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APPLICATION OF IT TECHNOLOGY IN WASTEWATER TREATMENT

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Abstract: *The paper that will be presented below deals with the application of modern information technology solutions in wastewater treatment and processing. Described solutions are applied to the treatment of water in the production process of the chemical industry, which deals with anodizing, galvanizing, nickel plating, chrome plating and cleaning of metal products. Microcomputers are also used to control the processing process, as well as an industrial server which parameters obtained from sensors and actuators are entered. This data is further processed to obtain relevant plant management data. The operation of the plant is fully automated with a minimum number of people who are now manipulating to add the raw materials necessary for the operation, as well as to take away the by-products created by the operation of the plant. All decisions and control are performed by a microcomputer and a PLC. The results obtained during the operation of the plant give up to 18% better results than the plants that are not fully automated. The results were verified in a certified laboratory. The following programming languages Java, C, C ++, PYTHON, MySQL, Ladder were used for the functioning of the existence.*

Keywords: *pH, sensors, PLC, microcomputer.*

1. CHARACTERISTICS OF WASTEWATER QUALITY – UNPROCESSED

Significant characteristics of the quality of wastewater from chemical industry processes are:

- extremely high content of substances in the suspension, including fats and oils, which must be removed, because they would extremely quickly block - saturate the surface of activated carbon and prevent the access of dissolved and other substances that should be adsorbed.
- the content of H_2S - sulfides above MDK, which causes a very unpleasant smell of water and atmosphere in the premises of the chemical industry. H_2S originates from the extraction process, where sodium sulphide is used. It should be emphasized that hydrogen sulfide is treated as a dangerous industrial pollutant (of water and air) and as such is one of the test substances for assessing the quality of industrial protective agents. [1]
- high content of organic substances, dissolved in water, which cause high values of $KMnO_4$, HPK, BOD, etc.
- content of trivalent chlorine (Cr^{3+}) above MDK originating from chemical industry processes. The quality characteristics of chemical industry process wastewater are given based on average analyzes of water taken from several different chemical industry factories, as well as on the basis of data from the literature.

Table 1 gives a rough overview of the quality of waste water from chemical industry processes before treatment:

Table 1. Overview of the quality of waste water before treatment

TYPE OF ANALYSIS	VALUE
pH value	6,5 – 10
Water temperature	10 – 20 °C
Dry residue	6 – 10 g/l
Residue after annealing suspended matter	4 – 6 g/l
Electrical conductivity	above 2000 µS/cm
Turbidity (in degrees)	about 100
Color (in degrees)	400 – 50
Consumption of $KMnO_4$	200 – 500 mg/l
HPK	100 – 300 mg/l
BPK	20 – 50 mg/l
Ammonia (N)	0,5 – 2 mg/l
The appearance of the water	partly cloudy
Sulfides (H_2S)	5 – 20 mg/l
Cr^{3+} content	30 – 50 mg/l
Chloride content	10 – 30 mg/l
Nitrate content (N)	about 1,5 mg/l

Nitrite content	below 0,03 mg/l
Calcium (CaO)	300 – 350 mg/l
Iron content	about 0,25 mg/l
The water hardness	about 20 °D
Oxygen content	about 5 mg/l
Sulphate content (SO_4)	averages 30 – 40 mg/l
Phosphate content	below 1 mg/l
Sedimentary substances	about 1,5 % mg/l
Manganese content	0,0 mg/l

2. QUALITY CHARACTERISTICS OF PROCESSED WASTEWATER

Bearing in mind the Rulebook on Hazardous Substances in Water (Official Gazette of SRS No. 31/82), table 2 lists certain average values of significant quality characteristics of processed wastewater from chemical industry processes.

