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# Use of action of electric field on the water's medium for the purification of the industrial waste waters

Michael Shoikhedbrod[1]

[1]*Electromagnetic Impulse Inc., Toronto, Ontario, Canada*

## Abstract

The most essential deficiencies in the electrofloatation method of cleaning include the increase of the alkalization space near the cathode that leads to formation of the salts sediments on the cathode because of passing of the electric current through the water environment. In certain cases, salts so tightly cover cathode's surface that can cause the total curtailment of the process of electrofloatation. The reason for this deficiency consists of in the fact that as the anode of the method is used the dense grid from the wire of the defined thickness, which increases the current density, and, therefore, a quantity of generated hydrogen bubbles that promote to the intensification of the process of floatation. During the time, the generated of the sediment of salts simply close the grid and thus lock the output of the hydrogen bubbles through the grid.

It should be also noted the fast depreciation of anodic grid as a result of its oxidation (formation on it of oxygen). To another deficiency of the process can be attributed uneven generation of gas bubbles on the surface of electrodes, which leads to the concentration of gas bubbles in the specific zones of floatation camera. The paper represents the use of a new developed method and constructed electroflotator for the purification of the industrial waste waters that remove these deficiencies, because of its form and construction of its electrolytic base, and of use of the negatively charged with calculated dispersiveness of hydrogen bubbles in the technological process of industrial waters purification, connected to the separation of microscopic particles from waste water - the creation of strong complex of the hydrogen bubbles + valuable microscopic particles of the waste component of industrial waste water in the process of the elementary act of floatation.

**Keywords:** Separation, Purification of the industrial waste water, Manyphase systems, Electric field influence on the water solutions, Hydrogen electrolysis gas bubbles.

## Introduction

The problem of cleaning of the sewage and industrial waste waters requires ever more serious importance, since the majority of the cleaning construction of plants is old and unable to provide the qualitative cleaning of drains in accordance with the existing norms. At present time, the electrofloatation technologies are becoming more widespread. The method of electroflotation is used for removal of pollution in the form of suspended matter, phosphates and hydroxides of metals, suspensions, resins, emulsified substances, petroleum products, industrial oils, fats and surfactants from sewage and wash waters, technological solutions of galvanic production and production of printed-circuit boards [1-6].

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***Corresponding author:** Dr. Michael Shoikhedbrod, Electromagnetic Impulse Inc., Toronto, Ontario, Canada. Email: mshoikh@primus.ca

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In comparison with other forms of floatation the electroflotation has the following principle special features and the distinguishing features, which are simultaneously its advantages. The extremely microdispersed gases are produced by the electrolysis. If in the mechanical type of flotators the average diameter of the generated of gas bubbles is 0.8-0.9 mm, in the pneumatic flotators the average is 2 mm, and in the vacuum and pressure floatation is 0.1-0.5 mm, then in the electroflotator are formed bubbles with the sizes less than 100 mcm. Depending on the conditions of electrolysis the generation of bubbles by the diameter to 8-15 mcm is possible that is inaccessible with other methods of floatation.

Furthermore, the bubbles of electrolytic gases are uniform in the sizes, possess the small tendency to the coalescence after detachment from the electrodes and preserve during the retaining time in the liquid the constant diameters. The most essential deficiencies of this method of cleaning include the fact that as a result of passing of the electric current through the liquid the alkalization cathode space increases, and because of this, the salts sediments are formed on the electrodes. In certain cases, the salts so tightly cover the electrodes surface that can be cause of the total curtailment of the process of electroflotation. The reason for this deficiency consists of in the fact that as the anode in the method is used the dense grid from the wire of the defined thickness, which increases current density, and, therefore, a quantity of generated hydrogen bubbles that promote to the intensification of the process of floatation.

During the time, the generated of the salts sediment simply close the grid and thus lock the output of the hydrogen bubbles through the grid. It should be also noted the fast depreciation of anodic grid as a result of its oxidation (formation on it of oxygen). To another deficiency of the process can be attributed uneven generation of gas bubbles on the surface of electrodes, which leads to the concentration of gas bubbles in the specific zones of floatation camera. Because of this it leads to the circulating motion of liquid, which worsens the process of cleaning. The need of the development of new constructions of the electrolytic base of the process, which will remove these deficiencies, appears.

