public. When a web-based tool called Vesikartta² (literally water map in English) was published in 2016 for the public to review the condition of Finnish lakes and rivers, it received 83 000 visits in one day [2]. In Finland, the current classification system emphasizes the ecological state of water areas, including several biological parameters such as fish populations, phytoplankton and aquatic vegetation. However, the quality of water is an essential component in the well-being and living conditions of biological organisms, thus monitoring of the water quality in lakes and rivers remains important. [3]

Water resource contamination by toxic substances is increasing, and is a cause of major concern to local people [4][5]. Several human activities may cause heavy metals to spread into ground water resources such as processing of metals, mining, discharge of agricultural waste, discharge of industrial waste, and use of pesticides containing

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²<http://paikkatieto.ymparisto.fi/vesikartta>

compounds of heavy metals. [6][7] Concentrations of heavy metals exceeding a certain threshold level may affect the food chain and cause damage in aquatic organisms or to an industrial process. Safe levels of heavy metal concentrations in water are generally well established (e.g. [8][9][10]), but the synergistic effect of multiple heavy metals may affect the toxicity [11], and [9] remarks that the synergic effects of metals must be taken into consideration.

The River Heavy Metal Evaluation Index (rHMEI) is an environmental index that aggregates and rates the influence of each individual heavy metal parameter. It is a flexible tool for calculating and classifying water quality in a water resource in terms of heavy metals. The rHMEI can present the results of the environmental situation in terms of several heavy metal parameters and type of target category, such as irrigation or aquatic life. The index is also compared with six other methods. [12]

In this paper we present a web-based tool for reviewing the quality of water by applying the rHMEI method to an openly available data set. The algorithm to calculate the water-quality index is based on the findings of [12], and is the first implementation of rHMEI on an interactive web site. The open data set contains the physico-chemical determination values of water samples and is a repository of systematically collected data from various locations in Finland since the beginning of the 1960s.

The contents of this paper are as follows. Section 2 explains the background of the study; Section 3 describes the technical aspects of the implemented prototype application and explains the features of the user interface; finally, Section 4 concludes the paper and lists possible directions for future research.

2. Background

Visualization of data in a meaningful way is becoming more and more important as the amount of data increases. A good visualization also helps the user of the data to interpret it more easily. With visualization, more useful knowledge can be extracted from data. Visualizations of data allow the user to gain insight into the data and come up with new hypotheses and research questions about the phenomena behind the data. The analysis of Big Data, and especially Open Data from public administration may provide interesting and innovative solutions. Open resources such as Open Data can be seen as enablers for new applications [13] and it is expected to have at least the following advantages [14][15][16][17][18]: new jobs, new companies, new services and products, improved innovations, improved governance, more efficient use of the information, and even improved democracy. Concern about personal privacy related to openly available data has been raised [19], but environmental data – such as the data involved in this study – typically does not contain information that would breach anyone's privacy, so in that respect it would be safe to use this data.

Cyber-Physical Systems (CPSs) represent a new generation of digital systems where cyber entities and physical devices cooperate towards a set of common goals. [20] The CPS aims to be a complete solution, in order to integrate the dynamics of the changing environment in physical space, and dynamics among computers and networking in cyber space. It is expected that the CPS will be used for the design and development of future environmental monitoring systems. In the use case of environmental monitoring, the CPS can provide a solution for gathering, analyzing, and visualizing data from any device connected to the Internet. [21]

The prototype application is loosely based on the CPS concept by utilizing Open Data sources for data collection, the rHMEI [12] water quality evaluation method for analysis of data, and HTML5 web technologies for visualization. Our focus is on the visualization step which binds the results of physical and cyber spaces together. The result from physical space is the collected raw sensor data – in our case the Open Data provided by the Finnish Environment Institute – and the result from cyber space is the processed and evaluated environmental information. The result of the visualization step is an attempt to create an example solution based on Open Data in a way that can benefit the potential end users and the owner/publisher of the data. It is also an effort to disseminate the results of scientific research to non-specialist users.