Table 2. Average values of significant quality characteristics of processed wastewater

Type of analysis	Value
The appearance of the water	clear
Visible waste materials	not present
Color (in degrees)	below 50
pH value	6,5 – 9,5
HPK	1000 – 1500 mg/l
BPK	500 – 800 mg/l
Sulfides (H_2S)	0 – 0,1 mg/l
Cr^{3+}	0 – 0,5 mg/l and in higher concentrations is not treated as a pollutant
Fats and oils	below 20 mg/l
Turbidity (in degrees)	below 50

The quality of processed water must correspond to the Rulebook on the discharge of waste water into the recipient. [3]

3. TECHNOLOGICAL PHASES OF THE WASTEWATER PROCESSING PROCESS

During the treatment of wastewater from chemical industry processes, the following technological stages dominate:

– - removal of substances in suspension by the processes of chemical dosing, flocculation, coagulation and precipitation

– removal of excess content of trivalent chromium (Cr^{3+}) by processes of flocculation and precipitation at a certain pH value.

– removal of hydrogen sulfide (H_2S) by processes such as oxidation and adsorption, processes on activated carbon. Bearing in mind that, apart from H_2S dissolved in water, H_2S vapors are also in the gas phase, it is also necessary to filter the air. This process through filters which contain granulated activated carbon in order to eliminate traces of H_2S.

– removal of organic matter dissolved in water by processes of flocculation, coagulation, sedimentation, filtration and adsorption on activated carbon. Bearing in mind that the content of substances of organic origin can be in a wider range of concentrations, in addition to eliminating them by the process of filtration on granulated activated carbon, the removal of substances of organic origin, when they are found in higher concentrations, will also be done by dosing activated carbon powder together with flocculants, in the pretreatment of waste water. [2]

3.1 Block diagram of the wastewater treatment process

Wastewater from processes in the chemical industry is separated using two independent pipelines. Wastewater of basic origin resulting from the use of various degreasers, detergents, fats and oils is drained through pipeline I, and acidic waters resulting from the chemical process of chroming, galvanizing, and graphitization are drained through the second pipeline (pipeline II).

Wastewater from pipeline I is first treated separately, in a basin with two chambers, which is located in pipeline I itself, and then it is processed together with water from pipeline II, collectively, in a separate basin with a volume of about 50 m^3, divided into three segments. Collective waste water from pipelines I and II is finally processed by passing it through sequentially connected filter units with hydroanthracite and granulated activated carbon incorporated in them.

During the process of wastewater treatment, processes of flocculation, coagulation and sedimentation, the formation of sludge has been present, and it`s collected in certain chambers of the basin for collecting wastewater, namely:

– in the pipeline I, at most, in the first chamber of the pool for collecting waste water.,

– in the first and partly in the second chamber of the pool for collecting wastewater from pipeline II and for collective treatment of wastewater from pipelines I and II.

The following figure shows a functional plant diagram of the wastewater treatment process:

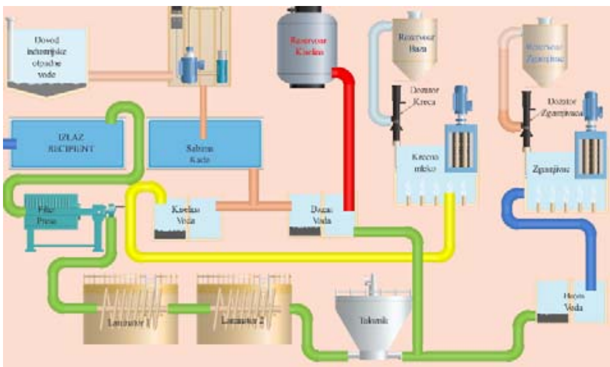


Figure 1. Functional plant diagram

3.2 Description of the technological stages of the water treatment process

The wastewater treatment process includes technological stages that are implemented as:

– pretreatment of water in basins into which water is introduced from chemical industry processes and

– final filtration and adsorption on granulated activated carbon.

It is planned that the wastewater treatment process is carried out 6-7 times during the month, depending of the intensity of work processing plant and the implemented processing processes.

