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Numerical Modeling of Ground Water Treatment through Ceramic Membranes

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ABSTRACT: Recent advances in oil field water treatment have led to the conclusion that conventional remediation techniques are expensive, slow and ineffective in removing oil products from reservoir waters. The need to introduce methods that remove the disadvantages of conventional ones led to the appearance of modern depollution techniques, methods such as chemical, biological or thermal, etc. However, before starting a depollution process, a profitability study must be carried out and a compromise established between the cost of depollution and the depollution yield. The article presents the classic depollution methods but also a new, modern method (water treatment with ceramic filters) which, even if it has quite high investment costs, even proves its economic efficiency in addition to the qualitative one of protecting the environment.

KEYWORDS: water treatment, oil field, ceramic filter, chemical and physical water techniques treatment

I. INTRODUCTION

Techniques for treating water polluted with petroleum products are often economically and technologically expensive. They are also sometimes slow and ineffective in removing oil products from planetary waters. The need to introduce methods that remove the disadvantages of conventional ones led to the appearance of modern depollution techniques, methods such as chemical, biological or thermal, etc. However, before starting a depollution process, a profitability study must be carried out and a compromise established between the cost of depollution and the depollution yield. The idea emerged that the environment, as a global problem.

But is necessary to be addressed at the planetary level.

As a concrete expression of this awareness, 25 developed and developing countries agreed in November 1990 to create an assistance instrument in the matter called: "The Global Environment Facility" (GEF). Since then, the common policy regarding environmental protection has advanced enormously, not quite yet, but with big and bold steps, with the help of the mechanisms of the European Union, this being the most representative structure worldwide and with the most drastic regulations [1].

Albert Schweitzer's words are famous: (Nobel Peace Prize winner - philosopher, theologian and missionary for human rights and environmental protection in Africa) "Man has lost his ability to predict and anticipate. It will end up destroying the planet."

We hope that these remain only at the stage of words and that they do not end up being truly translated into reality and the environment suffers irreversible damage.

Just as man has the claim to live in a clean house, to eat in a clean kitchen, etc., so he should also take care of the environment in which he lives and carries out his daily activities. This will probably be achieved when people will understand that the economic plan is not primary, but there are other areas that have greater importance and require greater attention from us, all of us.

II. METHODS OF TREATMENT OF WATER INFESTED BY OIL

II.1. Physics methods

II.1.1. Gravitational methods

Gravitational separation of coarse particles, not dissolved in water, under the influence of the Earth's gravitational field, by sedimentation, by flotation or by centrifugation.

The phenomenon of agglomeration (flocculation) is possible, the flakes having larger masses and which sediment faster.

As an example, fig. 1, a decanter, which can be with vertical and horizontal water flow. Sludge removal from the decanter can be done manually and intermittently.

According to the shape, the decanters can be circular or rectangular [2].

Clear water is discharged through spillways.

Sedimentation is the physical process of separating organic or inorganic solid particles from wastewater by gravimetric deposition in spaces with a controlled hydraulic regime.

The operation can also be called decantation or, depending on the role of the process in the treatment/purification technology, clarification, clarification or thickening.

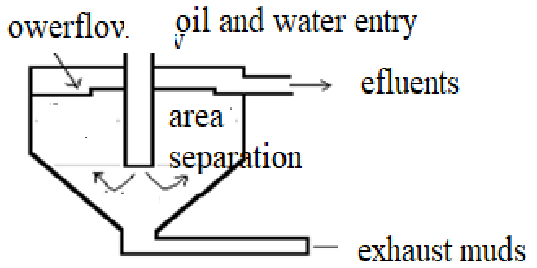

Figure 1. Gravitational water separation

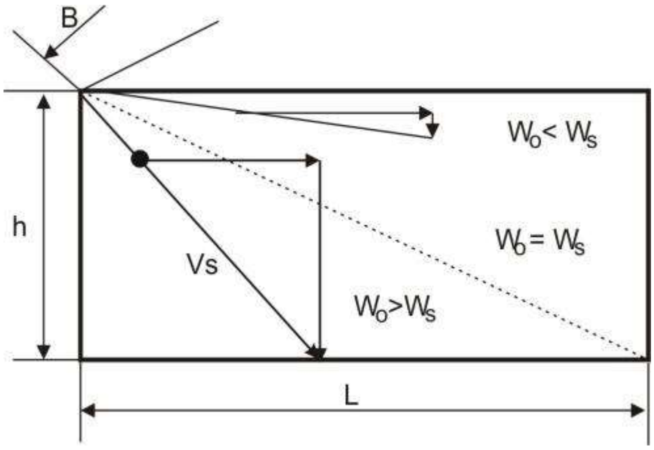

Figure 2. Conventional decantor
(W_0 is flow rate, W_s is sedimentation rate, L is leght of decantor, h is hight of decantor)