How to increase public's awareness of environmental matters? It is suggested that the use of mobile technologies in education helps increasing students' awareness [22]. Furthermore, increasing environmental awareness with a computer application can be seen as a research problem in the field of human-computer interaction (HCI). While this topic is not assessed in this article, it could prove to be a fruitful method for studying whether the prototype application has effect on the user's environmental awareness or not. An approach of problem-solving in HCI research is given in [23] where they claim that it consists of three different problem types (empirical, conceptual, and constructive), and that the validity and reliability of the research can be evaluated by five criteria (significance, effectiveness, efficiency, transfer, and confidence).

3. Prototype Application

The prototype application for reviewing the quality of water is implemented as a HTML5 web page utilizing JavaScript for interactive features. The goal of the prototype is to provide an easy-to-access and a simple user interface with a minimal amount of configurable options. A simple classification (safe or toxic) for different categories should be clear enough for a user to determine the water quality.

3.1. Implementation

The web page follows single-page application design, and relies on client side processing for user interactions and external services for data retrieval. The data is loaded by using the asynchronous JavaScript and XML (AJAX) technique together with `jQuery` and `tabulator.js` libraries to produce interactive tables. The website requires the web browser to support at least ECMAScript 2015 (ES6). Although most of the code still uses the older JavaScript syntax, ES6 has a large number of useful improvements and new features [24] compared to the previous version.

The PIVET API³ – the source of the Open Data utilized in the application – is based on Open Data Protocol (OData) version 3.0, which enables the use of RESTful calls to query data. From the API, we firstly needed to retrieve a list of sampling locations in a specified area, and secondly the actual data of the selected sampling location. In total, two different OData method calls are used by the application.

³PIVET APIv2.0: <http://rajapinnat.ymparisto.fi/api/vesla/2.0/>

The list of sampling locations was acquired by calling the method “Paikka” on the OData API, and using Finnish municipalities⁴ as a filter. A numerical identifier is given for each municipality, for example number 609 corresponds to Pori, and number 837 corresponds to Tampere. The identifier only changes if the municipality is disbanded, divided, or consolidated with another. The identifier is widely used in public administration data systems in Finland, and due to its static nature it is useful in all kinds of applications where municipalities need to be managed. Finally, the list of result entities is retrieved by calling the method “Result_Wide” and by using the desired location entity as a filtering parameter.

3.2. User Interface

Figure 1 shows a screenshot of the web page after completion of loading and rendering. The user may control the following aspects of the data to be retrieved: selection of municipality, selection of desired water area (i.e. sampling location, see Figure 2), selection of starting date, and an option to filter out all values that are deemed safe (i.e. showing only the hazardous values, see Figure 4).

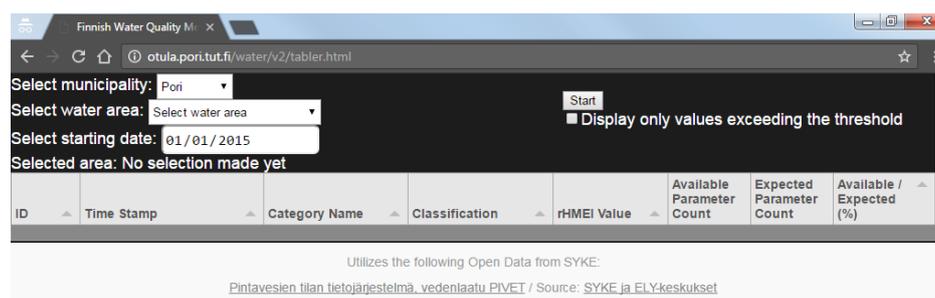


Figure 1. Screenshot of the initial view of the web page.

The table seen in Figure 1 contains the following columns: ID is the identifier of a sample used in the original dataset; Time Stamp shows the time when the sample was collected; Category Name explains what domain this information relates to; Classification indicates the meaning of the rHMEI value in plain language; rHMEI Value is the evaluated index value of the sample for the corresponding category; Available Parameter Count indicates the aggregate of suitable analytes found in the corresponding sample; Expected Parameter Count indicates the count of analytes that may be used for calculation of the corresponding category; Available / Expected (%) is simply the percentage figure of the two former columns.

To use the web page, the first step is to select one of the municipalities from the first drop-down menu. This menu simply contains a static list of active Finnish municipalities. By making this selection now, the user can filter out most of the unrelated water areas seen in the next step.