The pre-treatment of wastewater from pipeline I will be carried out in this department, in a pool divided into two chambers (the total volume of the pool is about 10 m^3).

The characteristic of these waters is a high content of suspended matter (particles of dirty from washing leather, fat and oil, etc.) and a high content of H_2S, above the MDK value, which is separated from Na_2S.

In the first chamber of the pool, substances suspended in the water settle, which is enhanced by adding, dosing a certain amount of flocculant. By overflowing, the water from the first chamber of the pool passes into the second, where it is processed in order to effectively remove H_2S.

H_2S is, in principle, removed by adsorption on activated carbon but previously it is necessary to carry out a rapid pretreatment of water in order to oxidize H_2S. Oxidation of H_2S, which is dissolved in water, is often insufficient only by the aeration process (by blowing air with a compressor), but water must be pre-treated by adding a certain amount of Zavel water solution (sodium hypochlorite NaClO), a very effective oxidizing agent for H_2S.

The mechanism of the H_2S oxidation process can be represented by the following equations:

$$8H_2S + 4O_2 \rightarrow S_8 + 8H_2O$$

$$2H_2S + 3O_2 \rightarrow 2H_2O + 2SO_2$$

$$H_2S + 2O_2 \rightarrow H_2SO_4$$

$$H_2S + SO_2 \rightarrow 3S + 2H_2O$$

$$H_2SO_4 + H_2S \rightarrow S + 2H_2O + SO_2$$

$$S_8 + 8O_2 \rightarrow 8SO_2.$$

For the adsorption of H_2S, i.e. sulfur and sulfur compounds, on granulated activated carbon, a layer of water film on the surface of activated carbon is required.

Oxidation of H_2S is additionally carried out in larger, coarser pores, followed by sulfur adsorption in micropores of activated carbon. In order to protect the adsorption capacity of GAU (granular activated carbon) and extend its service life, smaller doses of powdered activated carbon can be used in water pretreatment, which is dosed together with flocculant.

The final elimination of H_2S, i.e. sulfur and sulfur compounds, is carried out by filtration on the GAU of the collected waste water from pipelines I and II, which are discharged into the second part of the pool with a volume of 50 m^3.

3.2.1. Pretreatment of wastewater from pipelines II

The pre-treatment of this waste water is carried out by treatment with a special flocculant for the precipitation of trivalent chromium (Cr^{3+}) at a certain pH value of the water, in the first of three water treatment basins.

Precipitation of trivalent chromium (Cr^{3+}) can be carried out without adding flocculant if ferric hydroxide floc ($Fe(OH)_3$) is present. These waters also have an increased content of suspended matter, which settles after treating the water with flocculants and coagulants.

After the discharge of waste water from pipeline I , which are basic, into the same pool, the water is practically neutralized, so that a special adjustment of the pH value is not necessary.

Collective wastewater from the first basin is poured into the second basin, from where its further processing is carried out by filtration and adsorption on GAU.

3.2.2. Water treatment by filtration and adsorption on GAU

The final treatment of waste water is carried out by the processes of filtration and adsorption, whereby water is transported by a pump at a certain speed through two regularly connected filters, i.e. an adsorber filter.

Final water treatment is done 4-5 times a month, in batches of about 2-2.5 m^3. Finishing capacity is 0.5 m^3/h.

The first filter in the row is filled with hydroanthracite, type HYDRACIT M* (0.6-1.6), as a filtration material, up to about two-thirds of the height of the filter in order to ensure conditions for countercurrent washing of the filter filling. Filtration on a "mechanical filter" is necessary to eliminate residual substances in suspension and to protect the GAU filter.

The second filter has the role of filter adsorber. It is filled with granulated activated carbon (K-81/B or H-0.8) up to two-thirds of its height, in order to ensure countercurrent washing of the filter filling. It is intended for the adsorption of organic substances dissolved in water and H_2S oxidation products, which are also dissolved in water. [4]

The operating parameters of the filter adsorber are:

– dwelling time 15 – 20 minutes.

