Data Analysis and Visualization for
Industrial Enterprise Water Supply System

Vladislav Noskov, Aleksey Kychkin

Microprocessor Means of Automatization Department, Perm National Research Polytechnic University
Komsomolsky Prospect 29, 614990, Perm, Russia
noskov_v_v_@mail.ru, aleksey.kychkin@gmail.com

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Abstract: In this article the method of the industrial enterprises water supply system data analysis based on search of dependences of emergencies number on environmental parameters is considered. The example of water supply system with a standard structure is given, possible places of accidents are shown. The mathematical models of the monitoring results analysis in order to identify the relationship of accidents in knots, piping lines, consumer systems for water supply and sanitation by external factors are proposed. Calculation of correlation function showed dependence of the accident number on water temperature. Histograms of distribution of water temperatures in system and quantities of emergencies, graphics of the average values with use of the smoothing filters, dependence of temperature in the giving system of water from the number of accidents are constructed. Data visualization is carried out with using the OpenJEVis information system. The received results can be used for forming of observations statistics, an impact assessment of other parameters of system, accident rate forecasting. Research has been completed under the PNRPU grant No.2016/PI-2 «Methodology development of monitoring and heat flow utilization as low potential company energy sources».

1   INTRODUCTION

Today industrial enterprises are using a large amount of water except energy resources. Water at the enterprise is used in production processes, for washing and drinking needs, on ensuring fire safety, including fire extinguishing, etc.

Strict requirements are imposed to quality of water that together with requirements for ensuring stable water supply determines both product quality, and overall performance of all enterprise. The permanency in water supply and it`s quality are provided due to use of an effective engineering water supply system, standards and regulations, the supplied system of monitoring of emergencies with functions of control and forecasting (Hong et al., 2013). Such engineering system, which includes a subsystem of water treatment and water disposal (sewerage), is represent the geographically distributed network with a huge number of consumers, nodes and complex pipeline topology (Jacobsen, 1985).

Despite daily control and elimination of various emergencies, for example, breaks of the pipeline, leakages in systems of consumers or in nodes, etc., time periods when the number of accidents considerably exceeds average values we be observed (Seem, 2007). Usually such time frames fall on the summer period when it becomes difficult to find a leakage. Besides, there can be several emergencies at the same time that leads to a stop of production process or brings big water losses as a resource. That`s why data analysis and visualization for the production enterprise water supply system based on the searching dependences of accidents number on external factors, including water temperatures of a source and the environment is an urgent task (Lyakhomskii, Perfil'eva, Kychkin and Genrikh, 2015).

2   WATER SUPPLY SYSTEM

Production of concrete designs, silicate blocks and other construction materials requires the large volume of water therefore the engineering water supply system of such production represents by the big territorially distributed network. The purified

water on system of pipelines arrives to consumers, who are divided on large consumers. For example it can be a production of materials, cooling systems for compressors and power units, small consumers, including various processing equipment, economic, etc.

At the entity the closed water use cycle implying its reuse at the expense of the developed sewer system and cleaning is realized. The main volume of water is concentrated into the accumulation system. For maintenance of the set water level exist an additional water source.

Large engineering system of water supply geographical distribution, outdated technologies of water supply and pipeline systems, high pressure on sites of technological processes, lead to emergence of emergencies in various positions are shown in the figure 1. Such data can be collected using the energy monitoring system (Kychkin, 2016).

On the scheme the following designations are used:

$n_{p_{1..j}}$ – the accidents number on large consumers per day, where j – the number of large consumers;

$n_{p_{j+1..i}}$ – the accidents number on small consumers per day, where i – a total quantity of consumers at the entity;

$n_{L_{1..q}}$ – the accidents number on water supply pipelines per day, where q - the number of lines of a supply of water;

$n_{L_{q+1..e}}$ – the accidents number on water disposal lines per day, where e - total of lines;

$n_{U_{1..k}}$ – the accidents number in water supply nodes per day, where k - the number of water supply nodes;

$n_{U_{k+1..m}}$ – the accidents number in water disposal nodes per day, where m – total of nodes.