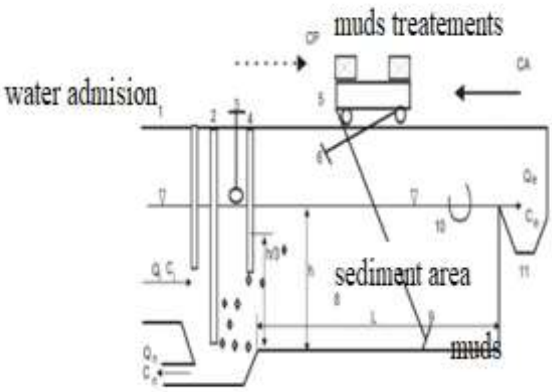

Figure 3. Sedimentation basin with mechanical muds treatment

The impurities present in the water have sizes depending on the nature of the basic bodies and the state of dispersion in the liquid mass (sand, gravel), colloidal particles (groups of molecules or substances with a size of 0.5...500 nm) and molecules or macromolecules in the case of dissolved substances with dimensions below one nanometer.
The settling time is dependent on the size of the particles dispersed in the water mass.
Sedimentation is applied in the following constructions:
a) sandblasters - granulated suspensions, discrete particles;
b) primary decanters - for granular and flocculent suspensions resulting from the coagulation of substances in water;
c) secondary decanters - for retaining particles that come from biological purification;
d) concentrators or sludge thickeners.

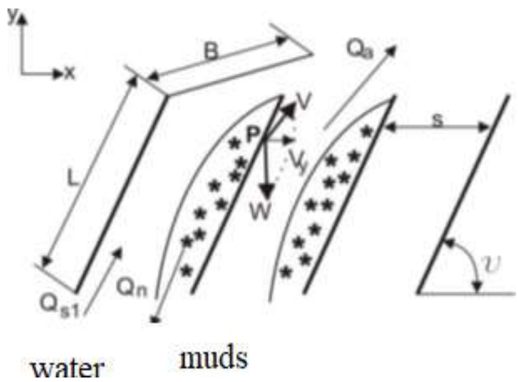

Figure 4. Lamellar separation (L is length of basin, Q_a is water rate, V is water particle rate, W is mud particle rate, Q_{S1} is muds and water rate),

II.1.2. Floatation muds-water separation

Flotation is a unitary process of separation from water, under the action of the earth's gravitational field, of particles with an average density lower than that of water. Flotation can be natural or with air introduced into the water in the form of fine bubbles through porous diffusers. The purpose of flotation is to form a stable foam that incorporates the insoluble particles. Flotation can be done in circular or rectangular basins. In fig. 5 shows the diagram of a pressurized air flotation installation [3].

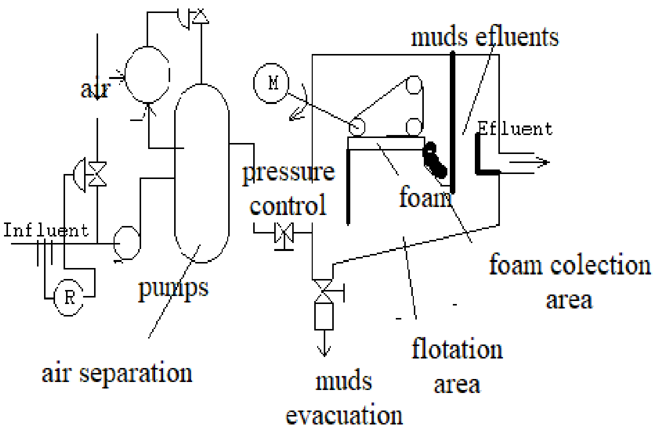

Figure 5. Floatation sediment water separation

II.1.3. Filtration separation

Filtration consists in the passage of water through a porous medium in which retention takes place through predominantly physical phenomena. Filtration is a sieving process using a fine cloth or felt.
This method is the one chosen to be presented in detail. The installation that is the basis of the case study operates in compliance with this industrial wastewater treatment principle [4].

II.1.4. The method of separation by retention on grates and sieves

The retention of coarse impurities (twigs, wires, etc.) on the grates and the smaller ones on the sieve. The speed of the water entering the grates is approx. 0.3 m/s to avoid deposits on the grill but not higher than approx. 1 m/s in order not to stiffen the coarse bodies between the bars. The sieves serve to retain undissolved impurities of smaller sizes and are made of metal sheets or perforated plastic plates. Sieves can be static or mobile (vibrating or rotating sieves). The removal of materials from the sieve is done with brushes, by simple sliding (fig. 6) where a sieve formed by triangular bars is presented. Fine mesh screens made of metal threads or threads of plastic materials are used for suspensions of fine particles.

