EFFICIENT MONITORING OF VARIATION IN THE PARAMETERS OF DRINKING AND WASTEWATER QUALITY USING SPATIAL DATABASE AND APPLICATION OF RAPS

Professional paper

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Abstract: Currently, most communal utility management companies continually and automatically follow the changing trends in the drinking and wastewater quality (DWWQ) within their area of activity. Different control systems and applications are used for this purpose. Efficient monitoring of DWWQ should also include the analysis of water-quality parameters, such as the range of changes and trends. The method of Rescaled Adjusted Partial Sums (RAPS) is very suitable for the visualization and determination of the readily apparent features, which may be hidden from the common time-series plots of values. This paper presents different approaches for the tracking and analysis of the DWWQ parameters using a combination of the open-source spatial database, PostgreSQL, and the open-source GIS software. The proposed approach has not yet been used in the management of communal utilities. The main advantages of this modern system are the use of open-source programs and the high efficiency of water-quality monitoring with large datasets. However, the application of this system would require further training of employees in communal utility companies. The analysis results were all obtained for real locations.

Keywords: drinking water; wastewater; quality; spatial database; GIS; RAPS

1 INTRODUCTION

The automation of the change of drinking and wastewater quality (DWWQ) has been widespread in communal utility management [1] owing to the large number of analyzed parameters. The measured parameters of DWWQ are compared with the maximum permissible values prescribed by regulations. The measured parameter values, i.e., their time series, are commonly displayed in a graphical manner in the form of a change in value chart over time. The rescaled adjusted partial sums (RAPS) method is suitable for the visualization and determination of the readily apparent features, which may be hidden from the common time-series plots. Most communal utility companies use a particular software, such as SCADA [2], Locus [3], and WASP [4], for tracking and analyzing the DWWQ parameters. However, such software is usually expensive and requires at least basic training to work on the parameters. In this paper, the method for efficient monitoring of the changing of DWWQ parameters by using the spatial database, PostgreSQL, and the GIS software, QGIS [5,6].

2 QGIS, POSTGRESQL, AND RAPS

The QGIS software is a user-friendly open-source geographic-information system licensed under the General Public License [6]. QGIS has a large number of users along with excellent user support and different tutorials. The software can be used to map different parameters and is compatible with different software types, regardless of them being open source. PostgreSQL is an open-source object–relation database system that is reliable, robust, and shows great performance [5]. SQL is used to communicate with databases and is the standard language in relational database management systems. As mentioned earlier, both applications (QGIS and PostgreSQL) are easy to learn and compatible with each other. This paper shows how to easily search, display, and perform different queries on DWWQ parameter data.
The RAPS method is based on time-series analysis using the data deviation sum curve. The visualization of the RAPS method is suitable as it overcomes the fluctuations, systematical and random changes, and errors and variabilities in the analyzed time series. The graphical representation of the RAPS method includes the existence of subseries with similar characteristics, larger number of trends, sudden value changes, irregular fluctuations, and existence of the periodicity of the analyzed time series.

The RAPS method, expressed as (1), is very often used in hydrology, i.e., for the analysis of the river flow, sediments, water temperature, and precipitation [7–10]. The application of this method in wastewater analysis has also been approved [11] in irrigation [12], geochemistry [13], and many other fields.

$$RAPS_k = \sum_{t=1}^{k} \frac{Y_t - \overline{Y}}{S_Y} \tag{1}$$

where $\overline{Y}$ is the average value of the considered time series, S_y is the standard deviation of the same series, n is the number of data in a time series, and k is the summation counter (k = 1, 2, 3…, n) [14].
The graphical representation of the *RAPS_k* values clearly points to the existence of regularities in the fluctuations of the analyzed parameters (Y_t) [15]. In general, the decreasing patterns in the RAPS method are the result of the mostly below-average Y_t values, whereas the increasing patterns result from the periods of mostly above-average Y_t values.

3 CASE STUDY

In this case study, the Čakovec wastewater treatment plant and Osijek water supply system located in Croatia, as shown in Figure 1, were considered for observation and analysis. These locations were selected based on scientific research conducted by authors.

Figure 1 Locations of case study: Čakovec and Osijek in Croatia [16]

For the Čakovec wastewater treatment plant, the RAPS analysis was conducted for the composite total daily nitrogen input values for 2015 [17]. The second example includes the RAPS analyses of the composite average monthly concentration values of Fe and Mn (μg/L) for 2018 for the Osijek water supply system [18]. The analyzed parameters were selected because they are problematic with respect to values approaching the maximum allowable in the above-mentioned cases.