The paper represents the use of a new developed method and constructed electroflotator for the purification of the industrial waste waters that remove these deficiencies, because of its form and construction of its electrolytic base, and of use of the negatively charged with calculated dispersiveness of hydrogen bubbles in the technological process of industrial waters purification, connected to the separation of microscopic particles from waste water - the creation of strong complex of the hydrogen bubbles + valuable microscopic particles of the waste component of industrial waste water in the process of the elementary act of floatation.

## Materials

Method has been tested at the galvanic plant of Packer YadPaz Tubes and Profiles Ltd (Kiryat - Malachi, Israel). The galvanic production is one of the most dangerous sources of environmental pollution, mainly of the surface and underground reservoirs, in view of the formation of the large volume of waste waters. The metal compounds, contained in waste waters of galvanic production, very adversely influence on the ecosystem reservoir-soil-plant-animal world-human. These compounds possess the toxic, cancerogenic (caused of the malignant new formations - As, SE, Zn, Pd, Cr, Be, Pb, Hg, Co, Ni, Ag, Pt.), the mutagenic (caused of changes in the heredity - ZnS), the teratogenic (capable of causing deformities in the being born themselves children - Cd, Pb, As, Co, Al and Li) and allergenic ($Cr^{6+}$) harmful properties.

Furthermore, some inorganic compounds render disastrous action on the microorganisms of cleaning construction; they terminate or slow down the processes of biological purification of waste water and the fermentation of sediments in the digesters (devices for the anaerobic fermentation of liquid organic withdrawals with obtaining of methane). The toxic metals in the reservoirs disastrously act on the flora and the fauna and obstruct the processes of the self-purification of reservoirs. With the use of water of the contaminated reservoirs for the irrigation, nonferrous metals will be brought to the fields and are concentrated in the upper most fertile layer of soil, decreasing the nitrogen-fixing ability of soil and the productivity of agricultural crops, and caused the accumulation of metals of higher than the permissible concentrations in the fodders and other products.

With the simultaneous presence in the waste waters of galvanic production of several harmful components is manifested their combined action on the organism of the human, warm-blooded animals, of the flora and the fauna of reservoirs, of the micro flora of the cleaning constructions of canalization, that is expressed in the effect of action is more than simple summing, in the effect of the action of several poisons is less than integrated also in simply the summing up. Thus, the basic components of the pollution of waste water of galvanic production are microparticles, harmful biological microorganisms and chlorine.

The method has been tested on the base of the company of Tnuva (Kiryat-Malachi, Israel). The contaminated waste waters at the dairy plants are produced in the process of the washing of container, equipment when cleaning the industrial premises. These waste waters are contaminated by the losses of milk, dairy products, by production wastes, by reagents, used with the washing of equipment, and by admixtures, washed off from the surface of container, floor and other. The temperature of waste water of the factory of dairy industry varies from 16 to 33°C. The average monthly temperature of waste water composes in winter 17-18°C, in summer 22-25°C. The value of pH of the waste water in a considerable degree depends on the technology of production, variety of production. For the productions, not connected with the processes of milk fermentation, pH of drain is close to the neutral value (6.8-7.4 for the milk-canning and butter-making plants).

For the cheese-making plants, the factory, which manufactures the cottage cheese and other sour-milk products, pH of waste water is reduced to 6.2. The composition of waste waters of the plants of dairy industry is represented in the Table 1. The major portion of the suspensions (to 90%) is organic solids, as a rule, of protein origin. The concentration of suspended solids varies over wide limits depending on the technological cycle of production. The values of COD and BOD of waste waters of dairy plants also vary over wide limits and on the average comprise for municipal dairy plants 1400 and 1200 mg/l, for the cheese-making plants 2400-3000 mg/l. It is established that the COD and BOD for the waste waters of dairy plants have the follow direct dependence BOD = (0.8-0.84) COD. Using this relationship, based on value COD, it is possible to approximately calculate BOD of waste waters of the milk production factory of any profile that considerably facilitates the compositional analysis of waters and control over the work of cleaning construction.