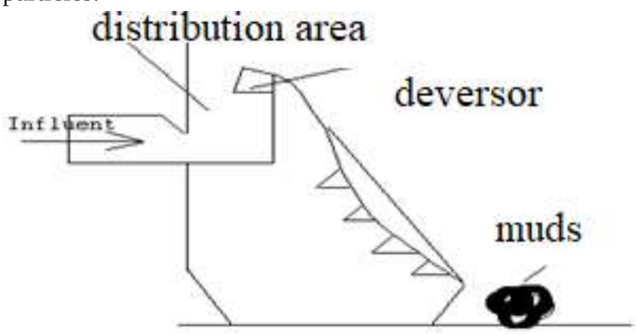

Figure 6. Separation with sieves.

II.1.5.The method of separation by purification in filters granulation and pre-layer filters

Purification in granular filters and pre-layer filters.

The granular material used as filter filling is quartz sand. Filters with several layers of granular materials, with different densities (e.g. anthracite, quartz sand, garnet) are also used which can be washed, the granules being arranged with decreasing diameter in the direction of flow [5].

II.1.6. Membrane purification separation method

The membrane is a barrier to the molecular or ionic species present in the water stream passing through it.

Cellulose acetate, polymer materials stable over time (polyamides, polysuflons, etc.) are used as membrane materials. The purification process with membranes is called osmosis, which can be direct or reverse, depending on the direction of the water from a dilute solution to a concentrated one or vice versa.

There can be several types of osmosis modules, such as tubular ones, fig. 7.

Other membrane purification methods are:

- ultrafiltration - several membranes with selective permeability for certain components are used.
- electrodialysis - uses membranes with selective permeability to anions, respectively cations, their displacement being done under the influence of an electric field, as in electrolysis.

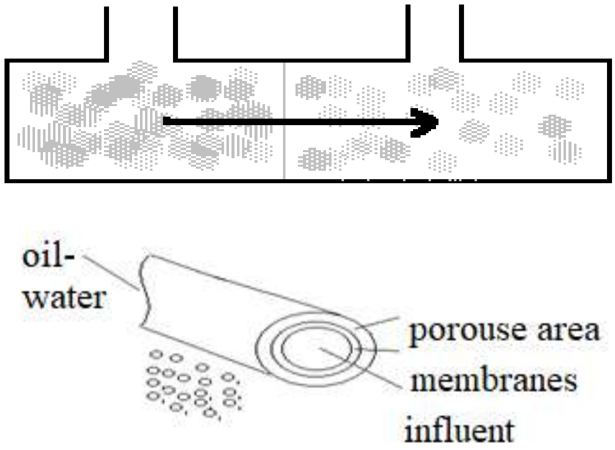

Figure 7. Membrane purification

II.1.7. Phase separation methods

The transfer between phases is based on the passage of pollutants into another phase, immiscible with water, which can be liquid, solid or gaseous. Thus there is liquid-liquid extraction (a solvent is used in which the pollutant is much more soluble than in water, then, after stirring, the sedimentation process takes place, when two layers are formed: the extracted water and the extract), liquid-gas extraction (air, combustion gases are used instead of solvent). For example, at low pH values it is possible to remove hydrogen sulphide:

$S^{2-} + 2H^{+} \rightarrow H_2S$ (molecular hydrogen sulfide

Sulfur soluble in water less soluble in water)

and at high values of ammonia pH and, in general, weak volatile bases:

$NH^{4+} + OH^{-} \rightarrow NH_3 + H_2O$

water soluble ammonium ions molecular ammonia sparingly soluble in water

II.1.8. Method of separation by distillation

Distillation is done by purifying waste water by passing the water into the vapor phase, by heating, followed by the condensation of the vapors, because the impurities have a lower volatility than water.

II.1.9. Method of separation by freezing

Freezing consists in the passage of water into a solid phase in the form of ice crystals, which separate from the residual solution enriched in impurities.

II.1.10. Method of separation by foaming

Foaming is a process of separating dissolved organic impurities from water, due to the addition of foaming agents and by bubbling the water with air in the form of fine bubbles.

II.1.11. Absorption separation method

Absorption is based on the phenomenon of retaining molecules of a substance dissolved in water on the surface of a body (fig. 8).

