Generalized Net Model of Mechanical Wastewater Pre-treatment

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Abstract: In the current paper, a Generalized Net (GN) model of mechanical treatment of wastewater in a wastewater plant is presented. The technological scheme comprises the main processes in this first stage of wastewater treatment. The proposed GN-model allows for more complex monitoring and managing the individual steps in the mechanical stage of the treatment process. Moreover, it can be helpful in tracing, analyzing and setting of some parameters related to the operation of the equipment.

Keywords: Wastewater treatment, Mechanical purification, Generalized Net, Modelling.

Introduction
In the process of industrial usage, water is usually polluted with different types of dispersions and impurities. As a result, these have to be removed from the production process and discharged into the environment. Discharge of wastewater into the environment without pre-treatment or purification causes pollution of natural water and could become a real threat for environmental disaster in entire regions. Due to this fact, it is obligatory to perform purification of the contaminated water before discharging it into the receiving water [3].

The first confirmed records related to the wastewater treatment (WWT) plant date back to 2500-3000 years BC during the Mesopotamian Empire [13]. Nowadays, the application of EU Directive 91/271/EEC requires purification of the wastewater up to a degree that would allow discharging the water in water intake bodies in a manner consistent with the permission of water usage or the individual emission norms of the complex industrial enterprises. All these facts put an emphasis on the maintenance of WWT plants as a whole, but also turn the focus to the technology, equipment, and last but not least – effective control of the processes execution at the separate stages of the wastewater treatment process [4, 29].

The diversity of pollutants contained in wastewater determines the different methods used in their processing in the course of their treatment. Mechanical purification technology is a mandatory first step for treatment of municipal and industrial wastewater [13, 28]. This step includes removing the coarse particles to prevent the next technological steps from damage or contamination and to facilitate their work.

There are some approaches successfully applied to the WWT modeling processes, e.g. neural networks [10]. Among them the theory of Generalized Nets (GNs) [1] is an effective approach for modeling, analysis and decision making in different areas of application – expert
systems [2, 17, 24], optimization [5, 23], biology [11], neural networks [12, 26], genetic algorithms [15, 21, 22], medicine [18-20], e-learning [25], intercriteria analysis [27]. There have been already a variety of applications of GN apparatus for modelling of WWT processes, i.e. modeling of the processes in the “bioreervoir – sedimentor” system [6], WWT processes of methane fermentation [14] and in fixed-bed bio reactors [16], simulation of a WWT [8], etc. Considering the modelling of the main stages in a WWT plant, there have been developed GN-models of physico-chemical [9] and of biological treatment of wastewater [7]. So, the next logical step in the application of GNs to modelling of WWT plants is the development of a GN-model of mechanical wastewater pre-treatment, which represents the first purification step of a WWT plant. Since its reliability is thus the prerequisite for all subsequent treatment steps, in this paper a detailed GN-model, describing the main processes in this step, is proposed.

Technological scheme of mechanical wastewater treatment
Mechanical treatment involves several steps: percolation through grates and screens, averaging, sedimentation and filtration. A typical scheme of mechanical treatment stage is presented in Fig. 1.

Strain is typically used to remove larger floating and insoluble fibrous substances with the help of grids and screens. The grids are used to retain the coarsest materials found in the water, and the screens are designed to keep relatively rough-dispersion impurities. A process of averaging follows, which is used for averaging the composition of the effluent containing more than 500 mg/l suspended solids. The process is carried out in the so-called mixing and averaging tank (mixing of water streams and averaging their parameters at the exit). After this process, wastewater falls in the so-called precipitators, where precipitation process is carried out to separate sedimenting in water free mechanical pulp by precipitation, precipitation
unfree or slurry precipitation. The sand and other particulate matter of mineral origin, which show free sedimentation, can be removed prior to the precipitation of the other substances suspended in the so-called sand traps. Also, by precipitation (emerge) as the most common method, removal of oil and petroleum products from water is performed. The process is carried out in the so-called oil separators. The final stage in mechanical WWT is the filtration process. The wastewater leaving the mechanical stage for further processing is with a 60% reduced content of suspended solids and contaminants from the organic matter is reduced by 15 to 35%.