The content of the fats in the waste waters of the plants of dairy industry is determined basically by the assortment of output products and by the technology of production. Waste waters of whole-milk productions contain fats in that form, that also natural milk has. The fats of milk are the smallest balls, surrounded by the hydrated protein shell. The large balls of fat are extracted from the production of cream, sour cream and oil from the milk; where their coalescence and enlargement occur. The nitrogen in the waste waters is contained basically in the form of the amino groups of protein compounds and insignificant admixtures of ammonium salts. The chloride concentration reaches 800-1000 mg/l and comprises in average 150-200 mg/l.

Thus, the basic components of the pollution of waste water of milk production are microparticles, harmful biological microorganisms and chlorine. Pulp and paper industry is one of the most hygroscopic branches of economy. The almost 9.2 million cubic meters of fresh water are every day expended by plants of this branch of economy. Depending on quality and assortment of production the specific expenditures of water for technological needs vary over a wide range. Thus, on 1 ton of cardboard and paper, produced from the unbleached cellulose, are formed 10-50 $m^3$ of waste water, from the bleached cellulose - 150-250 $m^3$ and so on.

The waste waters are formed:

a) During the preparation of chemical solutions;

b) In the process of the cooking wood chips with chemical solutions;

c) During washing of cellulose;

d) During the bleaching of cellulose;

e) During the pouring, the pressing and drying of cellulose;

f) During the evaporation of alkalis.

The physical chemistry structure of waste waters depends on output products. The waste waters contain the fibers of cellulose, paper, fillers, dyes, latexes, emulsions, adhesives and others. They have the different colors, with the high content of the weighed and organic substances, with specific smell. The acidic (sulfite) and alkaline (sulfate) methods of obtaining the cellulose in a technological aspect are distinguished. Sulfate method provides the possibility of obtaining the cellulose not only from the conifers, but also from the deciduous species. The high content of the diverse substances is the typical property of the waste waters, which are formed with the sulfate method of obtaining the cellulose: 33% - inorganic and 67% - the organic substances.

Waste waters of sulfite-cellulose production contain 10% of inorganic and 90% of organic substances. The Table 2 presents the composition and the pollution concentration of waste waters from the production of the semi-finished products of pulp and paper production. Depending on the composition of pollution of the plants of pulp and paper industry the alkaline streams of the waste waters are considered that contain predominantly: crust, alkali, fiber, acid, slime, and ashes - the substances with the unpleasant smell. Furthermore, on the territory of plant are formed conditionally clean and surface waste waters. The special

**Table 1:** The classification of waste waters of the plants of dairy industry. COD- the chemical oxygen demand defines a quantity of organic pollutants in the water. BOD- the biochemical oxygen demand determines a quantity of contaminating bacteria in the waste water. SS- Suspended Solids.

| Plants | SS, mg/l | COD, mg/l | BOD, mg/l | Fats, mg/l | Chlorides, mg/l | Total nitrogen, mg/l | Phosphorus, mg/l | pH |
|---|---|---|---|---|---|---|---|---|
| Municipal dairy plants | 350 | 1400 | 1200 | To 100 | 150 | 60 | 8 | 6.6-8.5 |
| Plants of the dry and condensed milk | 350 | 1200 | 100 | To 100 | 150 | 50 | 7 | 6.8-7.4 |
| Cheese plants | 600 | 3000 | 2400 | To 100 | 260 | 90 | 16 | 6.2-7.0 |

**Table 2:** Composition and the pollution concentration of the waste waters from the production of the semi-finished products of the pulp and paper production.

