Survey of Nanofiltration Technology In Removing Heavy Metals (Ni, Cu and Zn) From Industrial Waste Water

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Abstract**—** one of the main sources of environment pollution is the industrial wastewater which contains heavy metals and can be found in many industries such as plating industry. If these heavy metals enter in human body, would cause many health problems. The aims of this study were to assess nanofiltration technology efficiency in removal of three metals of nickel, zinc, and cupper as the index of heavy metals in plating sewages and evaluate the effects of pressure, concentration, and filtration time on removal efficiency. For studying of concentration effect on the membrane performance, was used two concentration levels of heavy metals, 25 and 50 mg/l and it was examined the effect of pressure with three pressures of 4,6 and 8 bar. pH and temperature were considered constant in all exams. The results showed that increasing of pressure increase rejection as its effect in 8 bar of pressure in Cu was more than the other metals (Zn and Ni) and 100% of that was rejected. Also, increasing of concentration was caused rejection increasing, which Zn rejection increase from 99% in 25 mg/l to 97/07% in 50 mg/l .Finally, the filtration time is a positive agent in the heavy metals rejection.

Keywords**—**Nano filtration, heavy metals, wastewater, membrane process

I. Introduction

ONE of the most important factors in environmental pollution is industrial waste water .industrial waste water which contain heavy metals are part of dangerous pollutions and we can observe them in the production process in most industries such as plating industry [1] .One of the most fundamental problem about heavy metals is the lake of their metabolism in body .in fact ,when the heavy metals enter the body ,not only they do not expel , but also they will accumulated and deposit in tissues such as facts muscles , bones and joints that these cause some diseases and variety illness in body . Heavy metals , also substitute , the other salts and mineral materials which are necessary in body .harmful results of heavy metal in human body cause some diseases for example , cancers , lack of nutritious , fatness , abortion , respiratory , cardiac disorders , damage to liver , kidneys and brain . on the other hand, the property of gathering the heavy metals in plants and their entrance to nutritious chain will cause , to be multiplied their resulted dangers[8]. Human will probably face more with their resulted dangers through the development of industry and increase in consumption of chemical materials in water , dust , air and environment which is contaminated . one of the most suitable ways for the removal of heavy metal is the exploitation of modern technical nano filtration . Membrane separation has been increasingly used recently for the treatment of inorganic effluent due to its convenient operation. There are different types of membrane filtration such as ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) Electrotreatments such as electrodialysis has also contributed to environmental protection. Photocatalytic process is an innovative and promising technique for efficient destruction of pollutants in water . nano filtration is a new membrane which we can observe it is property between reversible osmosis processes and Ultra filtration . and it can use in low pressure difference ,(10 times to 20 times).practical and protective costs of this process do not need to chemical materials because it will do in low pressure and higher recovery and thick , pressed productive infusions and also it is transportation and repellent costs will be less.

The significance points about nano filtration than to the other membrane is the selective ability in ion removal which is possible to separate single ions from double ions and omit positive large scale ions such as heavy metals in system[9]. There are a significant difference in the penetration of particles in the way which they are similar in molecule body but they have opposed ion loads that this property can separate heavy metals from the other same size particles. The research of Lee and Choo in south Korean university showed that the samples had been poured in 100 ml erlen that the experiment had been done on a 2 liter sample of waste water an it had been anticipated 100 minutes for every filtration and the measure of molecule body was 200 Dalton , pH is equal to 7 and zeta potential is equal to -21/6 and the percentage of removal for mercury , cadmium , silver through nano filtration process more than 50% and for Pb and Al was less than 50%[1] . Victor Pauper and Edit Csefslvay in Budapest , Hungary , in Technology Economics university surveyed the effect of copper removal from weaving waste water through nano filtration process in laboratorial scale and the experiments were measured 96% copper removal in 25 degree centigrade,

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entrance pressure with 30 Pascal , the level of membrane with 28 cm2 and pH equal to 11. [6]

II. Materials and Methods

A. Methods

The design of this project is intervention- experiential and is based on the experimental results which were done in the laboratory by some researchers and I. it is valid that all experiments in this research had been done in experimental pilot and were used synthetic sample instead of real waste water . The most obvious present metals in plating infusions were investigated such as nickel , copper and zinc because of many heavy metals , and saving in cost and time. Polyamide membrane was used in this experiment because this membrane has better efficiency among nano filter membranes in the removal of heavy metals . the parameters which for the removal of metals are measured contain pressure and density and other factors contain pH and fixed temperature .in following there is characteristic of shomal novin factory waste water which is sample from characteristic of plating factory waste water and also the membrane that used in experiments is as follow.