**Generalized net model of mechanical wastewater treatment**

Based on the discussed scheme of mechanical wastewater treatment a GN-model is developed. The presented in Fig. 2 GN-model contains 18 transitions and 52 places and has the following description:

\[ A = \{Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8, Z_9, Z_{10}, Z_{11}, Z_{12}, Z_{13}, Z_{14}, Z_{15}, Z_{16}, Z_{17}, Z_{18}\} \]

The transitions represent the following processes:

- Polluted wastewater obtaining – transition \(Z_1\);
- Emergency buffer tank functions – transition \(Z_2\);
- Grids functions – transition \(Z_3\);
- Sand trap functions – transition \(Z_4\);
- Hydrocyclones functions – transition \(Z_5\);
- Screw pumps functions – transition \(Z_6\);
- Emergency overflow chamber functions – transition \(Z_7\);
- Oil separators functions – transition \(Z_8\);
- Functions of the tank for oil and oil products from oil separators – transition \(Z_9\);
- Functions of the pumps for oil and oil products from oil separators – transition \(Z_{10}\);
- Functions of the tank for bottom sludge from oil separators – transition \(Z_{11}\);
- Functions of the pumps for bottom sludge from oil separators – transition \(Z_{12}\);
- Mixing and averaging tank functions – transition \(Z_{13}\);
- Primary precipitators functions – transition \(Z_{14}\);
- Functions of the tank for surface (float) sludge from primary precipitators – transition \(Z_{15}\);
- Functions of the pumps for surface (float) sludge from primary precipitators – transition \(Z_{16}\);
- Functions of the tank for bottom sludge from primary precipitators – transition \(Z_{17}\);
- Functions of the pumps for bottom sludge from primary precipitators – transition \(Z_{18}\).

Initially, tokens \(\alpha, \beta, \gamma, \chi, \delta, \varepsilon, \phi, \theta.1, \theta.2, \theta.3, \varphi, \mu, \tau, \lambda, \sigma, \psi.1,1, \psi.1,2, \rho, \nu, \eta\) and \(\kappa\) occupy places \(l_3, l_5, l_8, l_{12}, l_{15}, l_{17}, l_{20}, l_{24}, l_{25}, l_{26}, l_{28}, l_{30}, l_{33}, l_{35}, l_{39}, l_{43}, l_{44}, l_{46}, l_{48}, l_{50}\) and \(l_{52}\). They remain in these places throughout the whole time of the generalized net functioning with the following initial and present characteristics:

- \(\alpha\)-token in place \(l_3\) with a characteristic “Flowing amount polluted wastewater”;
- \(\beta\)-token in place \(l_5\) – “Emergency buffer tank”;
- \(\gamma\)-token in place \(l_8\) – “Grids”;
- \(\chi\)-token in place \(l_{12}\) – “Sand trap”;
- \(\delta\)-token in place \(l_{15}\) – “Hydrocyclones”;
- \(\varepsilon\)-token in place \(l_{17}\) – “Screw pumps”;

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- $\phi$-token in place $l_{20}$ – “Emergency overflow chamber”;

Fig. 2 GN-model of mechanical stage in WWT plant

- $\theta_{1,1}, \theta_{1,2}, \theta_{1,3}$-tokens in places $l_{24}, l_{25}, l_{26}$ – “Oil separator 1”, “Oil separator 2” and “Oil separator 3”, respectively;
- $\varphi$-token in place $l_{38}$ – “Tank for oil and oil products from oil separators”;
- $\mu$-token in place $l_{30}$ – “Pumps for oil and oil products from oil separators”;
- $\tau$-token in place $l_{33}$ – “Tank for bottom sludge from oil separators”;
- $\lambda$-token in place $l_{35}$ – “Pumps for bottom sludge from oil separators”;
- $\sigma$-token in place $l_{39}$ – “Mixing and averaging tank”;
- $\psi_{1,1}, \psi_{1,2}$-tokens in places $l_{43}, l_{44}$ – “Primary precipitator 1” and “Primary precipitator 2”, respectively;
• $\rho$-token in place $l_{46}$ – “Tank for surface (float) sludge from primary precipitators”;
• $\nu$-token in place $l_{48}$ – “Pumps for surface (float) sludge from primary precipitators”;
• $\eta$-token in place $l_{50}$ – “Tank for bottom sludge from primary precipitators”;
• $\kappa$-token in place $l_{52}$ – “Pumps for bottom sludge from primary precipitators”.