Total quantity of emergencies in an engineering water supply system of the construction materials production during a day is N:

$$N = n_{p_{1..i}} + n_{L_{1..e}} + n_{U_{1..m}}, \qquad (1)$$

where $n_{p_{1..i}} = n_{p_{1..j}} + n_{p_{j+1..i}}$ – total accidents number per day on the party of consumers; $n_{L_{1..e}} = n_{L_{1..q}} + n_{L_{q+1..e}}$ – total accidents number per day on pipelines; $n_{U_{1..m}} = n_{U_{1..k}} + n_{U_{k+1..m}}$ – total accidents number per day in distribution knots.
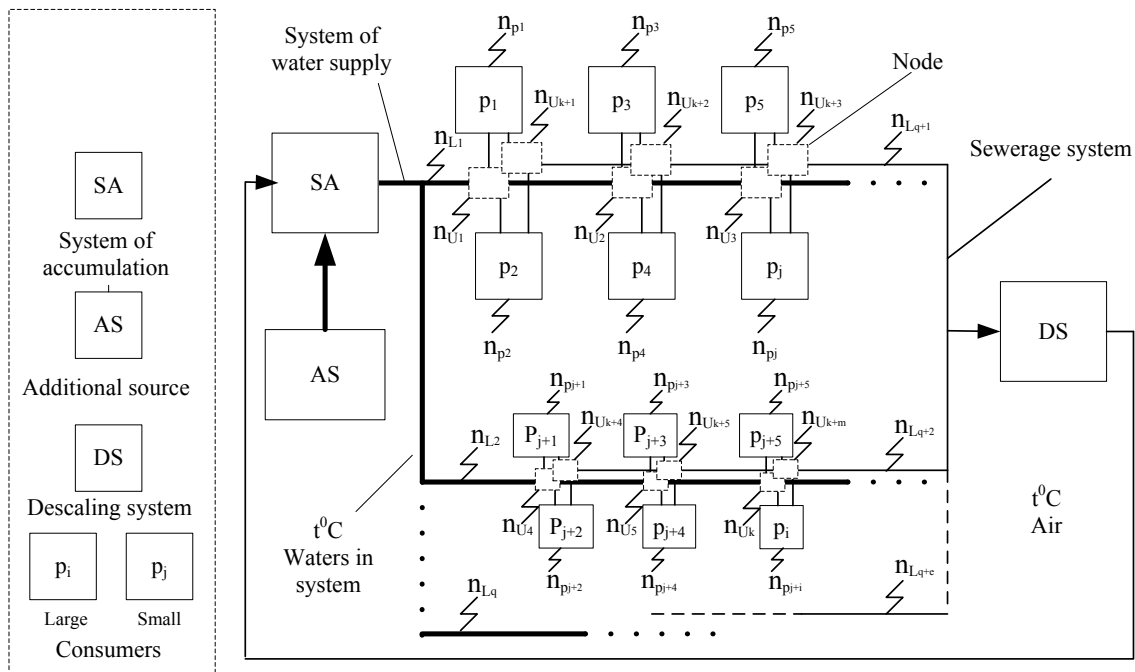

Figure 1: Water supply system structure and emergence accidents places.

3 DATA ANALYSIS

For dependence assessment of accidents number in engineering water supply system from external factors it is necessary to carry out the mathematical analysis of the ambient temperature and water temperature in a source observations results (Kychkin and Mikriukov, 2016). To find the values of the degree of temperature influence on the number of accidents it is necessary to analyze the behavior of the function f (Kychkin, 2013):

$$N = f(t_1^0, t_2^0), \qquad (2)$$

where t_1^0 – air temperature in the period of emergencies; t_2^0 – source water temperature in the pipeline.

Correlation coefficients for couples of observations (N, $t_1°$) and (N, $t_2°$) can be found using formulas:

$$r_{N,t_1^0} = \frac{\sum (\overline{N} - N) \cdot (\overline{t_1^0} - t_1^0)}{\sqrt{\sum (\overline{N} - N)^2} \cdot \sqrt{\sum (\overline{t_1^0} - t_1^0)^2}}, \qquad (3)$$

$$r_{N,t_2^0} = \frac{\sum (\overline{N} - N) \cdot (\overline{t_2^0} - t_2^0)}{\sqrt{\sum (\overline{N} - N)^2} \cdot \sqrt{\sum (\overline{t_2^0} - t_2^0)^2}}, \qquad (4)$$

where $\overline{N}$ – the average number of accidents in engineering water supply system in one day; $\overline{t_1^0}$ – average value of air temperature in the period of emergencies; $\overline{t_2^0}$ – average value of source water temperature in the pipeline.