TABLE I
THE PROPERTY OF PLATING WASTE WATER IN SHOMAL NOVIN FACTORY

Q (m^3/s)	pH	TDS mg/lit	TSS mg/lit	COD mg/lit	Ni mg/lit	Cu mg/lit	Zn mg/lit	Cyanide mg/lit
5-14	1.7-10.7	3050-17500	40-3160	55-550	24-39	25-170	720-810	1.25-150

TABLE II
THE PROPERTY OF USED MEMBRANE IN EXPERIMENTS

Variation	Value	Removal efficiency		Energy consumption			
		Aluminum	Iron	Aluminum		Iron	
				kWh/m^3	kWh/kgF	kWh/m^3	kWh/kgF
Current density (volt)	5	59.6	22	0.29	97	0.32	293
	10	70	25	1.56	445	1.87	1493
	20	97.86	29.58	7.02	1435	8.27	5590
Electrode distances (mm)	20	97.86	29.58	7.02	1435	8.27	5590
	30	93	28	5.33	1147	4.8	3429
	40	86.96	25	4	920	4	3200
Number of electrodes	2	61.02	24	2.04	670	2.53	2111
	4	97.86	29.58	7.02	1435	8.27	5590
	6	99.35	34	11.29	2273	12.22	7190
pH	4	98.44	23.44	7.02	1427	8.27	7054
	7.5	97.86	29.58	7.02	1435	8.27	5590
	10	91.56	30.77	7.02	1534	8.27	5373
Initial concentration	1	89	43.09	4.89	5493	7.69	17844
	3	96.67	38	6	2069	8	7018
	5	98	30	7.02	1435	8.27	5590

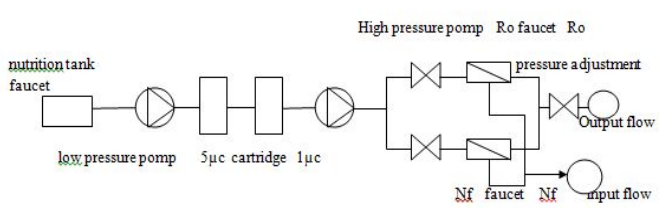

Fig 1 Schematic of used pilot in experiments

Pilot which is used in the experiments contains one tank with 60 liter capacity , two pumps with high and low pressure , two faucet for the regulation of pressure , two flow meter one for permit and the other for concentrate , two cartridge with 1 and 5 micron size, Ro and NF faucet and two shilling one for entrance flowing and the other for exit flowing to tank . the first stage of experiments conclude synthetic waste water which is mixture of distilled water, reactive color (almost 10 gram)with nickel salt, zinc and copper and the amount of 25 and 50ml density per liter have been investigated and we enter them in to the nutrition tank and increase the volume of tank solution. Then the solution in to the tank directed in to cartridge through low pressure pump . it had been used two cartridges with 5 microns and 1 micron . then solution will direct to nano filter membrane through high pressure pump . the experiments had been conducted in 3 intervals during one hour on a 4,6,8 Bar, pressure .it should be mentioned that closed RO faucet and opened NF during the experiments , when the pressure on the mentioned numbers of samples through plastic plates (80 cc) in permit shilling in to the tank were regulated and directed them for the analysis of system and abortion reading by atomic mechanism for the measurement , all Experiments

had been conducted in the 25 Celsius and one electrical hitter in order to avoid temperature changes which is equipped to thermostat and change the temperature to normal position automatically in order to decreases the temperature . if the temperature increases , the cool water directs in to the tank through copper pipe and decreases the temperature . during the experiments , pH is measured by pH meter for solution in to the tank and regulate by adding some drops of phosphorus acid.