4 RESULTS AND DISCUSSION

Figure 2 shows the input values for Čakovec and the linear trend for the same time series. Using Microsoft Excel, the RAPS analysis was conducted with the obtained research data. Figure 2 shows that the prediction of the future increases or decreases is not reliable even from linear trend. As shown, the maximum allowable value (MAV) of 15 mg/L [19] is attained most of the year.

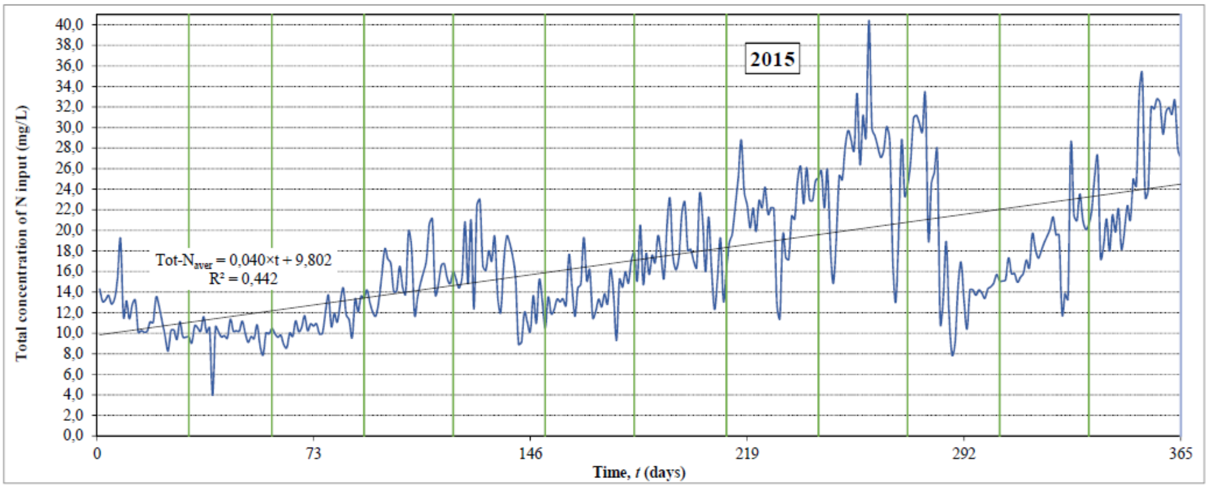

Figure 2 Linear trend of the input values of total daily nitrogen in 2015 at the Čakovec wastewater treatment plant

Although the increases in the values could be determined, owing to the small value of the coefficient of determination, R^2, the regression was not significant. Therefore, the application of the RAPS method results in a new subseries, as shown in Figure 3.

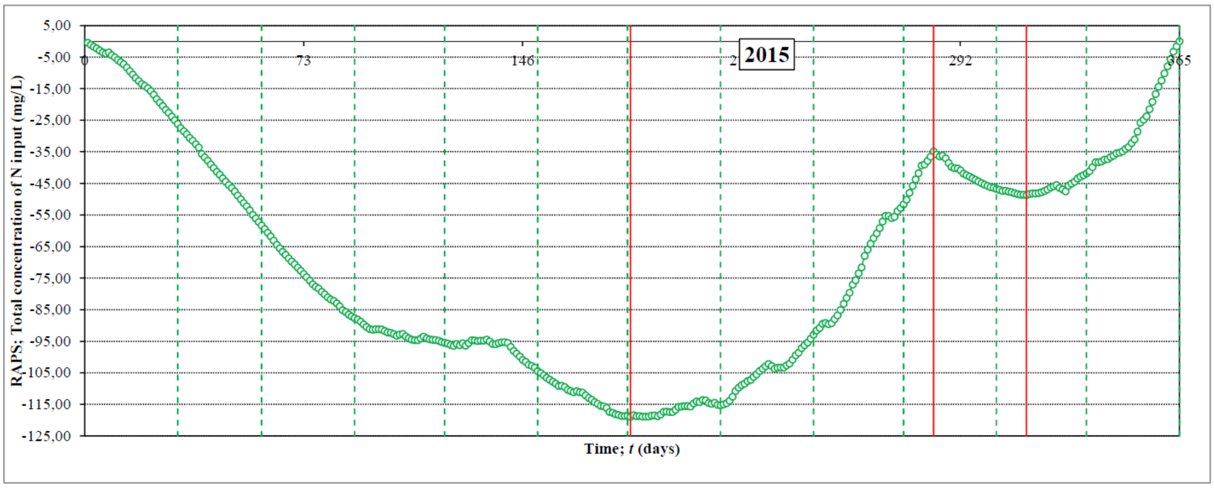

Figure 3 Application of the RAPS method for the input values of total daily nitrogen in 2015 at the Čakovec wastewater treatment plant