The correlation coefficient for couples of observations (N, $t_1°$) has made 0.35. This value means that there is weak dependence between two of these parameters. For couples of observations (N, $t_2°$) it has made 0.62 that corresponds to average degree of dependence. On the basis of these results we will choose dependence between the number of accidents and value of temperature in system of water supply.

To evaluate the frequency of origin abnormal a situation and the frequency of appearance of values of temperatures in the giving system of water-supply, it is necessary to construct the distributed histogram for a summer season for 2015 and 2016. In a figure 2 the distributed histogram of number of accidents in two years is shown. On a graphics asymmetry to the left – offset of the histogram in the left part is watched. It is visible that there is a mean value of number of accidents which makes 3 accidents for 2015 and 6 accidents for 2016.

In the figure 3 the temperature values distribution histogram for the source system in two years is constructed. The data bimodalness can be observed. It means that distribution isn't normal.
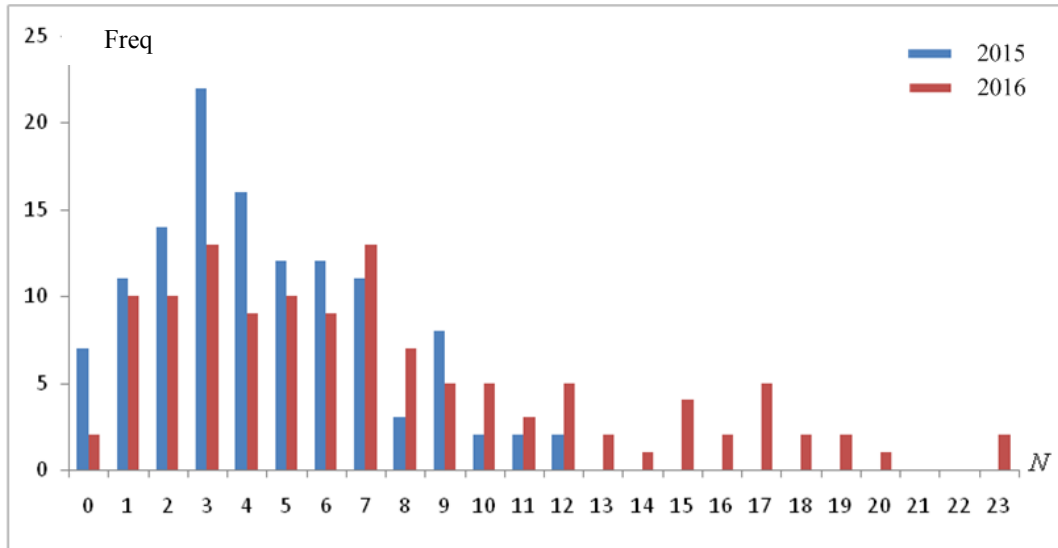

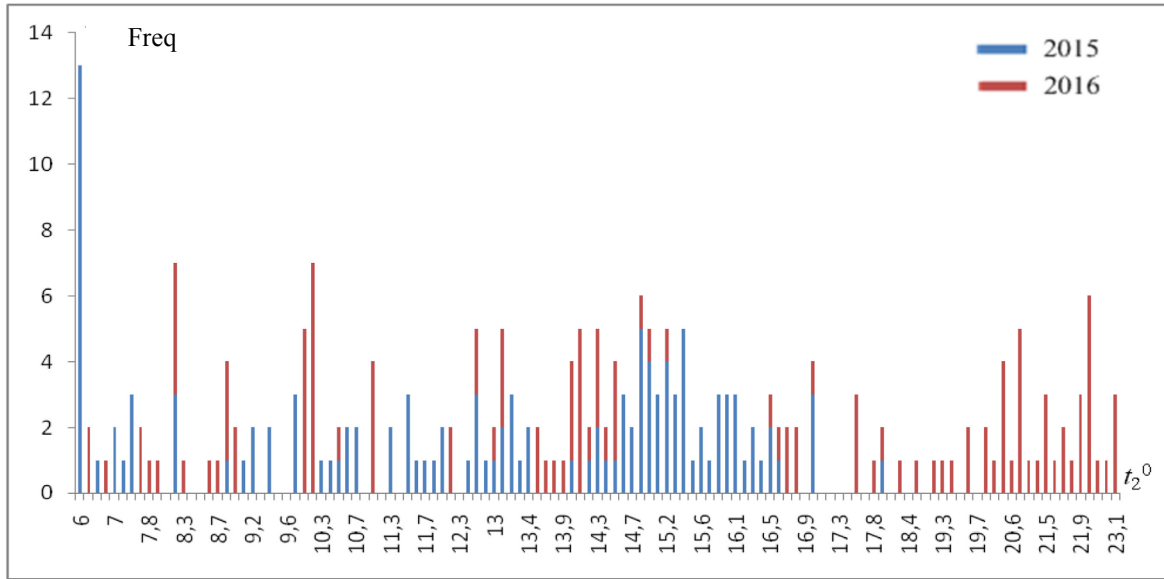Figure 2: The accidents number distribution histogram.