In the second step – after the user has selected the municipality – the list of water areas contained in the corresponding municipality is retrieved. In Figure 2, the selected

⁴List of Finnish municipalities in 2016: <http://tilastokeskus.fi/meta/luokitukset/kunta/001-2016/> (in Finnish)

municipality is Pori, and several sampling locations are shown in the selection list. The name of the water area might also be an acronym or contain more detailed information defined by the maintainer of the data, thus these names cannot be accurately translated. In this example, the water sampling location Eteläjoki tie 272 mts is selected. Each location is also associated with coordinate information, which enables the software to embed a map, or generate a corresponding URL link to any of the popular mapping web sites.

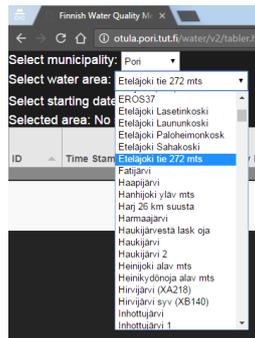


Figure 2. Screenshot of the list containing available water areas in the selected municipality.

The third and last step before retrieving and processing the data is to select the starting date of the dataset. Some of the observation stations may contain data from the beginning of the 1960s, so it might be useful to limit the amount of data retrieved to the latest data only. This is just the default behavior of the web page, so users can retrieve the data from the beginning if they choose to do so. Once the user is ready, the data can be retrieved and processed by clicking the Start button.

ID	Time Stamp	Category Name	Classification	rhMEI Value	Available Parameter Count	Expected Parameter Count	Available / Expected (%)
2016-03-17T00:00:00+02:00 (5 items)							
2802633	2016-03-17T00:00:00+02:00	Industrial	Safe and secure	0.80	1	7	14.29
2802633	2016-03-17T00:00:00+02:00	Estuary Harbour Basin	Safe and secure	0.27	1	9	11.11
2802633	2016-03-17T00:00:00+02:00	Irrigation	Toxic	4.00	1	9	11.11
2802633	2016-03-17T00:00:00+02:00	Aquatic Life	Toxic	2.67	1	9	11.11
2802633	2016-03-17T00:00:00+02:00	Livestock/Wildlife	Toxic	2.67	1	7	14.29
2015-12-07T00:00:00+02:00 (5 items)							
2793788	2015-12-07T00:00:00+02:00	Industrial	Safe and secure	1.80	5	7	71.43
2793788	2015-12-07T00:00:00+02:00	Livestock/Wildlife	Toxic	6.00	5	7	71.43
2793788	2015-12-07T00:00:00+02:00	Estuary Harbour Basin	Safe and secure	0.60	7	9	77.78
2793788	2015-12-07T00:00:00+02:00	Irrigation	Toxic	9.00	7	9	77.78
2793788	2015-12-07T00:00:00+02:00	Aquatic Life	Toxic	7.55	7	9	77.78
2015-11-23T00:00:00+02:00 (5 items)							
2793764	2015-11-23T00:00:00+02:00	Industrial	Safe and secure	0.90	5	7	71.43
2793764	2015-11-23T00:00:00+02:00	Livestock/Wildlife	Toxic	3.00	5	7	71.43
2793764	2015-11-23T00:00:00+02:00	Estuary Harbour Basin	Safe and secure	0.30	7	9	77.78
2793764	2015-11-23T00:00:00+02:00	Irrigation	Toxic	4.50	7	9	77.78
2793764	2015-11-23T00:00:00+02:00	Aquatic Life	Toxic	4.81	7	9	77.78
2015-10-07T16:05:00+02:00 (5 items)							
2788322	2015-10-07T16:05:00+02:00	Industrial	Safe and secure	0.70	5	7	71.43
2788322	2015-10-07T16:05:00+02:00	Livestock/Wildlife	Toxic	2.33	5	7	71.43
2788322	2015-10-07T16:05:00+02:00	Estuary Harbour Basin	Safe and secure	0.23	7	9	77.78

Figure 3. Screenshot of the unfiltered results table.