| Indicators, mg/l | Production of wood pulp | Production of craft brown stock | Production bleached craft pulp | Production of sulfate craft browns tock | Production sulfate bleached craft pulp |
|---|---|---|---|---|---|
| Temperature, ºC | 30 | 30 | 40 | 35 | 40 |
| Chromaticity, degrees | - | 1500 | 3100 | - | - |
| Odor, points | - | 3.5 | 3.5 | 4 | 4 |
| SS | 1500 | 105 | 100 | 165 | 132 |
| Total hardness, mg –equiv/l | - | 7.5 | - | 9 | 7 |
| Dry residue | 1150 | 2200 | 2800 | 2650 | 2500 |
| COD | 1000 | 1600 | - | 1375 | 1150 |
| $BOD_5$ | 40 | 230 | - | 185 | 185 |
| Chloride-ion | - | 100 | 620 | - | 350 |

feature of sewerage of the plants of pulp and paper industry is the fact that the waste waters, formed as a result of isolated production processes, pass the first local removal of alkaline pollution.

Thus, crust is moved away from the waste waters using the drum and reticulated filters. Fibers are filtered through the reticulated filters with further settling in the horizontal or vertical sumps. The alkalis are moved away from the waste waters. The substances, which have unpleasant smell, are moved away by chlorination with the settling. After local purification the waste waters collect to the general flow and remove to the all-factory construction of mechanical, physical chemistry or biological cleaning. Important is the fact that even 90-95% technical effectiveness of the construction of biological cleaning does not guarantee a sufficient removal from the waste water of the organic solids of pulp and paper industry.

The biologically purified waste waters have high colorfulness. The smell of waste waters disappears upon watering with water in 200 times. The COD of the biologically purified water reaches 280-350 mg/l. With the removal of such waste waters to the surface reservoirs of the water, the water has unpleasant smell at a distance to 20 km lower water discharge area. It disappears only upon dilution with water in 2-5 times. The colorfulness of water in the reservoirs grows in 3-4 times, the concentration of dissolved oxygen in the water sharply is reduced. The content of the weighed particles dozens of times grows. Thus, the basic components of the pollution of the waste waters of the pulp and paper production are microparticles, harmful biological microorganisms and chlorine.

## Method and Developed Devices

At present time, the electrofloatation technologies are becoming more widespread. The method of electroflotation is used for removal of pollution in the form of suspended matter, phosphates and hydroxides of metals, suspensions, resins, emulsified substances, petroleum products, industrial oils, fats and surfactants from sewage and wash waters, technological solutions of galvanic production and production of printed-circuit boards. However, the most essential deficiencies of this method of cleaning consist in the fact that as a result of passing of the electric current through the liquid the alkalization cathode space increases, and because of this, the salts sediments are formed on the electrodes.

In certain cases, the salts so tightly cover the electrodes surface that can be cause of the total curtailment of the process of electroflotation. The reason for this deficiency consists in the fact that as the anode in the method is used the dense grid from the wire of the defined thickness, which increases current density, and, therefore, a quantity of generated hydrogen bubbles that stimulate the intensification of the process of floatation. During the time, the generated of the salts sediment simply close the grid and thus lock the output of the hydrogen bubbles through the grid.

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Under the action of electric field on the industrial waste waters, the negatively charged bubbles of hydrogen are formed on the cathode. The size of formed negatively charged hydrogen bubbles can be controlled and can be as small, as this requires the technological process of waste water purification. The use of negatively charged with calculated dispersiveness of hydrogen bubbles permits to solve the primary task of the technological process of waste water purification, connected to the separation of microscopic particles of waste from wastewater, - the creation of strong complex of the hydrogen bubbles + microscopic particles of the solid waste of waste water in the process of the elementary act of floatation.

After formation and detachment from the surface of cathode, the charged negatively bubbles of hydrogen, rising up in the waste water; meet on its way the microscopic particles of the solid waste component of the waste water by the dimensions of considerably larger than single bubble and bubbles induce the positive charge on the area of the microscopic particle of solid waste. As a result of the attraction of opposite charges, the bubbles stick to the microscopic particle, forming strong contact, and volume of formed complex of microscopic particles + hydrogen bubbles strongly increases, and under the action of the considerably increased Archimedes force, the complexes of microscopic particles + hydrogen bubbles with the increased speed float upward.