The token $\alpha_0$, with a characteristic “Polluted wastewater”, enters the GN in place $l_0$. The form of the first transition of the GN-model is as follows:

\[
Z_1 = \langle \{l_0, l_3, l_4\}, \{l_1, l_2, l_3\}, r_1, \nu(l_0, l_3, l_4) \rangle,
\]

where

\[
W_{3,1} = W_{4,3} = “\text{There are polluted wastewater for mechanical treatment}”;
W_{3,2} = “\text{There are wastewater for emergency buffer tank}”.
\]

$\alpha_0$-token, entering in place $l_3$ (through place $l_0$), keeps its characteristic “Polluted wastewater”. $\alpha_1$-token, entering in place $l_1$, obtains a characteristic “Wastewater for mechanical treatment”. $\alpha_2$-token, entering in place $l_2$, obtains a new characteristic “Wastewater for emergency buffer tank”.

The form of the second GN-model transition is as follows:

\[
Z_2 = \langle \{l_2, l_5, l_{19}\}, \{l_4, l_5\}, r_2, \nu(l_2, l_5, l_{19}) \rangle,
\]

where

\[
W_{5,4} = “\text{There are wastewater from emergency buffer tank for mechanical treatment}”.
\]

$\alpha_2$ and $\phi_2$-tokens, entering in place $l_5$ (through places $l_2$ and $l_{19}$ from transition $Z_7$), keep their characteristics. $\beta_0$-token, entering in place $l_4$, obtains a characteristic “Wastewater from emergency buffer tank for mechanical treatment”.

The form of the third GN-model transition is as follows:

\[
Z_3 = \langle \{l_1, l_8\}, \{l_6, l_7, l_8\}, r_3, \nu(l_1, l_8) \rangle,
\]

where

\[
W_{8,6} = “\text{There are wastewater purified from rough admixtures}”; \quad W_{8,7} = “\text{There are rough admixtures for disposal}”.
\]
α1-token, entering in place \( l_8 \) (through place \( l_1 \)), keeps its characteristic. \( γ_1 \) and \( γ_2 \)-tokens entering in places \( l_6 \) and \( l_7 \) when the value of predicates \( W_{8,6} \) and \( W_{8,7} \) is “true”. \( γ_1 \) and \( γ_2 \)-tokens obtain the following characteristics: “Purified wastewater from rough admixtures” in place \( l_6 \) and “Rough admixtures” in place \( l_7 \).

The form of the fourth GN-model transition is as follows:

\[
Z_4 = \langle \{l_6, b, l_{12}\}, \{l_{10}, l_{11}, l_{12}\}, r_4, \lor(\land(l_6, b), l_{12}) \rangle,
\]

\[
r_4 = \begin{array}{c|ccc}
l_6 & l_{10} & l_{11} & l_{12} \\
false & false & true & false \\
l_9 & false & false & true \\
l_{12} & W_{12,10} & W_{12,11} & true \\
\end{array}
\]

where

\( W_{12,10} = “\text{There are wastewater purified from sands}”; \)

\( W_{12,11} = “\text{There are sands for the hydrocyclones}”. \)

\( γ_1 \) and \( γ_0 \)-tokens, entering in place \( l_{12} \) (through places \( l_6 \) and \( b \)), keep their characteristics. \( χ_1 \) and \( χ_2 \)-tokens entering in places \( l_{10} \) and \( l_{11} \) when the value of predicates \( W_{12,10} \) and \( W_{12,11} \) is “true”, \( χ_1 \) and \( χ_2 \)-tokens obtain the following characteristics: “Purified wastewater from sands” in place \( l_{10} \) and “Sands with transport water” in place \( l_{11} \).