The material, liquid or solid, on which retention takes place is called absorbent, and the retained substance absorbed.
Solid materials with a large specific surface area, activated carbon, fine ash, etc. are used as absorbents.
The most used absorption purification installations are of the dynamic type, with fixed beds of activated carbon.
Clogging with suspended particles should be avoided. Activated carbon can retain a mass of organic substances up to 5% of its weight.
The regeneration is done thermally, at around 900°C in a controlled atmosphere

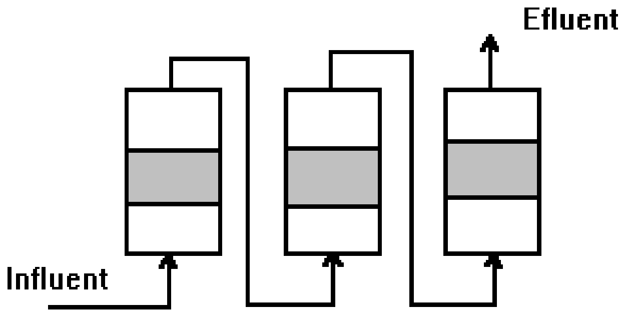

Figure 8. Adsortion process

II.2. Chemical methods whith oil-water separation

Through the chemical purification processes, the pollutants are transformed into other substances that are easier to separate, insoluble precipitates, gases, which can be stypals, which have a reduced harmful activity or are more likely to be removed.
In the decanters, 80-90% of the suspensions present in the water are removed by gravity sedimentation. Fine suspensions with dimensions below 10-3 mm and colloidal ones with a diameter of 10-6 mm cannot be removed by gravity sedimentation due to the colloidal balance in which these suspensions are located. When the amount of very fine and colloidal particles does not exceed 10-20%, the water from the decanters can be directly filtered. Otherwise, to avoid frequent clogging of the filters, it is necessary to remove the colloidal suspensions from the water with the help of chemical reagents.
Coagulation is defined by most authors as the complex physico-chemical process of water treatment with chemical reagents, in order to eliminate fine and colloidal particles from the water, and simultaneously with the elimination of microorganisms and some pollutants existing in the water.
Coagulation was introduced into water technology at the end of the last century when the growing need for drinking water led to the replacement of slow filters with rapid filters whose operation required the pretreatment of water with chemical reagents to remove non-settleable suspensions. At present, coagulation has become a mandatory step in the process of making natural water potable and in the process of purifying waste water.
A colloidal system is a dispersed system with dispersed phase particles from 1 to 200 mμ. Due to the high degree of dispersion, the colloidal particles have a very large surface area, a surface energy and a high adsorption capacity. Due to the adsorption capacity, the colloidal particles adsorb from the external environment a part of the ions existing in the water, becoming electrically charged [6].
Thus, the dispersed system has an electrokinetic potential in which all particles are charged with charges of the same sign. In these conditions, it is not possible to agglomerate the colloidal particles in a natural way, it being necessary to reduce the electrokinetic potential of the system and cancel the repulsive forces.
The purpose of the coagulation process is to increase the size of the particles of the dispersed phase by sticking and fusing them.
The coagulation process is characterized by kinetic stability and aggregation stability.
Kinetic stability means the property of dispersed particles to remain in suspension, distributing themselves in space due to Brownian motion. The more uniform the distribution, the greater the kinetic stability of the system. Aggregation stability represents the ability of a colloidal system to maintain its degree of dispersion, that is, to oppose the increase in the size of the dispersed particles. Colloidal systems are stable from a kinetic point of view, but they are less stable from an aggregation point of view because under the influence of external factors they can change their particle sizes. The elimination of suspensions from water with the help of chemical reagents aims at the destruction of aggregation stability by increasing the size of the particles and their deposition, which leads to the destruction of kinetic stability. The process of destruction of stability during aggregation has the general name of destabilization of colloidal systems.

II.2.1. Neutralisation methods of separation

Neutralization is a process by which the pH of a used solution is adjusted by adding acids or bases.
Acidic waters are neutralized with basic substances (oxides, hydroxides, carbonates).
The neutralizers that are used are: lime stone (calcium carbonate), dolomite (calcium and magnesium carbonate), lime (calcium oxide) in the form of calcium hydroxide (milk of lime or slaked lime powder).
The neutralization of alkaline waters is done with residual acids, with combustion gases rich in CO_2 (14%), etc.
Since the influents have variable flow rates over time, a pH control loop is required, increasing the neutralizing agent flow rate, fig. 9.

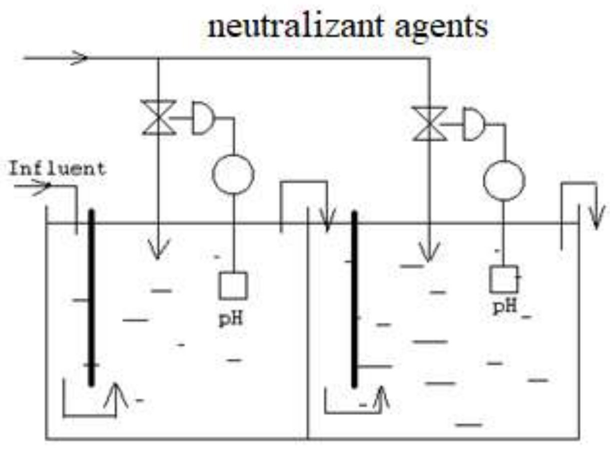

Figure 9. Neutralisation separation process

II.2.2. the method of separation by oxidation and reduction

The purpose of oxidation is to convert unwanted chemical compounds into less harmful ones.