Besides, the developed laboratory electroflotator of unique construction (Figure 1) permitted to remove all deficiencies of the method of the electroflotation, described above, because of its form and construction of its electrolytic base. The electrolytic base does not contain the electrodes, which use the dense grids with the small cells. The under electrode (cathode) is the disk of the stainless steel (graphite), fixed based on electroflotator. The upper electrode (anode), also from the stainless steel and was executed in the form of ring with the cross in the middle.

The regulation by inter electrode gap is provided. The floatation camera has cylindrical form and does not, therefore, have stagnation zones for the hydrogen bubbles, formed under the influence on the water of electric field. The effectiveness of the work of electroflotator is determined by the gas content of the system in the electroflotator.

In accordance with the Faraday law, the mass of the gas (M) that is released on the electrode in time t:

$M = jigSt$ (2.1)

where j - the electrochemical equivalent of gas (for hydrogen j = 1.0 $10^{-7}$ кг/ (A· s); for oxygen j = 8.29 $10^{-8}$ кг/ (A· s)); i - the current density, A/$m^2$; g = 90%, 95% - current output (the ratio of actual gas mass transfer to the theoretical calculated in percentage terms); S - square of upper electrode, $m^2$.

If we represent i - the current density of the process as I/S, where the I- the direct current of process, then the equation (2.1) takes the following form:

$M = jIgt$ (2.2)

From the equation (2.2) it can be seen that the mass of the gas, which releases on the electrode in time t, is directly proportional to the value of direct current, and does not depend on the square of electrode.

However, in accordance with Ohm's law, the value of the direct current of process is directly proportional to the electrode voltage (U) and is inversely proportional to the resistance of inter electrode medium (R):

$I = U/R$ (2.3)

The resistance of inter electrode medium (R), in turn, depends on the inter electrode gap (L) and the square of upper electrode (S) as follows:

$R = \rho L/S$ (2.4)

Where ρ – resistivity of the inter electrode medium.

Substituting (2.4) to (2.3), we will obtain:

$I = (US/\rho L)$ (2.5)

Thus, from (2.5) the reduction of the square of upper electrode (**S**), in our case a change of the form of electrode, can be compensated by rising of the voltage (U) on the electrodes for maintaining the previous effectiveness of the work of electroflotator (the previous gas content of system - M).

An increase of the electrode voltage not only does not decrease the effectiveness of the work of electroflotator, but also, as it was indicated earlier; it provides the maximum dispersion of the generated of the negatively charged hydrogen bubbles and the additional acceleration of the floating up of bubbles because of the positive charge of upper electrode (anode). The effectiveness of the work of electroflotator also depends on the inter electrode gap (L), the less the gap, the greater the value of direct current, the greater the value the gas content of system, the greater the gap, the less the value of direct current and, therefore, the less the value the gas content of system.

All these factors were laid in the construction of developed laboratory electroflotator (Figure 1). The special laboratory electroflotator presents the cylindrical container from the organic glass with inside diameter of 2.0 cm, by height 11 cm, whose bottom (with square S=3.8$cm^2$) is made from the stainless steel and serves as the cathode. The anode, made in the form of ring from the stainless steel, was fixed at a distance by 5 mm from the cathode. Electroflotator was supplied by the manual separator in the upper part of electroflotator for the collection of waste component of waste water, obtained during the process of the industrial waste water purification, in the receiver collector.

The volume, which fills electroflotator by waste water, was about 40 $cm^3$. Thus, the construction of electroflotator of this form is electroflotator of discrete action. The tests were conducted in the discrete, discontinuous regime. The waste water, in the process of purification, was filled from top of the electroflotator. During the process of the test, the waste component of waste water, using manual separator, was collected in the receiver collector, and remained clean water was derived through the pin valve of electroflotator, located on the bottom of electroflotator. For the realization of waste water purification of continuous action, the following electroflotator was constructed (Figure 2).