– filtration speed 4-6 m/h.

In any case, treated wastewater is discharged into the third pool with a volume of about 15 m^3, so the chemical industry can operate for five months without releasing the treated wastewater or returning it to the process.

3.2.3. Sludge filtration

In the first chamber of the basin for waste water in pipeline I and the first basin for discharging water from pipeline II, after pre-treatment of water, sedimentation of suspended substances is carried out. Pool cleaning, sludge filtration, is done once a month, using a special sludge filter, which squeezes the sludge, keeping the sludge on a special filter cloth, from which it can be easily cleaned and separated. Sludge filtration separates sediment and filtrate. The separated sediment can be deposited in PE bags and deposited together with solid waste from chemical industry processes. The filtrate is, in principle, returned for reprocessing.

3.2.4. Example of a plant for the processing and purification of waste water in the chemical industry

Each of these species of wastewater has its own bathtub. In each tub there is a water level meter, a pump for transferring water to the collection tub located in the water treatment plant, a water flow meter (these water flow meters are a legal obligation to monitor the efficiency of the wastewater treatment plant). These meters are also located on the outlet tubs towards the recipient. At any moment, these flow parameters are recorded in the database, in order to create reports on the efficiency of the plant on a daily, monthly, and annual basis and calculate the payment for the discharge of wastewater into the recipient. The pump further uses a pipe to transfer water to the electromagnetic valve (it is transferred from tubs 1 and 2, i.e., the tub for acidic and basic water to the collection tub for acidic and basic wastewater located in the wastewater treatment plant), while from tub 3 a separate pipeline in particular, the water with heavy metals and chromium is transferred to the chromium collection tank. The purpose of the electromagnetic valve is to close the water supply in the sump - only one of the waste waters can come, either alkaline or acidic. In the collection tub for basic and acidic water, there is a pH meter whose role is to measure the pH value of waste water (picture no. 2)

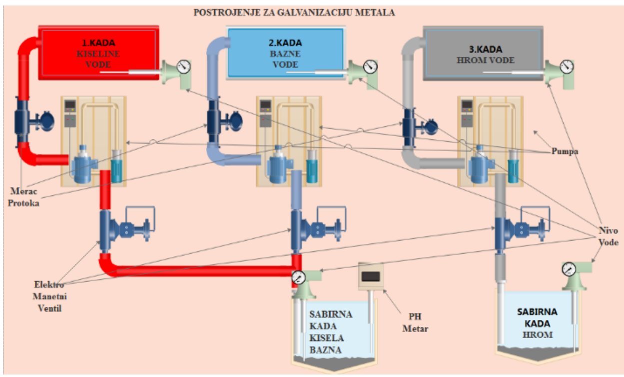


Figure 2. Wastewater processing processes

Waste water from the collection tub is transported to tanks (acid or base tanks) based on the pH value parameter (at 25°C water with a pH less than 7 is acidic, above 7 is basic). These tanks have mixers that maintain the concentration in a stable mode, without the possibility of sedimentation. The water from one of these canisters is transported through a pipeline to a collection tank where the pH value is checked again. If the pH is less than 5, base from the base canister is added, otherwise, acid. This water is mixed and oxygen is pumped in. If the pH value of the water cannot be brought to a value of 6 to 8, concentrated acid is added, that is, prepared milk of lime, if basic water is needed. The water remains in this tank until its value is within the range of 6 to 8. Then the water is transported to the precipitator and after settling and checking the pH value, it is discharged into the recipient or returned for processing (picture no. 3).[5]