The form of the fifth GN-model transition is as follows:

\[
Z_5 = \langle \{l_{11}, l_{15}\}, \{l_{13}, l_{14}, l_{15}\}, r_5, \lor(\land(l_{11}, l_{15})) \rangle,
\]

\[
r_5 = \begin{array}{c|ccc}
l_{11} & l_{13} & l_{14} & l_{15} \\
false & false & true & false \\
l_{15} & W_{15,13} & W_{15,14} & true \\
\end{array}
\]

where

\( W_{15,13} = “\text{There are wastewater purified in hydrocyclones}”; \)

\( W_{15,14} = “\text{There are sands for disposal}”. \)

\( χ_2 \)-token, entering in place \( l_{15} \) (through place \( l_{11} \)), keeps its characteristic. \( δ_1 \) and \( δ_2 \)-tokens entering in places \( l_{13} \) and \( l_{14} \) when the value of predicates \( W_{15,13} \) and \( W_{15,14} \) is “true”. \( δ_1 \) and \( δ_2 \)-tokens obtain the following characteristics: “Purified wastewater in hydrocyclones” in place \( l_{13} \) and “Sands” in place \( l_{14} \).

The form of the sixth GN-model transition is as follows:

\[
Z_6 = \langle \{l_{10}, l_{13}, l_{17}\}, \{l_{16}, l_{17}\}, r_6, \lor(\land(l_{10}, l_{13}), l_{17}) \rangle,
\]

\[
r_6 = \begin{array}{c|cc}
l_{10} & l_{16} & l_{17} \\
false & true & false \\
l_{13} & false & true \\
l_{17} & W_{17,16} & true \\
\end{array}
\]

where \( W_{17,16} = “\text{There are wastewater for emergency overflow chamber}”. \)
\( \chi \) and \( \delta \)-tokens, entering in place \( l_{17} \) (through places \( l_{10} \) and \( l_{13} \)), keep their characteristics. \( \varepsilon \)-token, entering in place \( l_{16} \), obtains a characteristic “Wastewater for emergency overflow chamber”.

The form of the seventh GN-model transition is as follows:

\[
Z_7 = \langle \{ l_{16}, l_{20} \}, \{ l_{18}, l_{19}, l_{20} \}, r_7, \lor(l_{16}, l_{20}) \rangle,
\]

\[
r_7 = \begin{bmatrix}
    l_{16} & l_{18} & l_{19} & l_{20} \\
    \text{false} & \text{false} & \text{true}
\end{bmatrix},
\]

where

\( W_{20,18} = "\text{There are wastewater from emergency overflow chamber for the oil separators}"; \( W_{20,19} = "\text{There are wastewater from emergency overflow chamber for emergency buffer tank}". \( \varepsilon \)-token, entering in place \( l_{20} \) through place \( l_{16} \), keeps its characteristic, \( \phi \) and \( \phi^2 \)-tokens entering in places \( l_{18} \) and \( l_{19} \) when the value of predicates \( W_{20,18} \) and \( W_{20,19} \) is “true”. \( \phi \) and \( \phi^2 \)-tokens obtain the following characteristics: “Wastewater from emergency overflow chamber for the oil separators” in place \( l_{18} \) and “Wastewater from emergency overflow chamber for emergency buffer tank” in place \( l_{19} \).

The form of the eighth GN-model transition is as follows:

\[
Z_8 = \langle \{ l_{18}, l_{24}, l_{25}, l_{26}, l_{32} \}, \{ l_{21}, l_{22}, l_{23}, l_{24}, l_{25}, l_{26} \}, r_8, \lor(l_{18}, l_{24}, l_{25}, l_{26}, l_{32}) \rangle,
\]

\[
r_8 = \begin{bmatrix}
    l_{21} & l_{22} & l_{23} & l_{24} & l_{25} & l_{26} \\
    l_{18} & \text{false} & \text{false} & \text{false} & \text{true} & \text{true} \\
    l_{24} & W_{24,21} & W_{24,22} & W_{24,23} & \text{true} & \text{false} & \text{false} \\
    l_{25} & W_{25,21} & W_{25,22} & W_{25,23} & \text{false} & \text{true} & \text{false} \\
    l_{26} & W_{26,21} & W_{26,22} & W_{26,23} & \text{false} & \text{false} & \text{true} \\
    l_{32} & \text{false} & \text{false} & \text{false} & \text{true} & \text{true} & \text{true}
\end{bmatrix},
\]