As oxidants can be used: oxygen, ozone, permanganates, hydrogen peroxide, chlorine and chlorine dioxide.

An example is the destruction of cyanides with chlorine until the formation of cyanates or molecular nitrogen:

$CN^- + OCl \rightarrow CNO + Cl^-$

$2\ CNO + 3\ OCl \rightarrow N_2 + 2HCO_{3-} + 3Cl^-$

The reduction consists in the transformation of some oxidizing pollutants into harmless substances that can be easily purified.

An example is the reduction of hexavalent chromium to trivalent chromium, in order to precipitate it as hydroxide:

$Cr_2O_7^{2-} + 6\ FeSO_4 + 7\ H_2SO_4 \leftrightarrow Cr_2(SO_4)_3 + 3\ Fe_2(SO_4)_3 + 7\ H_2O + SO_4^{2-}$

Trivalent iron salts, sulfates, sulfuric acid are used as reducing agents.

II.2.3. Method of separation by precipitation

Precipitation is a purification process based on the transformation of pollutants from waste water into insoluble products.

An example is the removal of fluoride from water by introducing calcium ions:

$2\ F^- + Ca_2 \leftrightarrow CaF_2$ - precipitate

II.2.4. Method of separation by coagulation and flocculation

Coagulation and flocculation represent the removal of some particles by sedimentation (coagulation) and destabilization by absorption of large polymer molecules that form bridges between particles (flocculation).

They are used for colloidal particles.

For this purpose, synthetic organic or inorganic polymers are used [7].

II.2.5. Ion exchange separation method

Ion exchangers are mainly used for water softening, using cations in the form of sodium (Na), and their regeneration is done with sodium chloride:

$2\ ZNa + Ca^{2+} \leftrightarrow Z2\ Ca + 2\ Na^+$

Using ion exchangers is a more expensive solution.

II.3.Biological methods for water-oil separation

The factors influencing the biological purification process are:

- temperature,
- pH,
- content of oxygen,
- nitrogen,
- phosphorus,
- heavy metals,
- toxic organic compounds.

The rate of biochemical reactions doubles for every 10°C increase in temperature, up to about 37°C when most bacteria die.

Bacterial activity is optimal at pH values between 6.5-8.5. Soluble ions of iron, aluminum, copper, chromium, zinc, cadmium, some organic compounds such as formaldehyde and phenol in high concentrations have a toxic effect on bacteria.

Industrial biological treatment plants are stabilization ponds and basins, biological filters and activated sludge treatment systems.

Aerated stabilization ponds and ponds are slow-decrease CBO systems, so with long wastewater retention times ranging from days to weeks, biological oxidation is similar to that occurring naturally in rivers and lakes.

The necessary oxygen comes from the atmosphere through surface aeration and from the vital activity of algae.

An additional amount of oxygen can be introduced through aeration systems.

Biological filters are systems with a high rate of CBO reduction, made of a layer of solid material (slag, crushed stone, plastic material) over which residual water is sprinkled. The necessary oxygen is introduced through natural or mechanical ventilation.

The biological sludge that develops on the fixed layer retains through biosorption and coagulation the colloidal and dissolved substances which are then biologically oxygenated. Activated sludge treatment of waste water is a method in which biological sludge flocs are continuously recirculated and contracted with waste water in the presence of oxygen.

There are situations in which the mentioned methods do not give results due to the presence in the water of so-called "refractory pollutants" (halogenated aromatic compounds, phenol and its derivatives, lower carboxylic acids) which are resistant to biodegradation and are toxic to microorganisms. For their elimination, non-conventional methods of water treatment, catalytic oxidation and photochemical methods are applied.

Photochemical degradation can be carried out in the absence or presence of catalysts.

Through these processes, refractory pollutants are oxidized to chemical, biodegradable or non-toxic compounds.

Organic substances can be removed from water by microorganisms that use them as food, respectively a source of carbon.

Enzymatic reactions have two phases:

- the molecules of enzyme and substance used as food (substrate) form complexes
- the complexes decompose releasing the reaction product and the enzyme

Enzyme + Substrate $\leftrightarrow$ (Enzyme substrate) K_2

(Enzyme substrate) $\rightarrow$ Enzyme + Reaction product

Aerobic biological purification is carried out in constructions where the biomass is suspended in water in the form of aggregates of microorganisms (flakes), the systems being supplied with oxygen.

Anaerobic biological purification of wastewater is carried out in closed enclosures (fermentation basins) protected from the access of oxygen that inhibits the activity of anaerobic microorganisms. Through the decomposition of organic pollutants, combustible fermentation gases are obtained, due to the high content of methane.