Structurally developed electroflotator of continuous action for the industrial waste water purification has floatation camera - **7**, fulfilled in the form of the rectangular capacity, whose angles are supplied by the special inserts, in consequence of which, the internal part of the camera

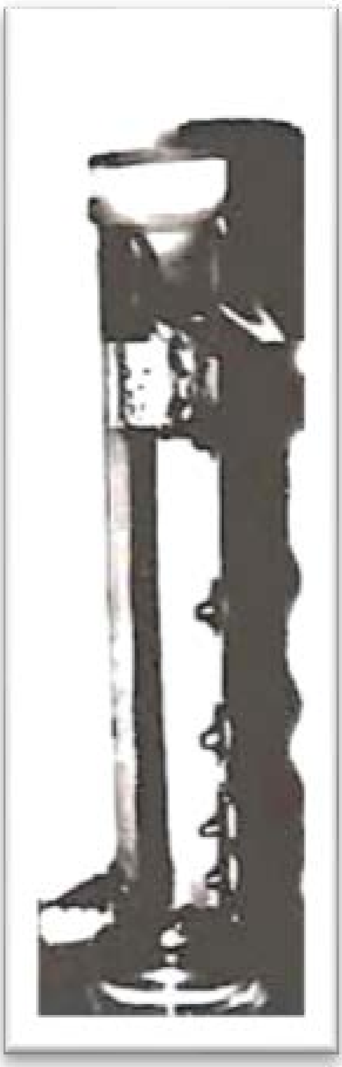

**Figure 1:** The common form of laboratory electroflotator.

accepts the form of cylinder, and rear upper wall is supplied by the reflector. In the process of waste water purification, the waste water is entered to the floatation camera - 7 through the branch pipe with crane 1, pocket 2 and gap 4, for the realization of separation of the microscopic particles of the waste from the waste water. The clean water, after passing through the camera - 8 of additional cleaning, is moved away from electroflotator through the pocket and the drain branch pipe with crane – 6. The basic element of electroflotator is electrolytic base - 5, fulfilled in the form of plug and of special mechanism that permits simply to regulate by inter electrode gap size.

The cathode was produced from the stainless (graphite) and is mounted on the bottom of camera. The anode was produced from the corrosion-resistant metallic lattice uses the special construction, which is located on the cathode that simply regulates the size of gap between anode and cathode. After completion of works for washing of electroflotator and output of the entire remained water the branch pipe with crane - 9 is provided. Crane, during the process of the work of electroflotator, is closed. The floated microscopic solid particles of waste are collected in the foam layer in the upper part of the camera and are moved away by paddle device - 3 to the special receiver capsule.

## Results

The developed method and special constructed laboratory electroflotator (Figure 1) for the purification of waste water of galvanic production, where the toxic metals (Zn) of the waste water were moved away to the receiving collector, and purified water could be repeated used again in the technological process of galvanic production or used for different technical purposes, without bringing disastrously harm to the flora and the fauna, were used. Pure zinc, obtained in the process of cleaning, also can be used for repeated application in the technological process of galvanic production.

For achievement of cleaning the method uses the action of electric field on the waste water. As a result, the dissociation of the metal compound (in our case it was zinc) on the ions occurs:

$$ZnCl_2 = Zn^{+2} + 2\ Cl^{-1} \qquad (3.1)$$

With the passing of the direct current through the water, which contains the metal compound ($ZnCl_2$), one ion of hydrogen $H^+$ and cation of zinc $Zn^{+2}$ approach the cathode; the hydrogen takes from it one electron, and the cation of zinc two electrons. The four ions $OH^-$ approach the anode, which return four electrons. The two anions of chlorine $Cl^{-1}$ approach the anode, which return two electrons. As a result, the neutral atom of hydrogen H, formed on the cathode, in the Free State becomes unstable and combines in pairs to the diatomic molecule of hydrogen $H_2$, and the cation of zinc $Zn^{+2}$ is converted to the atom of zinc Zn.

The two molecules of water formed on the anode, and the formed neutral atom of oxygen O in the Free State becomes unstable and combined in pairs to the diatomic molecule of oxygen $O_2$. The neutral atom of chlorine Cl, formed on the anode, combines in pairs to the diatomic molecule of chlorine $Cl_2$.