The visual representation of the RAPS values shows lowest and highest values as valleys and hills, respectively (vertical solid red lines in Figure 3). Figure 4 graphically presents this procedure as a new subseries.

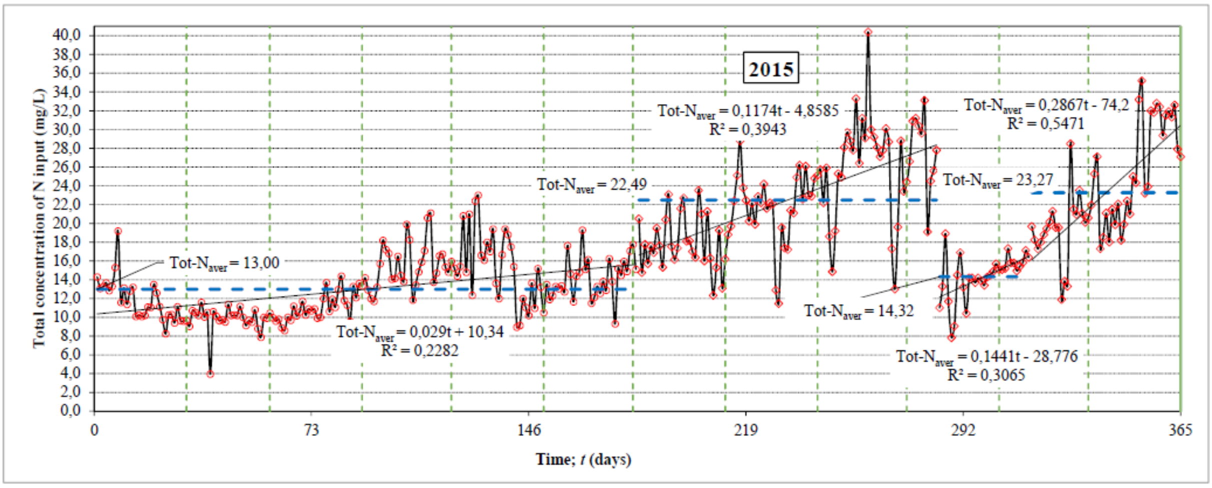

Figure 4 Application of RAPS method for the input values of total daily nitrogen in 2015 at the Čakovec wastewater treatment plant

Although the new obtained subseries do not have a higher coefficient of determination, R^2, than that of the linear trend for the entire time series (Figure 2), they highlight the period in the year that must be focused on. This is characterized by seasonal changes due to the human activities of migration and human habits. For example, from July till September, a new subseries was observed, which emphasizes yearly vacation, decrease in labor intensity, and seasonal departure of the people in the town. Such comprehension is useful for technologists and analysts at the laboratories in the wastewater treatment plants.

The second case study was the RAPS analysis of the average monthly concentration of Fe and Mn (µg/L) values in 2018 at the Osijek water supply system (Figures 5–8) [18]. In this case, MAVs of Fe and Mn, i.e., 200 and 50 µg/L, respectively, were considered [20].