II.4. Disinfection method

Disinfection is necessary in the case of wastewater containing microorganisms.

If sterilization involves the destruction of all microorganisms, disinfection does not destroy all of them. The disinfectant penetrates through the cell wall and denatures the protein materials in the protoplasm, including enzymes.

A disinfectant for water is active chlorine that acts in the form of hypochlorite ion, with pronounced effects at low pH values.

Among the physical methods of disinfection, the most used are the thermal method and irradiation with high energy radiation.

IV. CERAMIC METHODS OF TREATMENT OF WATER INFESTED BY OIL

Ceramic membranes for microfiltration and ultrafiltration were developed at least half a century.

Because this technology has a high cost, its use has been limited mainly to the food, beverage and pharmaceutical industries.

A new approved technology is used in oil industry, because is a good techniques to gas separation.

Their use in environmental applications has been very limited due to cost considerations, although they offer several unique advantages in this field, such as chemical and thermal stability, but also structural stability.

Figure 10. Ceramic filter

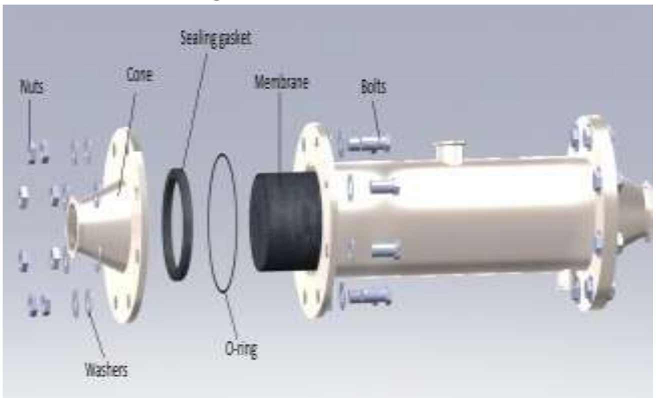

Figure 11. Ceramic filter

The basis of this technology is the principle of filtration. It involves the passage of a volume of residual water through the filtration installation (with passage through the ceramic membrane), which volume is divided into two parts after this passage. A part of the volume of residual water entering the installation will pass through the pores of the ceramic membrane, this being the filtered water (permeate), and the rest of the amount of water (retentate) will either recirculate inside the installation or be removed to a decanter.

Once filtered, the water can be used again in the technological processes from which it comes, or when it is desired to transform it from waste water into drinking water, it will go through another process time mentioned above (chemical or biological process depending on the nature of the polluting agent) .

The retentate can be circulated several times inside the installation in order to achieve a percentage of water recovery as high as possible but also so that the volume of water removed contains as many impurities as possible. This increases the efficiency of the installation in water recovery, but also helps the next process designed to manage this residue by agglomerating the impurities and implicitly increasing the mass of these conglomerates.

The installation has a fairly long applicability in other industries. The major differences in this regard consist in the polluting agents that must be removed, in the type of blockage these pollutants create for the ceramic membrane, but also in the method of removing the polluting agents. The difference can also be mentioned in the volume of water that must be filtered, the oil industry using very large amounts of clean water.

The main advantage of this installation, unlike the rest of the filtration installations, is the fact that it has the ability to execute washing programs (inside the installation) automatically. This process aims to remove the impurities (polluting agents) deposited on the ceramic membrane, but also those whose size allowed them to reach inside the filter pores. This blockage, once removed, gives the installation an increased capacity for operation (filtration), the blockage of the ceramic membrane being directly proportional to the volume of filtered water.

The possibility of self-washing of the installation presupposes its continuous operation and the exclusion of human intervention. Human intervention in industrial processes, as this filtering process is intended to become, is defined by the health and safety procedures of large companies as the one with the greatest weight in terms of work accidents. The automation of this process implies the removal of both work accidents and human handling errors, and of course the exclusion of operating costs.

From the point of view of applicability, the filtration installation based on ceramic membranes can be used for both ecological and technological purposes. As I mentioned before, the residual water after it has been filtered can be reintroduced into the technological processes from which it originates, but in the case of the current pilot unit, it is desired to filter the water used at the technological water injection probes. This technological water injection process is very important in the crude oil extraction industry because it increases the yield of crude oil recovery from aged deposits (with a low reservoir pressure) and thus created the situation in which this installation is profitable. The purpose in which the installation is used also determines the size required by the manufacturers for the filter pores, another advantage because, depending on the need, the cartridge containing the ceramic membranes can be easily changed and thus it is possible to switch to more advanced or coarser filtration.

The importance of filtering the water used by the injection probes is to eliminate particles above a certain size because they create blockages in the area of the perforations of the injection probe, decrease the volume of injected water and increase its injection pressure, leading to blocking the probe completely.