where

\( W_{24,21} = W_{25,21} = W_{26,21} = "\text{There are wastewater purified after the oil separators}"; \( W_{24,22} = W_{25,22} = W_{26,22} = "\text{There are oil and oil products from the oil separators}"; \( W_{24,23} = W_{25,23} = W_{26,23} = "\text{There are bottom sludge from the oil separators}". \( \theta_1, \theta_2, \theta_3 \)-tokens, in places \( l_{24}, l_{25} \) and \( l_{26} \), have initial characteristics “Oil separator 1 – parameters”, “Oil separator 2 – parameters”, “Oil separator 3 – parameters”, respectively. They entering in place \( l_{23} \) when the value of predicates \( W_{24,23}, W_{25,23} \) and \( W_{26,23} \) is “true”. \( \theta_2 \)-token, in place \( l_{23} \), obtains a characteristic “Bottom sludge from the oil separators”. \( \theta_3 \)-token, in place \( l_{22} \), obtains a characteristic “Oil and oil products from the oil separators” when the value of predicates \( W_{24,22}, W_{25,22} \) and \( W_{26,22} \) is “true”. Token \( \theta_6 \), in place \( l_{21} \), obtains a characteristic “Wastewater purified after the oil separators” when the value of predicates \( W_{24,21}, W_{25,21} \) and \( W_{26,21} \) is “true”.

The form of the ninth GN-model transition is as follows:

\[
Z_9 = \langle \{ l_{22}, l_{28} \}, \{ l_{27}, l_{28} \}, r_9, \lor(l_{22}, l_{28}) \rangle,
\]
where \( W_{28,27} = \text{“There are oil and oil products for emptying from tank of oil and oil products”}. \)

\( \Theta \)-token, entering in place \( l_{28} \) (through place \( l_{22} \)), does not obtain a new characteristic. \( \phi_1 \)-token, entering in place \( l_{27} \), obtains a characteristic “Oil and oil products from the tank for oil and oil products”.

The form of the tenth transition is as follows:

\[
Z_{10} = \langle \{l_{27}, l_{30}\}, \{l_{29}, l_{30}\}, r_{10}, \forall(l_{27}, l_{30})\rangle,
\]

\[
r_{10} = \begin{bmatrix}
l_{27} & l_{28} \\
l_{28} & W_{28,27}
\end{bmatrix},
\]

where \( W_{30,29} = \text{“There are oil and oil products depleted from pumps”}. \)

\( \phi_1 \)-token, entering in place \( l_{30} \) (through place \( l_{27} \)), keeps its characteristic. \( \mu_1 \)-token, in place \( l_{29} \), obtains a characteristic “Oil and oil products”.

The form of the eleventh GN-model transition is as follows:

\[
Z_{11} = \langle \{l_{23}, l_{33}, l_{38}\}, \{l_{31}, l_{32}, l_{33}\}, r_{11}, \forall(l_{23}, l_{33}, l_{38})\rangle,
\]

\[
r_{11} = \begin{bmatrix}
l_{23} & l_{31} & l_{32} \\
l_{31} & W_{33,31} & W_{33,32} \\
l_{32} & false & false
\end{bmatrix},
\]

where \( W_{33,31} = \text{“There are bottom sludge for emptying from tank for bottom sludge from oil separators”}; \)
\( W_{33,32} = \text{“There are oil separators cleaned from bottom sludge”}. \)

\( \Theta \) and \( \sigma_2 \)-tokens, entering in place \( l_{33} \) through \( l_{23} \) and \( l_{38} \), keep their characteristics. \( r_1 \) and \( r_2 \)-tokens entering in places \( l_{31} \) and \( l_{32} \) when the value of predicates \( W_{33,31} \) and \( W_{33,32} \) is “true”. \( r_1 \) and \( r_2 \)-tokens obtain the following characteristics: “Bottom sludge from tank for bottom sludge from oil separators” in place \( l_{31} \) and “Oil separators cleaned from bottom sludge” in place \( l_{32} \).