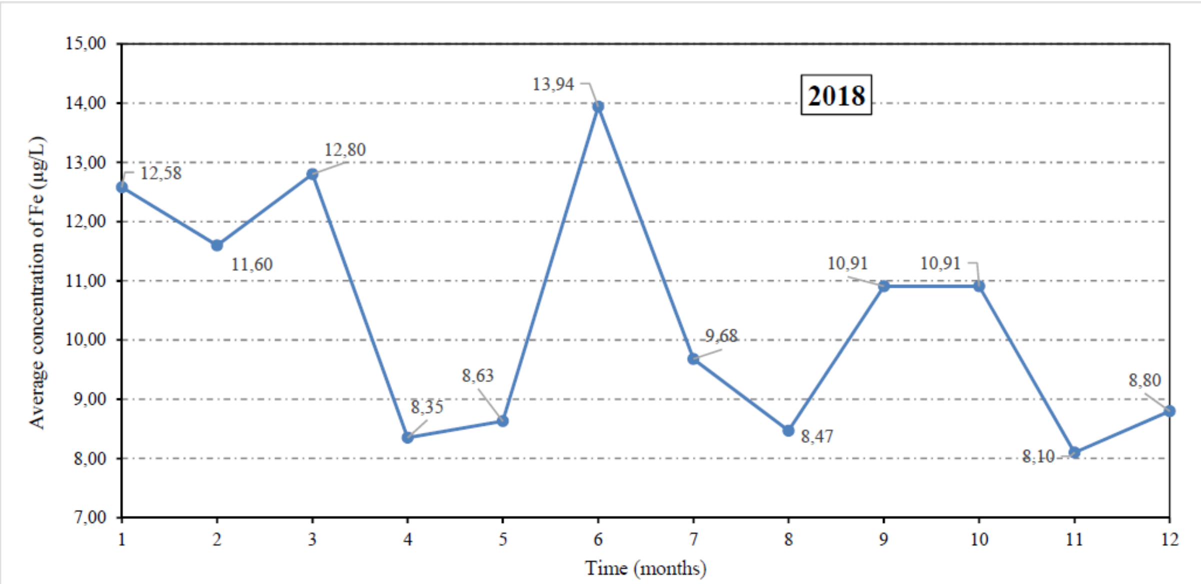

Figure 5 Input values of the average monthly concentration of Fe (µg/L) values in 2018 at the Osijek water supply system

According to Figure 5, 12 values cannot sufficiently reflect the trend in the Fe values. Nevertheless, the RAPS methodology was applied, as shown in Figure 6.

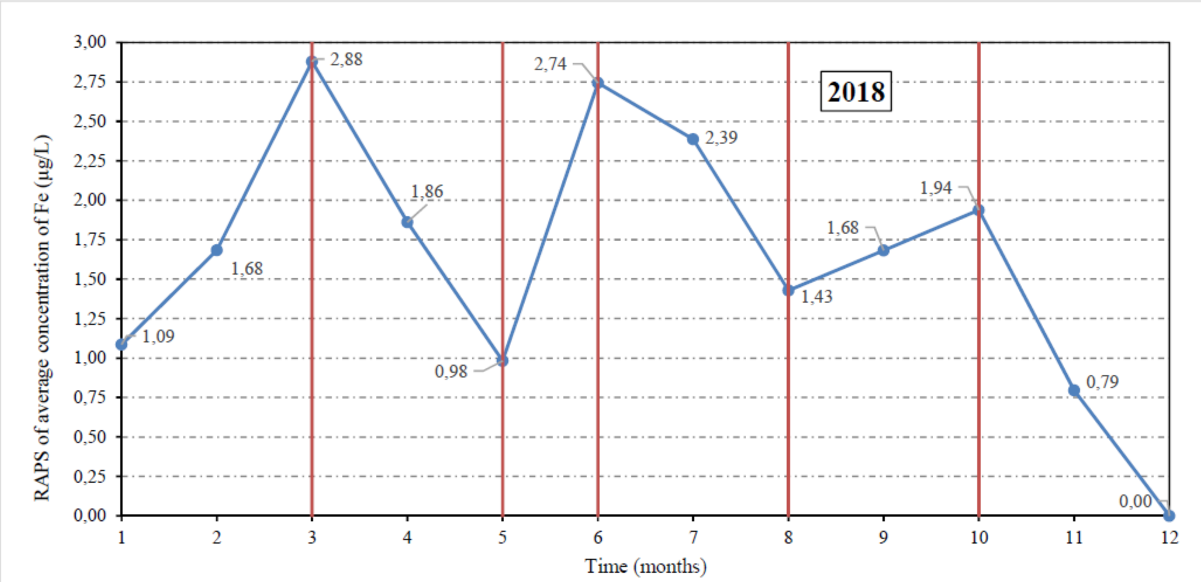

Figure 6 Application of RAPS method for an average monthly concentration of Fe (μg/L) values in 2018 for the Osijek water supply system

As evident in the figure, 12 values are insufficient for conducting the RAPS analysis, as represented by Figure 3, or defining a new subseries, as represented in Figure 4. The same procedure was applied for the MAVs of Mn, as shown in Figures 7 and 8.