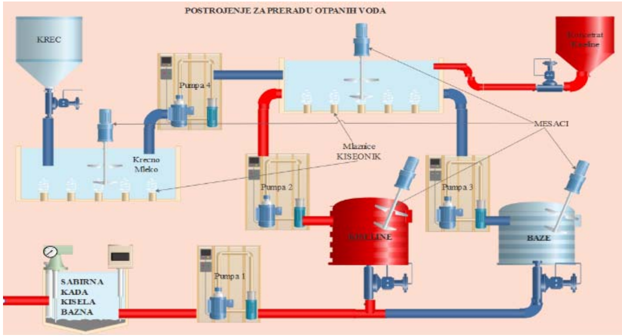


Figure 3. Processing of basic and acidic waste water

From the collection tank, chrome water is transported by pump to tank 2, where mixing, measurement of the water level in the tank, introduction of oxygen and introduction of thickener are carried out. The raw material is fed into the tank of the thickener. It is then transferred to tub 1 with a screw dispenser. A special mixer combines this thickener with clean water, and with the help of another dispenser, it is transferred to tub 2. After mixing for several hours, the water from tub 2 moves to tub 3, where the mixing of water continues and injection of oxygen. Then this water is transported by pump 2 to the filter press, where the collected heavy metals and thickeners are deposited on the filters, and the water obtained by pressing is returned to the precipitator tub 4 (picture no. 4).

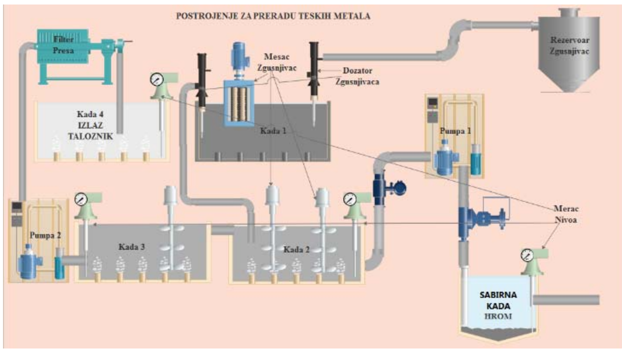


Figure 4. Separation of heavy metals from waste water

From the plant for the processing of basic and acidic waste water, water is delivered from sedimentation tank 1. It is then transported to sedimentation tank 2, where after measuring the pH value and temperature of the water, and in case the pH value is within the specified limits, the water is transported by pump 2 to the stabilization bath - laminator 1. This tub consists of numerous laminated metal spirals. The dimensions of the bathtub are 10 m long, 2 m wide and 2 m high. By using the laminator, the water path through the tub was extended so that it now amounts to 100m. This leads to additional purification of water and in these laminators, oxygen is pumped in, thereby increasing the electroconductive potential of water. Pump 3 transfers water from stabilization tub 1 to stabilization tub 2, which has the same dimensions and the same operating principles.

From the plant for processing water with heavy metals (bath 4 - outlet settler), water is transferred by pump 4 to the stabilization bath of laminator 1. The process is the same as in the previously explained example. At the exit of the stabilization tub of laminator 2, there is an electromagnetic valve whose role is to prevent waste water from spilling into the recipient in the event that the values on the pH meter located in the recipient do not meet the set parameters, that is, the value of the redox potential is not within the limit values. This valve can be closed, so in case of weather events, when the level of the recipient rises suddenly, the plant is protected from flooding in this way (picture no. 5).

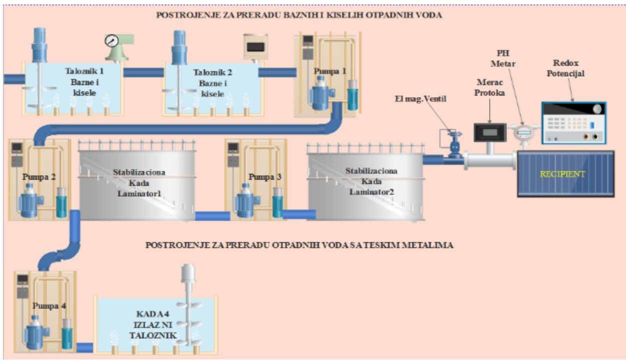


Figure 5. Discharge of treated water

4. VALUES MEASURED (VERIFIED) BY CHECKING IN AN AUTHORIZED (CERTIFIED) LABORATORY

By checking the value, which is carried out once a month in an authorized reference laboratory, exceptional results were obtained in which the values for the maximum allowed discharge from the plant are even 20% lower than the values prescribed by the legislator. In the tables below you can see the values for one month.