Figure 3: The temperature distribution histogram for water supply system.

Moving average is proposed to use for the data smoothing. It will allow to show the hidden changes on graphics.

For creation of moving averages will be used three types:

- simple (simple moving average, SMA);
- exponential (exponential moving average, EMA);
- weighted (weighted moving average, WMA).

For the construction of the simple average sliding it is necessary to use a formula (Prerez-Lombard, Ortiz, Pout, 2008):

$$SMA(k,n) = \frac{1}{n} \sum (x_1 + x_2 + ... + x_{k-(n+1)}), \qquad (5)$$

where $EMA[k, n]$ — the simple sliding n period average at the time of k; $x_{k-(n+1)}$ – the current value at the moment k-$(n+1)$.

For the construction of sliding weighed it is necessary to use a formula:

$$WMA[k,n] = \frac{n \cdot x_k + (n-1) \cdot x_{k-1} + (n-2) \cdot x_{k-2} + ... + x_{k-(n+1)}}{\left(\frac{n \cdot (n+1)}{2} \right)} \qquad (6)$$

where $WMA[k, n]$ — the weighed sliding n period average at the time of k.

For the construction sliding exponential it is necessary to use a formula:

$$EMA[n] = q \cdot x_n + (1-q) \cdot EMA[n-1], \qquad (7)$$

where $EMA[n]$ — the exponential sliding average with n period; q – weight coefficient in the range from 0 to 1, reflecting the speed of aging of last data; $EMA[n$-$1]$ – value of the exponential sliding average calculated for the previous period.

4 RESULTS VISUALIZATION

For data visualization will be used open software OpenJEVis by Envidatec GmbH Company (Faizrakhmanov, Frank, Kychkin and Fedorov, 2011) and RapidMiner software.

Water supply system temperature and environment air temperature for 2016 schedules are shown in the figure 4.
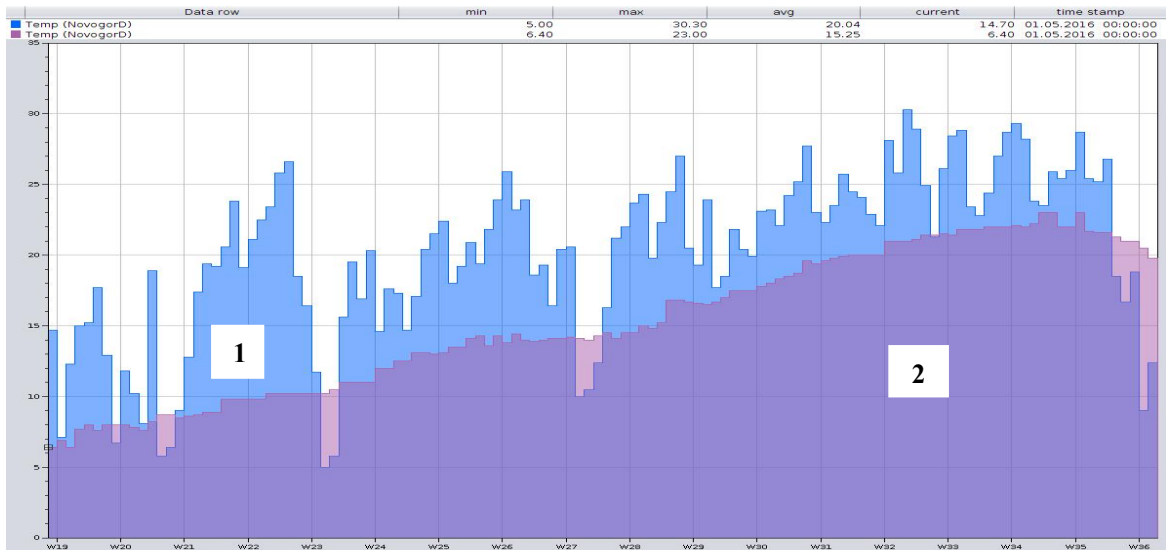
Figure 4: Environment air temperature (1) and temperature in water supply system (2).