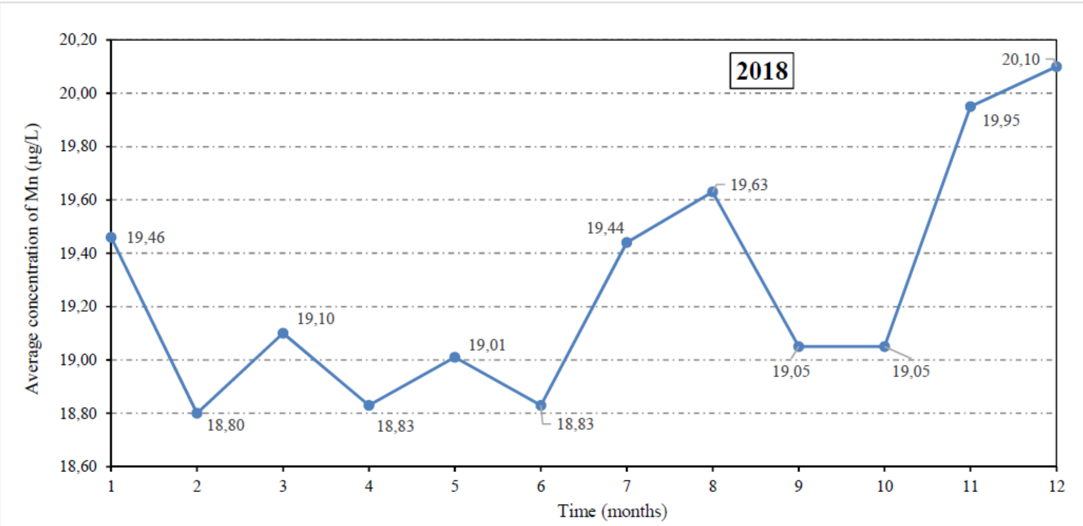

Figure 7 Input values of an average monthly concentration of Mn (μg/L) values in 2018 for the Osijek water supply system

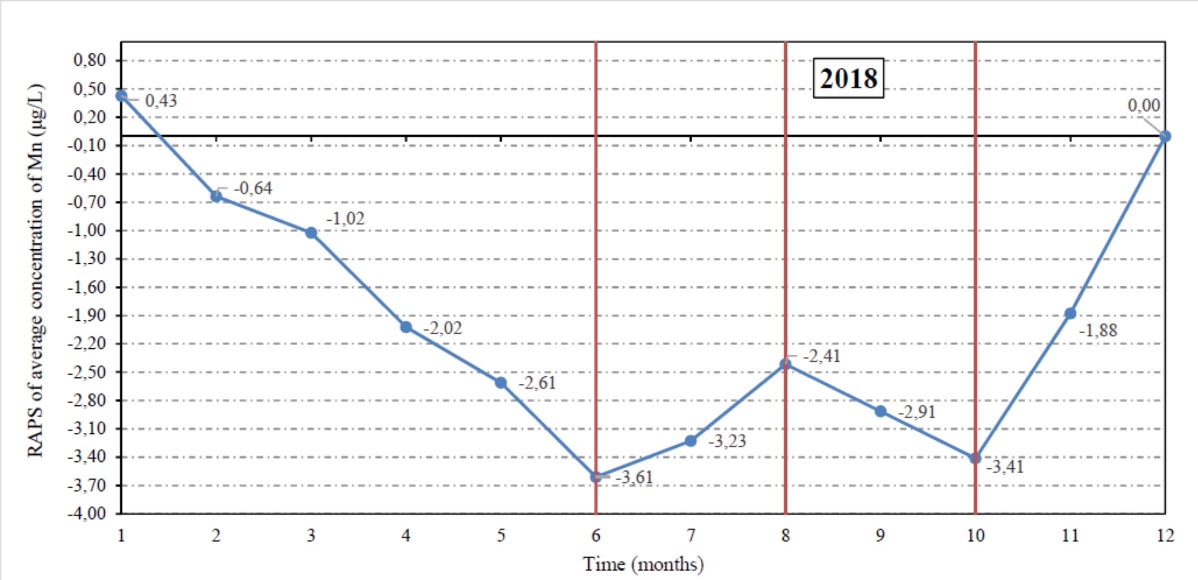

Figure 8 Application of the RAPS method for an average monthly concentration of Mn (µg/L) values in 2018 for the Osijek water supply system

The visual representation of the RAPS method shows periods when the MAVs of Fe and Mn change, i.e., when Fe and Mn have significant and dominant impacts extracted.