V. MATHEMATICAL MODELLING OF OIL-WATER SEPARATION BY CERAMIC FILTER

From the measurements made on the treatment plant, it can be seen that it works in batches (22 hours of treatment and 2 hours of cartridge recovery) (figure 12).

Under these conditions, based on the measurements, I tried to determine an equation of variation of the flow of filtered water and the flow of water with impurities.

The numerical model proposed by me refers to the least squares analysis of the output data according to the input data. We assume that the chemical phenomenon can be approximated by the method of least squares, with a polynomial of the first degree, in this way we find ourselves in the situation of approximating the phenomenon by the polynomial:

$$P_n(x) = a_0 + a_1 x$$

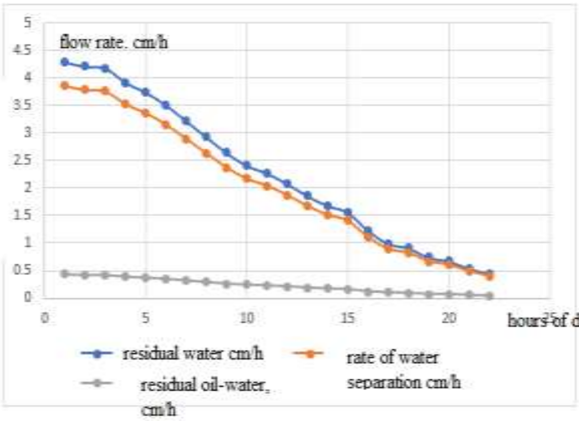

Figure 12. Flow rate of oil-water separation by ceramic filter

We will determine the coefficients a0 and a1 by solving the system below:

$$a_0 \sum_{i=1}^{n} x_i^0 + a_1 \sum_{i=1}^{n} x_i^1 = \sum_{i=1}^{n} y_i$$

$$a_0 \sum_{i=1}^{n} x_i^1 + a_1 \sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i y_i$$

The system is linear and has as unknowns on a_0 and a_1. Therefore, the solution is determined by Cromer's method:

$$a_0 = \frac{\Delta a_0}{\Delta}$$

$$a_1 = \frac{\Delta a_1}{\Delta}$$

The determinant of the system lies with the relation

$$\Delta = \begin{vmatrix} \sum_{i=0}^{n} x_i^0 & \sum_{i=0}^{n} x_i \\ \sum_{i=0}^{n} x_i & \sum_{i=0}^{n} x_i^2 \end{vmatrix}$$

Determinats is:

$$\Delta a_0 = \begin{vmatrix} \sum_{i=0}^{n} y_i^1 & \sum_{i=0}^{n} x_i \\ \sum_{i=0}^{n} x_i y_i & \sum_{i=0}^{n} x_i^2 \end{vmatrix} = \sum_{i=0}^{n} y_i^1 \cdot \sum_{i=0}^{n} x_i^2 - \sum_{i=0}^{n} x_i y_i \cdot \sum_{i=0}^{n} x_i$$

$$\Delta a_1 = \begin{vmatrix} \sum_{i=0}^{n} x_i^0 & \sum_{i=0}^{n} y_i \\ \sum_{i=0}^{n} x_i & \sum_{i=0}^{n} x_i y_i \end{vmatrix} = \sum_{i=0}^{n} x_i^0 \cdot \sum_{i=0}^{n} x_i y_i - \sum_{i=0}^{n} y_i \cdot \sum_{i=0}^{n} x_i$$

$$\sum_{i=0}^{n} x_i^0 = \sum_{i=0}^{n} 1 + 1 + 1 + 1 + \ldots + 1 = n + 1$$

$$\Delta = (n+1) \sum_{i=0}^{n} x_i^0 - \left(\sum_{i=0}^{n} x_i\right)^2$$

When measurement points is $x_o, x_1, \ldots, x_n$, which corresponds the measurement’s value $y_o, y_1, \ldots, y_n$, we have the equation:

$$\Delta = n \sum_{i=1}^{n} x_i^2 - \sum_{i=0}^{n} (x_i)^2$$

Assessing the significance of the coefficients of the regression equation is done using the Student test.
For this, the approximate s_0^2 of the dispersion of the y_i values is determined with the help of those repeated observations:

$$s_0^2 = \frac{1}{n_0 - 1} \sum_{k=1}^{n_0} (y_{0k} - \bar{y}_0)^2$$

În equation, $\boldsymbol{y_{ok}}$ represents the observation repeated $\boldsymbol{n_0}$ times and $\bar{\boldsymbol{y}}_{\boldsymbol{0}}$ represents the average of the repeated observations.