The form of the twelfth GN-model transition is as follows:

\[
Z_{12} = \langle \{l_{31}, l_{35}\}, \{l_{34}, l_{35}\}, r_{12}, \forall(l_{31}, l_{35})\rangle,
\]

\[
r_{12} = \begin{bmatrix}
l_{31} & l_{34} \\
l_{34} & W_{35,34}
\end{bmatrix},
\]

where \( W_{35,34} = \text{“There are bottom sludge from tank depleted from pumps”}. \)

\( r_1 \)-token, entering in place \( l_{35} \) (through place \( l_{31} \)), keeps its characteristic. \( \lambda_1 \)-token, in place \( l_{34} \), obtains a characteristic “Bottom sludge for after treatment”.

The form of the ninth transition is as follows:

\[
r_9 = \begin{bmatrix}
l_{27} & l_{28} \\
l_{22} & false \\
l_{28} & W_{28,27}
\end{bmatrix},
\]
The form of the thirteenth GN-model transition is as follows:

\[ Z_{13} = \langle \{ l_{21}, l_{36}, l_{39} \}, \{ l_{37}, l_{38}, l_{39} \}, r_{13}, \rightarrow(l_{21}, l_{36}, l_{39}) \rangle, \]

\[ r_{13} = \begin{bmatrix} l_{37} & l_{38} & l_{39} \\ l_{21} & false & false & true \\ l_{36} & false & false & true \\ l_{39} & W_{39,37} & W_{39,38} & true \end{bmatrix}. \]

where

\[ W_{39,37} = \text{"There are wastewater from mixing and averaging tank for the primary precipitators"}; \]
\[ W_{39,38} = \text{"There are sludge from mixing and averaging tank for the tank for bottom sludge from oil separators"}. \]

\( \sigma_0 \) and \( \theta_0 \)-token, entering in place \( l_{39} \) (through place \( l_{36} \) and \( l_{21} \)), keep their characteristics. Tokens \( \sigma_1 \) and \( \sigma_2 \) entering in places \( l_{37} \) and \( l_{38} \) when the value of predicates \( W_{39,37} \) and \( W_{39,38} \) is "true". Tokens \( \sigma_1 \) and \( \sigma_2 \) obtain the following characteristics: "Wastewater from mixing and averaging tank for the primary precipitators" in place \( l_{37} \) and "Sludge for the tank for bottom sludge from the oil separators" in place \( l_{38} \).

The form of the fourteenth GN-model transition is as follows:

\[ Z_{14} = \langle \{ l_{37}, l_{43}, l_{44} \}, \{ l_{40}, l_{41}, l_{42}, l_{43}, l_{44} \}, r_{14}, \rightarrow(l_{37}, l_{43}, l_{44}) \rangle, \]

\[ r_{14} = \begin{bmatrix} l_{40} & l_{41} & l_{42} & l_{43} & l_{44} \\ l_{37} & false & false & false & W_{37,43} & W_{37,44} \\ l_{43} & W_{43,40} & W_{43,41} & W_{43,42} & true & false \\ l_{44} & W_{44,40} & W_{44,41} & W_{44,42} & false & true \end{bmatrix}. \]

where

\[ W_{37,43} = W_{37,44} = \text{"There are wastewater from mixing and averaging tank for the primary precipitators"}; \]
\[ W_{43,40} = W_{44,40} = \text{"There are purified wastewater after the primary precipitators"}; \]
\[ W_{43,41} = W_{44,41} = \text{"There are surface sludge from the primary precipitators"}; \]
\[ W_{43,42} = W_{44,42} = \text{"There are bottom sludge from the primary precipitators"}. \]

\( \eta_{1.1} \) and \( \eta_{1.2} \)-tokens, in places \( l_{43} \) and \( l_{44} \), have initial characteristics "Primary precipitator 1 – parameters" and "Primary precipitator 2 – parameters", respectively. They entering in place \( l_{42} \) when the value of predicates \( W_{43,42} \) and \( W_{44,44} \) is "true". In place \( l_{42} \) \( \eta_{2} \)-token obtains a characteristic "Bottom sludge from the primary precipitators". In place \( l_{41} \) \( \eta_{3} \)-token obtains a characteristic "Surface sludge from the primary precipitators" when the value of predicates \( W_{43,41} \) and \( W_{44,44} \) is "true". Token \( \eta_{4} \) leaves the net through place \( l_{40} \) with a characteristic "Purified wastewater from mechanical stage".