Therefore, the value analysis/application of the RAPS method was improved using spatial database PostgreSQL, with input and output data linking, and QGIS connect spatial database for marking the locations for input and output data. This method is particularly useful for large amounts of data that need to be evaluated in a short period of time. PostgreSQL is straightforward, and with minimum training users, it can gain enough knowledge to write queries. It also shows the possibility of writing predefined queries of mostly used analysis so that the user only needs to select the query and obtain results. Figure 9 shows the visual representation of data available in the database, and Table 1 lists part of the of the predefined query result, i.e., data for November of 2015 for Čakovec.

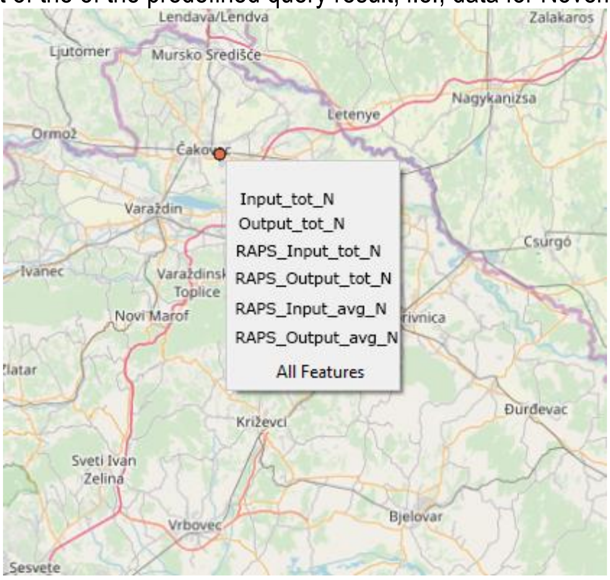

Figure 9 Presentation of the RAPS method using spatial database PostgreSQL and QGIS

Table 1 Example of predefined query: data for November 2015 for Čakovec

date	id	input_n	input_raps	in_raps_tot	output_n	output_raps	out_raps_tot
2015-11-01	305	15.1	−0.3272	−47.0402	5.0	−0.0240	−29.5535
2015-11-02	306	15.2	−0.3085	−47.3487	4.9	−0.0745	−29.6280
2015-11-03	307	17.3	0.0233	−47.3254	5.9	0.3379	−29.2902
2015-11-04	308	15.8	−0.2146	−47.5399	4.2	−0.3859	−29.6760
2015-11-05	309	15.8	−0.2146	−47.7545	3.8	−0.5289	−30.2049
2015-11-06	310	15.0	−0.3460	−48.1005	4.4	−0.2765	−30.4814
2015-11-07	311	15.4	−0.2709	−48.3714	4.4	−0.2765	−30.7579
2015-11-08	312	15.8	−0.2083	−48.5797	5.6	0.2200	−30.5378
2015-11-09	313	17.1	−0.0080	−48.5877	3.0	−0.8739	−31.4118
2015-11-10	314	16.4	−0.1238	−48.7115	3.2	−0.8150	−32.2268
2015-11-11	315	19.7	0.3927	−48.3188	3.3	−0.7645	−32.9914
2015-11-12	316	18.2	0.1673	−48.1515	3.5	−0.6636	−33.6549
2015-11-13	317	17.3	0.0202	−48.1313	3.6	−0.6467	−34.3017
2015-11-14	318	18.0	0.1297	−48.0016	4.2	−0.3690	−34.6707
2015-11-15	319	18.8	0.2549	−47.7467	3.2	−0.8150	−35.4857
2015-11-16	320	19.4	0.3551	−47.3916	3.6	−0.6383	−36.1240

CONCLUSION

The graphical representation of input/output and calculated RAPS is informative and transparent. Such a procedure does not require particular skills; knowledge of the application of any spreadsheet software (Microsoft Excel in this case) is sufficient. By using predefined queries, users can search for data directly in the QGIS and avoid using different software. PostgreSQL and QGIS are open source and user friendly. The proposed method could achieve high efficiency of DWWQ monitoring with a large dataset. The study proved that the proposed method is more effective than conventional analysis methods. It should be emphasized that the purpose of this work was not to determine the cause of appearance of new subseries in terms of natural or anthropogenic impact but primarily to simplify the analysis for technologists, scientists, and experts who analyze the time series of particular parameters. The RAPS method can be applied for all continuing time series of parameters, and it is recommended that the time series should be as long as possible.

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