In the figure 5 accidents number schedule in water system for 2016 is shown. After 28 week the accidents number was increased. This period coincided with the onset of warm weather in a region.
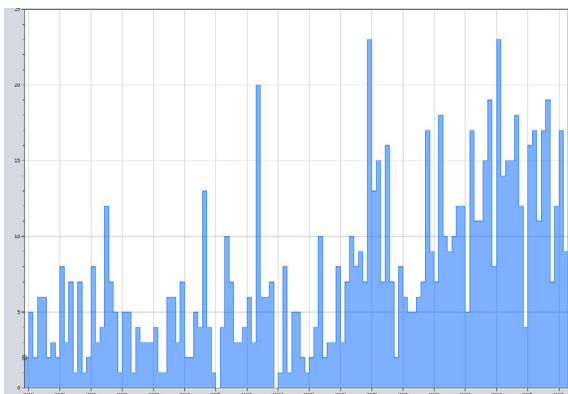

Figure 5: Accidents number in the water supply system.

In the figure 6 the simple moving average for accidents curve and water supply system temperature is shown. Accidents number increased in those days when water temperature in system was more than 15 degrees ($t_2 > 15$ °C).

The curves can be divided into two areas. Area *I* corresponds to area in which the number of accidents remains invariable.

Area *II* is an area in which the accidents number increases with increasing water temperature. Areas *I* and *II* are divided by temperature value $t_2 = 15$ °C.
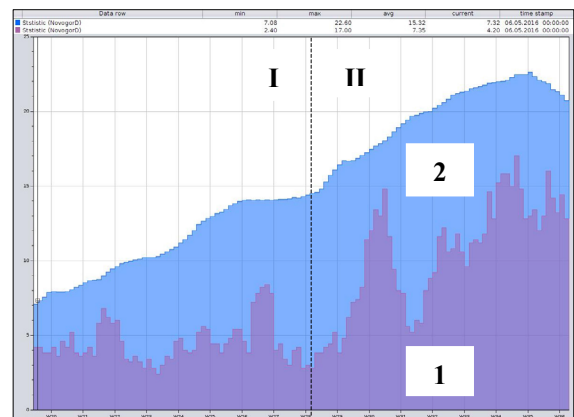

Figure 6: The moving average for accidents curve (1) and water supply system temperature (2).

It is possible to assume that function *f* can be piecewise determinate using statistic analysis (Claridge, 1998). The main results of calculations are given in table 1.

Table 1: Calculations results for 2016 year.

Parameter	t_1, °C	t_2, °C	N
Total accidents	-	-	930
Average value per day	20	15.3	7
Min	5	6.4	0
Max	30.3	23	23
Correlation coefficient	N, t_1°	N, t_2°	-
	0.35	0.62	-

5 CONCLUSIONS

The carried-out analysis and visualization of an engineering water supply monitoring results of the industrial enterprise specializing in release of construction materials are showing relation between numbers of emergencies and water temperature in system. This dependence is observed in case of excess of water temperature 15 ^{0}C. According to specialists this relation can be caused by increase in concentration of dissolved oxygen in water that is in turn leads to corrosion processes speed increasing. At the same time relation between water and air temperature is observed. In order to prevent the growth of emergencies it is proposed to realize water accumulating system based on isolated reservoirs, which are located at a depth of 1-2 meters of soil freezing level. In this case the level of ambient temperature influence on water temperature in the system during the season periods of year is minimal. The proposed analysis can be used for accident forecasting in the water supply system of other manufacturing and municipal services of the city.

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