Table 3. Confirmed values of wastewater from an authorized laboratory

Parameters	Unit of measure	Proccesses											
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Aluminium	mg/l	2	-	2	-	-	-	-	-	1	2	1	2
Nitrogen from ammonia	mg/l	80	-	-	-	25	45	-	-	15	20	-	-
HPK	mgO2/l	300	-	90	-	180	3500	-	-	90	300	320	200
Iron	mg/l	1	-	-	-	2	-	-	-	2	2	2	2
Fluorides	mg/l	40	-	40	-	40	-	-	-	40	20	-	-
Nitrogen and nitrates	mg/l	-	-	4	-	-	4	-	-	3	4	-	-
Hydrocarbons(III)	mg/l	8	-	9	-	7	9	-	-	8	8	7	9
Phosphor	mg/l	1	-	1	-	1	1	-	-	1	1	1	1
Toxsicity to fish (TF)(IV)		5	-	1	-	4	5	-	-	3	4	4	5

Table 4. Confirmed values of wastewater from an authorized laboratory

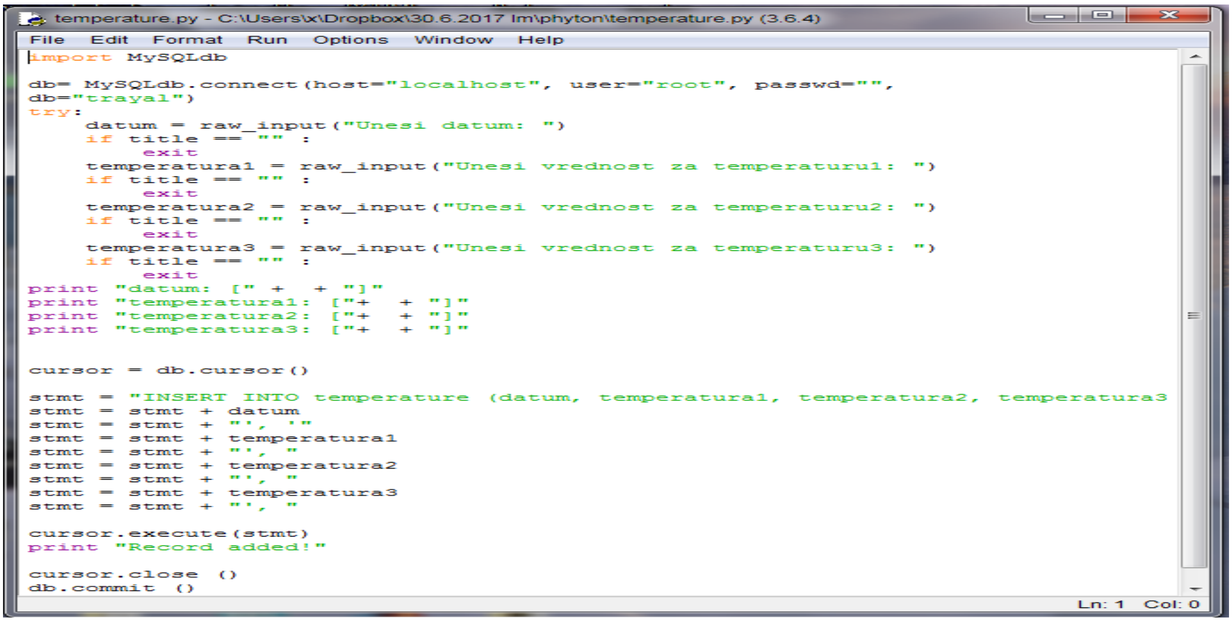
Parameters	Unit of measure	Proccesses											
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12