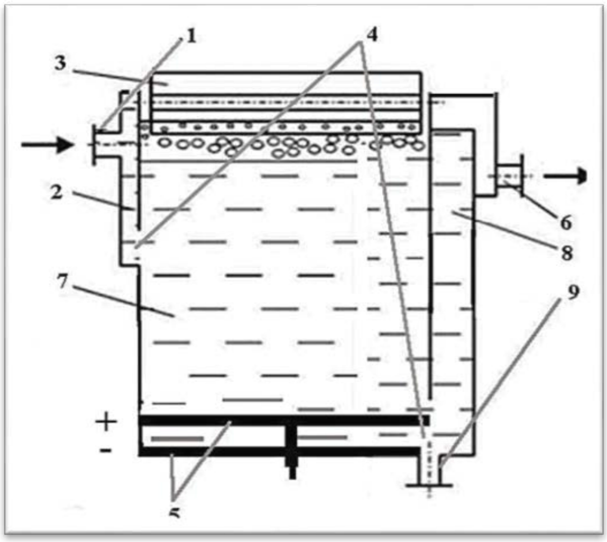

**Figure 2:** Electroflotator of continuous action for the juice concentration.

As a result, on the cathode the bubbles of hydrogen will separate, and the neutral atom of zinc will precipitate:

$$H^+ + e = H;\ H + H = H_2\uparrow\ Zn^{+2} + 2e = Zn \qquad (3.2)$$

On the anode will be detached two molecules of water, the bubbles of hydrogen and chlorine:

$$2Cl^{-1} - 2e = Cl + Cl = Cl_2\uparrow\ 4OH^- - 4e = 2H_2O + O_2\uparrow \qquad (3.3)$$

A method uses the negatively charged bubbles of hydrogen, which are formed under the influence of electric current on the waste water. In the method formed microdispersed hydrogen bubbles have the sizes less or are commensurate with the micro-solid particles of zinc settling on the cathode, and solidly are attached to the surface of these particles and, therefore, effectively float with them together and thereby provide their collections in the receiving collector and cleaning from them of waste water. Use in the method of the action of electric field on the waste water as it was described above, leads to the isolation of chlorine from the waste water and, therefore, to the purification of waste water from chlorine ions, what is also important factor for the ecology.

Method has been tested at the plant of Packer YadPaz Tubes and Profiles Ltd (Kiryat - Malachi, Israel). The Table 3 presents the results of purification of waste water, obtained after the completion of general technological process at the plant of Packer YadPaz Tubes and Profiles Ltd: Here MPC - the maximum of permissible of concentration - the maximum concentration of chemical elements and their compounds in the environment, with which the daily influence on the human organism does not for a long time cause pathologic changes or diseases, determined by the known methods of studies for any periods of life of present and subsequent generations of people.

From the Table 3 follows that after cleaning, the content of Zinc ($Zn^{2+}$) is decreased with 8 mg/l to 0. Entire zinc floated to the surface of water and selected by receiving collector. The content of chlorine decreased from 250mg/l to 25 mg/l (90%).

The bubbles of chlorine, generated as a result of the action of direct current on the waste water, floated to the surface of waste water and evaporated. The obtained results are evidence of the high efficiency of the application of the developed method for the purification of waste water of this plant. Furthermore, the obtained in the process of cleaning Zinc and purified water can be used in the galvanic process of plant repeatedly. Purified water corresponds to standards of MPC and can be used for other purposes also. Method is simple, fast and economically advantageous. The developed method showed the high efficiency of the purification of waste water of galvanic production. The basic components of the pollution of waste water of milk production are microparticles, harmful biological microorganisms and chlorine.

In connection with the fact that developed method of cleaning already showed its ability to clean similar type waste waters, the tests of the application of the developed method for cleaning of milk production on the base of the company of Tnuva (Kiryat-Malachi, Israel) were carried out. The Table 4 presents the results of purification of waste water, obtained after the completion of general technological process at the plant of the company Tnuva. From the Table 4 follows that after cleaning, suspended solids decrease from 600 mg/l to 30 mg/l, COD decreases with 3000 mg/l to 110 mg/l, BOD decreases from 2400 mg/l to 25 mg/l, fats from 100 mg/l to 10 mg/l, converting turbid waste water to the almost clear water.