The Selected area field is updated with corresponding information after clicking the Start button. This field also includes a link to this location using Google Maps. The data is retrieved from the server, and is then processed for visualization. Figures 3 and 4 show two different views of the same data, unfiltered and filtered views, respectively. Filtering hides all values that are below the threshold level, thus it may help to spot occasional values deemed hazardous. The hazardous values have a different background color – red – in order to differentiate them from the safe values.

ID	Time Stamp	Category Name	Classification	rHMEI Value	Available Parameter Count	Expected Parameter Count	Available / Expected (%)
2016-03-17T00:00:00+02:00 (3 Items)							
2802633	2016-03-17T00:00:00+02:00	Aquatic Life	Toxic	2.67	1	9	11.11
2802633	2016-03-17T00:00:00+02:00	Irrigation	Toxic	4.00	1	9	11.11
2802633	2016-03-17T00:00:00+02:00	Livestock/Wildlife	Toxic	2.67	1	7	14.29
2015-12-07T00:00:00+02:00 (3 Items)							
2793788	2015-12-07T00:00:00+02:00	Irrigation	Toxic	9.00	7	9	77.78
2793788	2015-12-07T00:00:00+02:00	Livestock/Wildlife	Toxic	6.00	5	7	71.43
2793788	2015-12-07T00:00:00+02:00	Aquatic Life	Toxic	7.55	7	9	77.78
2015-11-23T00:00:00+02:00 (3 Items)							
2793764	2015-11-23T00:00:00+02:00	Livestock/Wildlife	Toxic	3.00	5	7	71.43
2793764	2015-11-23T00:00:00+02:00	Irrigation	Toxic	4.50	7	9	77.78
2793764	2015-11-23T00:00:00+02:00	Aquatic Life	Toxic	4.81	7	9	77.78
2015-10-07T16:05:00+02:00 (3 Items)							
2788322	2015-10-07T16:05:00+02:00	Irrigation	Toxic	3.50	7	9	77.78
2788322	2015-10-07T16:05:00+02:00	Livestock/Wildlife	Toxic	2.33	5	7	71.43
2788322	2015-10-07T16:05:00+02:00	Aquatic Life	Toxic	2.39	7	9	77.78
2015-08-12T12:00:00+02:00 (3 Items)							
2775309	2015-08-12T12:00:00+02:00	Livestock/Wildlife	Toxic	3.17	5	7	71.43
2775309	2015-08-12T12:00:00+02:00	Irrigation	Toxic	4.75	7	9	77.78
2775309	2015-08-12T12:00:00+02:00	Aquatic Life	Toxic	3.57	7	9	77.78
2015-07-30T09:23:00+02:00 (3 Items)							

Figure 4. Screenshot of the filtered results table.

Each sample (a collection of water quality parameters) is swept in order to find the heavy metal analytes we are interested in. The values of these parameters are then processed against each pre-defined category. There are five different categories (Aquatic Life, Estuary Harbour Basin, Industrial, Irrigation and Livestock/Wildlife), and each of these contains a different set of heavy metal analytes and coefficients for producing the rHMEI value. As the formula for calculating the rHMEI value is additive, the threshold value may be exceeded even if only one – sufficiently toxic – analyte is found from the sample data (for example, see rows with ID 2802633 in Figure 3). If more suitable analytes are available, the borderline cases may become more evident.

4. Conclusion and Future Work

There is a lot of openly available data gathered by the public administration, at least in Finland, but the utilization of the data, such as visualizations and other applications, lags behind. Presenting the processed data in an intuitive and easily understandable way could make the service very popular and interesting for the public. In this paper we presented a tangible example of producing a simple user interface to review water quality by processing the water sample data collected in Finland. Currently, the prototype application

is not targeted at any specific user group, and serves the needs of the authors as a verification tool. A user study should be carried out to test the usability and applicability of the prototype and to determine the users' interest in environmental matters.

For further development ideas for the prototype application, the improvement of the look and feel and the addition of an interactive map of the corresponding measurement location were considered. For each location, the map could show an emoticon (e.g. happy, neutral, or sad) for each of the selected category (for example Aquatic Life) according to the analysis of the available data set. Extension of other fields, such as the quality of air, would complement the user's awareness of local environmental information. In addition, it would be interesting if it were possible to crowdsource the collection of water quality parameters. To implement this, it would be necessary to create a suitable back-end service for storing and validating the data.

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