AOH (adsorbing organic halogen)	mg/l	0,67	-	0,62	-	0,59	0,61	-	-	0,62	0,66	0,66	0,6
Arsenic	mg/l	0,06	-	-	-	-	-	-	-	-	-	-	-
Barium	mg/l	-	-	-	-	-	1,33	-	-	-	-	-	-
Lead	mg/l	0,33	-	-	-	0,32	-	-	-	0,34	0,33	-	0,33
Cadmium	mg/l	0,13				0,07			-	0,14	0,05		0,17
	kg/t	0,2							-				
Free chlorine	mg/l	0,33	-		-		0,32				0,33		
Total chrome	mg/l	0,33	-	0,33	-			-		0,33	0,33	0,5	0,32
Chrome VI	mg/l	0,06	-	0,06	-			-		0,05	0,05		0,08
Cobalt	mg/l			0,65						0,66			
Cyanides	mg/l	0,13					0,66	-			0,14		
Copper	mg/l	0,33	-					-	-	0,33	0,33	0,5	0,31
Nickel	mg/l	0,33	-		-			-	-	0,33	0,34	0,5	0,32
Hydrargyrum	mg/l								-				
	kg/t								-				
Selenium	mg/l									0,67			
Silver	mg/l	0,06						-	-				
Sulfides	mg/l	0,67	-		-			-	-	0,67			
Tin	mg/l	1,33		1,38		1,31		-					
Zinc	mg/l	1,33	-	1,36		1,37			-	1,35	1,33	1,32	1,344

5. AUTOMATISATION AND DATA COLLECTION

Data collected from sensors and actuators (pH -meters, redox potentials, sensors for measuring temperature, water level, etc.) are necessary for the automated operation of wastewater treatment and purification plants.

The results of the measurements collected from the sensors after processing are forwarded by the PLC to the application in the programming language "PYTHON", which reads the values of voltage, current, frequency and converted scaled values from the communication ports and sends them to the application in the programming language "PHP", and then this application writes the data into the MySQL database . Figure 6 represents an application written in the "PYTHON" program, which writes data into the MySQL database. The picture shows the connection string for connecting to the database, as well as the fields that need to be entered in the database. [6]




```
import MySQLdb

db= MySQLdb.connect(host="localhost", user="root", passwd="",
db="trayal")
try:
      datum = raw_input("Unesi datum: ")
      if title == "" :
            exit
      temperatura1 = raw_input("Unesi vrednost za temperaturu1: ")
      if title == "" :
            exit
      temperatura2 = raw_input("Unesi vrednost za temperaturu2: ")
      if title == "" :
            exit
      temperatura3 = raw_input("Unesi vrednost za temperaturu3: ")
      if title == "" :
            exit
print "datum: [" +  + "]"
print "temperatura1: ["+  + "]"
print "temperatura2: ["+  + "]"
print "temperatura3: ["+  + "]"


cursor = db.cursor()

stmt = "INSERT INTO temperature (datum, temperatura1, temperatura2, temperatura3
stmt = stmt + datum
stmt = stmt + "', '"
stmt = stmt + temperatura1
stmt = stmt + "', "
stmt = stmt + temperatura2
stmt = stmt + "', "
stmt = stmt + temperatura3
stmt = stmt + "', "

cursor.execute(stmt)
print "Record added!"

cursor.close ()
db.commit ()
```

Figure 6. Python application for entering data into the database

The "phpMyAdmin" database was used, the layout of the data table is shown in Figure 7. In the fields of the data table, enter the values of the temperature at the inlet and outlet of the purifier, the relative humidity of the air at the inlet and outlet, the air flow in front of the inlet and outlet filter of the air ionizer . The last field in this table is the date and time. Data is read from the sensor every 2 minutes and entered into the database. The time cycle between entries can be significantly longer, since the program continues to process the data, but due to data collection during the installation of the device, since each room has different parameters, it initially starts with the entry for 2 minutes, but after establishing the balance and adjusting, this time will increase to 3 or 5 minutes. This significantly affects the required space occupied by the database and stored on the installed SSD disk on the microcomputer. In order to increase the space, the program generates tables with data after a month of operation, and deletes the data for that period. Based on these data, the program can continue working and setting up its output actions.[7]