$$\bar{y}_0 = \frac{1}{n_0} \sum_{k=1}^{n_0} y_{0k}$$

Coeficients dispersion of $\boldsymbol{a_0}$ și $\boldsymbol{a_1}$ is calculated by relations:

$$s_{a_0}^2 = \frac{s_0^2 \sum x_i^2}{n \sum (x_i - \bar{x})^2} = \frac{s_0^2 \sum x_i^2}{n \sum (x_i^2 - (\sum x_i)^2}$$

$$s_{a_1}^2 = \frac{s_0^2}{n \sum (x_i - \bar{x})^2} = \frac{n s_0^2}{n \sum (x_i^2 - (\sum x_i)^2}$$

In final with calculus t student criteria:

$$t_i = \frac{|a_i|}{s_{ai}}$$

In the above equation a_i represents the coefficient i of the regression equation.

Where:

$t_i > t_p(\nu_0 = n_0 - 1; \alpha = 0{,}05)$,

then you would consider yourself significant.

To check the adequacy of the regression equation, the residual sum of squares is calculated with the equation:

$$\sum_{i=1}^{n} (y_i - \tilde{y}_i)^2 = \sum_{i=1}^{n} (y_i - (a_0 + a_1 x))^2 = S(a_0, a_1)$$

Then the adequacy dispersion is also determined:

$$s^2 = \frac{S}{n-2} = \frac{\sum y_i^2 - a_0 \sum y_i - a_1 \sum x_i y_i}{n-2}$$

The denominator of this relationship has the value n-2, because with the help of these data the values of the coefficients a_0 and a_1 have already been calculated.
The adequacy of the regression equation is checked using the Fisher criterion:

$$F = \frac{s^2}{s_0^2}$$

When the calculated Fisher F test value satisfies the condition:

$$F > F_p(\nu = n - 2; \nu_0 = n_0 - 1; \alpha = 0{,}05)$$

Then it can be stated that the regression equation is adequate.
If the regression equation is not adequate, the approximation polynomial must be modified.
The dispersion s^2 refers to the scatter of the experimental points around the regression line, and the dispersion $\boldsymbol{s_0^2}$ refers to the scatter of the same experimental points, but around their mean.
If the regression line is well constructed, then the two dispersions should reflect the same thing; they actually refer to "two selections coming from the same crowd".
Their ratio approaches 1 as ν and ν_0 increase.

VI. RESULTS AND DISCUTIONS

Equations between input parameters and output parameters were determined by the method of least squares, which we presented in table 8.4.

Table 1. Parameters of equation models.

Equation	Output parameters	Input parameters	a_0	a_1	Average value experimentals	Averaje values calculated
1	Rate water filtered (m^3/h)	Residual water rate (m^3/h)	-0,00007591	0,9	2,046318	2,0461968
2	Rate water with impurities (m^3/h)	Residual water rate (m^3/h)	0,052	0,083	0,2268	0,2407

Table 2. Parametrii statistici ai modelului matematic.

Equation	Averaje values calculated	Average value experimentals	t_{a0}	t_{a1}	t_p
1	1,336	0,501	0,1	-0,000151	8,981
2	0,016	0,056	0,011	0,935	7,494

for $\boldsymbol{\nu = 13}$, $\boldsymbol{\nu_0 = 14}$ and $\boldsymbol{\alpha = 0,05}$ results

Table 3. Fisher criteria results.

Ecuația	**Fisher criteria results**	**Fisher criteria literature**
1	1	3,24
2	0,696	3,24

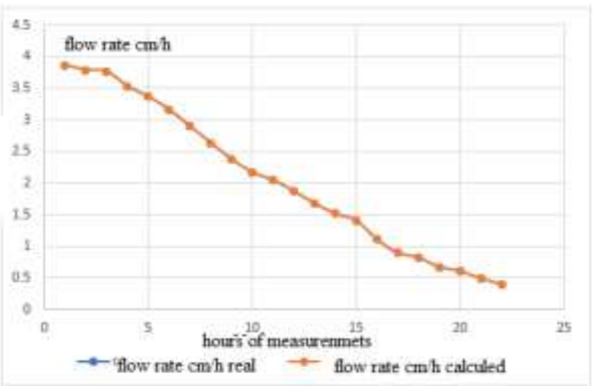

Figure 13. The variation of calculated filtered water flows compared to those determined (m^3/h) according to the measurements.

VII. CONCLUSIONS

Due to the fairly high investment costs, this waste water depollution method chosen as a case study even proves its economic efficiency in addition to the qualitative one of protecting the environment.

This means that only a person or company in bad faith would refuse such an investment!

In conclusion, I will quote a phrase from the book "The Prophecy of the Cree Indians" to put a question mark if we are really willing to go that far?!

"Only after the last tree has been felled, Only after the last river has been poisoned, Only after the last fish has been caught, Only then will you realize that money cannot be eaten."

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