All micro components of pollution floated to the surface of water and selected by receiving collector. The content of chlorine decreased from 260mg/l to 20mg/l. The bubbles of chlorine, generated as a result of the action of electric current on the waste water, float to the surface of water and evaporate. The obtained results are evidence of the high efficiency of the application of the developed method for the purification of waste water of this plant. Furthermore, the purified water, obtained in the process of cleaning, can be used in the technological process of plant repeatedly. Purified water corresponds to all permissible standards and can be used for other purposes also. Method is simple, fast and economically advantageous. The developed method showed the high efficiency of the purification of waste water of milk production.

The basic components of the pollution of the waste waters of the pulp and paper production are microparticles, harmful biological microorganisms and chlorine. In connection with the fact that developed method of cleaning already showed its ability to clean similar type waste waters, there were carried out the tests of the application of the developed method for cleaning of such type of waste waters on the base of the company American Israeli Paper Mills Ltd. (Chedera, Israel). The Table 5 presents the results of purification of waste water, obtained after the completion of general technological process at the plant of the company

**Table 3:** Results of the purification of waste water of plant by the developed method.

| | Zinc, $Zn^{2+}$, mg/l | Chlorides, $Cl^-$, mg/l |
|---|---|---|
| Before cleaning | 8 | 250 |
| Known methods | 0.5-1.0 | 100-250 |
| After cleaning | 0 | 25 |
| MPC, mg/l | 0.5 | 100 |

**Table 4:** Results of purification of waste water of general technological process at the plant of the company Tnuva.

| | SS, mg/l | COD, mg/l | BOD, mg/l | Fats, mg/l | Chlorides, mg/l |
|---|---|---|---|---|---|
| Before cleaning | 600 | 3000 | 2400 | 100 | 260 |
| After cleaning | 30 | 110 | 25 | 10 | 20 |

**Table 5:** Results of purification of waste water, obtained after the completion of general technological process at the plant of the company American Israeli Paper Mills Ltd.

| Indicators, mg/l | Waste water | Know methods | Developed method |
|---|---|---|---|
| Temperature, ºC | 30 | 22 | 22 |
| Chromaticity, degrees | 1500 | 400 | 0 |
| Odor, points | 3.5 | 5 | 0 |
| SS | 105 | 25 | 5 |
| COD | 1600 | 350 | 50 |
| $BOD_5$ | 230 | 25 | 10 |
| Chloride-ion | 100 | 10 | 2 |

American Israeli Paper Mills Ltd. From Table 5 follows that after cleaning, suspended solids decrease from 105 mg/l to 5 mg/l, COD decreases from 1600 mg/l to 50 mg/l, BOD decreases from 230 mg/l to 10 mg/l, chromaticity from 1500 degrees to 0, odor from 3.5 points to 0, converting turbid waste water to the almost transparent water.

All micro components of pollution floated to the surface of water and they were selected by receiving collector. The content of chlorine decreased from 100mg/l to 2 mgl. The bubbles of chlorine, generated as a result of the action of electric current on the waste water, float to the surface of water and evaporate. The obtained results are evidence of the high efficiency of the application of the developed method for the purification of waste water of this plant. Furthermore, the purified water obtained in the process of cleaning, can be used in the technological process of plant repeatedly. Purified water corresponds to all permissible standards and can be used for other purposes also. Method is simple, fast and economically advantageous. The developed method showed the high efficiency of the purification of waste waters of the pulp and paper industry.

## Conclusion

The conducted tests showed the high efficiency of the purification of waste water of galvanic, milk, pulp and paper productions by the developed method and constructed electroflotator. The purified water obtained in the process of cleaning can be used in the technological process repeatedly. The purified water corresponds to all permissible standards and can be used for other purposes also. Method is simple, fast and economically advantageous. The constructed electroflotators permit with the high efficiency to clean of waste water in industrial volumes.

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