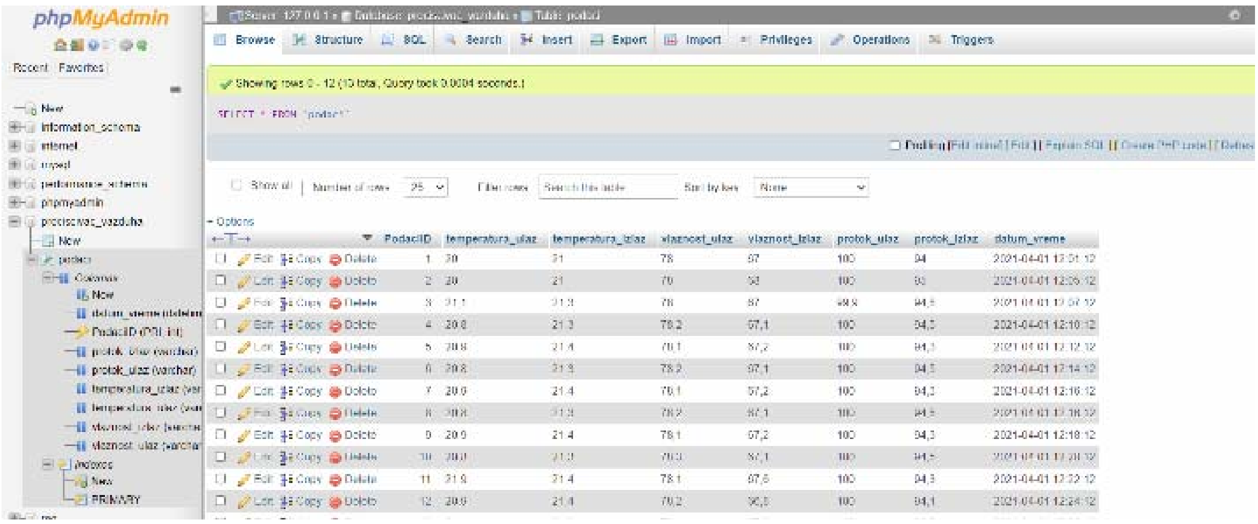


Figure 7. Table data phpMyAdmin

CONCLUSION

This paper shows the increase in the efficiency of waste water treatment in the chemical industry using filters with activated carbon, activated carbon powder. The goal of introducing information technologies and artificial intelligence is to limit the human factor to the lowest possible level of decision making, and leave process management and processing management to automation. The man's role is to regularly supply the plant with the necessary chemicals, thickener, lime, activated carbon, check the output parameters and empty the remains of the material created by the operation of the filter press, which extracts heavy metals in its filters. The facility has 24-hour monitoring of all parameters from the water level in all tubs, through pH and redox potential values, pressure, flow, and has an alarm system that is activated in the event of an accident. The system sends data on a daily basis to the plant manager who executes corrective measures in case of need. Based on the parameters saved on the PLC controller and the V BOX, reports are made on a daily, monthly and annual level, and the efficiency of the plant is checked by checking the values in the reference laboratory. This solution gives good results in practical use. Material savings (chemicals, thickeners) are achieved, because the PLC controller finds the ideal ratio. A significant increase in efficiency through the use of information technologies was shown, given that the microcomputer determines the optimal dosage of the necessary raw materials for obtaining water whose values are of the highest quality. The number of workers required for plant operation is also reduced. In addition to these economic results, the plant also produces better results in the quality of the water that is discharged into the recipient. This is the biggest contribution to the preservation of our waters.

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