The form of the fifteenth GN-model transition is as follows:

\[ Z_{15} = \langle \{ l_{41}, l_{46} \}, \{ l_{45}, l_{46} \}, r_{15}, \rightarrow(l_{41}, l_{46}) \rangle, \]

\[ r_{15} = \begin{bmatrix} l_{45} & l_{46} \\ l_{41} & false & true \\ l_{46} & W_{46,45} & true \end{bmatrix}. \]
where \( W_{46,45} = \) “There are surface sludge for emptying from the tank”.

\( \rho_1 \)-token, entering in place \( l_{45} \), obtains a characteristic “Surface sludge for emptying from the tank”.

The form of the sixteenth GN-model transition is as follows:

\[
Z_{16} = \langle \{l_{45}, l_{48}\}, \{l_{47}, l_{48}\}, r_{16}, \lor(l_{45}, l_{48}) \rangle,
\]

\[
r_{16} = \begin{bmatrix}
  l_{45} & l_{47} & l_{48} \\
  false & true & \text{true}
\end{bmatrix},
\]

where \( W_{48,47} = \) “There are surface sludge from tank depleted from pumps”.

\( \rho_1 \)-token, entering in place \( l_{48} \) (through place \( l_{45} \)), keeps its characteristic. \( \nu_1 \)-token leaves the net through place \( l_{47} \) with a characteristic “Surface sludge for after treatment”.

The form of the seventeenth GN-model transition is as follows:

\[
Z_{17} = \langle \{l_{42}, l_{50}\}, \{l_{49}, l_{50}\}, r_{17}, \lor(l_{42}, l_{50}) \rangle,
\]

\[
r_{17} = \begin{bmatrix}
  l_{42} & l_{49} & l_{50} \\
  false & true & \text{true}
\end{bmatrix},
\]

where \( W_{50,49} = \) “There are bottom sludge for emptying from the tank for bottom sludge from primary precipitators”.

\( \psi_2 \)-token, entering in place \( l_{50} \) (through place \( l_{42} \)), keeps its characteristic. \( \eta_1 \)-token, entering in place \( l_{49} \), obtains a characteristic “Bottom sludge for emptying from the tank for bottom sludge”.

The form of the eighteenth GN-model transition is as follows:

\[
Z_{18} = \langle \{l_{49}, l_{52}\}, \{l_{51}, l_{52}\}, r_{18}, \lor(l_{49}, l_{52}) \rangle,
\]

\[
r_{18} = \begin{bmatrix}
  l_{49} & l_{51} & l_{52} \\
  false & true & \text{true}
\end{bmatrix},
\]

where \( W_{52,51} = \) “There are bottom sludge from the tank depleted from pumps”.

\( \eta_1 \)-token, entering in place \( l_{52} \) (through place \( l_{49} \)), keeps its characteristic. \( \kappa_1 \)-token leaves the net through place \( l_{51} \) with a characteristic “Bottom sludge for after treatment”.

**Conclusion**

Following the technological scheme presented in Fig. 1, a GN-model is developed, describing in details the significant processes in the mechanical wastewater pre-treatment. Being the first step in the whole WWT process, the mechanical stage is essential as it ensures the effective start of the treatment processes in all further station’s facilities. The proposed GN-model makes it possible to track changes with sufficient accuracy in individual qualitative and quantitative characteristics of the treated water before and after going through specific facilities to ensure optimal conditions for conducting the treatment processes. Moreover, the
GN-model would also contribute to the more effective operation of the subsequent purification steps in the process of the WWT plant’s functioning.

References

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