III. Results and Discussion

When the number absorption of samples was read through the following formula, their removal percentage will be determined and it is results will be shown in the following table

The percentage of removal efficiency =

$$\frac{C_1 - C_2}{C_1} * 100$$

C_1 : input C_2 : output

C_p : metal concentration after treatment

Q_p : treated waste water flow

C_c concentrate waste water flow

C_f: metal concentration in input waste water

Q_f : input waste water flow to system

$Q_f = Q_c + Q_p$

$Q_f.C_f = Q_c.C_c + Q_p.C_p$

$$R = \frac{Cf - Cp}{Cf} * 100$$

TABLE III

HEAVY METALS REMOVAL EFFICIENCY IN CONCENTRATION 25 PPM

MWCO	Product Q	Membrane length	Diameter penetration	Membrane surface	Membrane form	Membrane material	The maker company	The kind of used membrane
2000 Da	9.1 m^3/hr	1016 mm	99 mm	7.6 m^2	spiral	Polyamide	USA Film Tec	NF_{90}

TABLE IV

HEAVY METALS REMOVAL EFFICIENCY IN CONCENTRATION 50 PPM

	Contact time	Sample No	Sample code	Absorption value			Removal percentage		
				Ni	Cu	Zn	Ni	Cu	Zn
pressure 4 bar	Hour 1	37L	1	0.32	0.04	0.50	98.7%	99.8 %	98%
	Hour 2	38L	2	0.23	N.D	0.25	99%	100 %	99%
	Hour 3	39L	3	0.23	N.D	0.2	99%	100 %	99.2%
pressure 6 bar	Hour 1	53L	4	0.2	N.D	0.20	99.2%	100 %	99.2%
	Hour 2	54L	5	0.19	N.D	0.21	99.1%	100 %	99.1%
	Hour 3	55L	6	0.19	N.D	0.19	99.1%	100 %	99.2%
pressure 8 bar	Hour 1	56L	7	0.18	N.D	0.16	99.1%	100 %	99.3%
	Hour 2	57L	8	0.11	N.D	0.25	99.5%	100 %	99%
	Hour 3	58L	9	0.11	N.D	0.23	99.5%	100 %	99%

3-1 the effect of pressure changes in the removal efficiency

As it observes the results of experiments in the table , the removal efficiency will be increased with the pressure increasing except in some samples which it is reason is that the more pressure to some extent , the more the amount of impressive flux . if the pressure of the solvent substance in synthetic waste water in aggregated membrane level increases , hydraulic resistance will be caused and the removal efficiency will be increased , in other words , density polarization increases and the efficiency will increase . of course , there is increase in low pressures but in high pressure , the result will be reversed because of extensive eclipse . this matter is not similar for 3 metals and is more effective for copper.

Notation : in following plot horizontal label is pressure variations and vertical label is removal percentage.

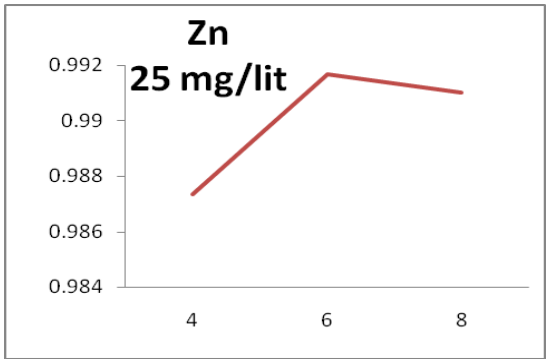

Fig- 1 removal percentage efficiency based on pressure variation in 25 mg/lit concentrate for zn

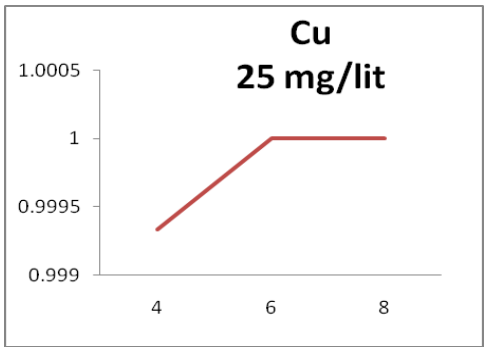

Fig-2removal percentage efficiency based on pressure variation in 25 mg/lit concentrate for cu

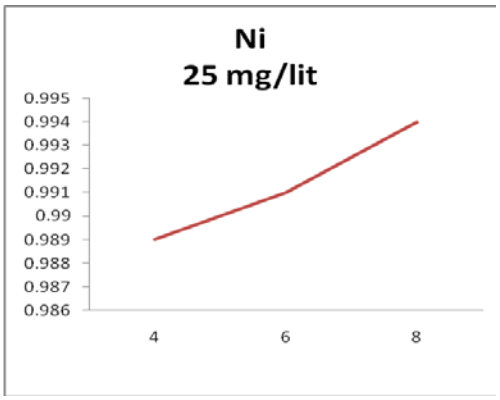

Fig-3 removal percentage efficiency based on pressure variation in 25 mg/lit concentrate for Ni

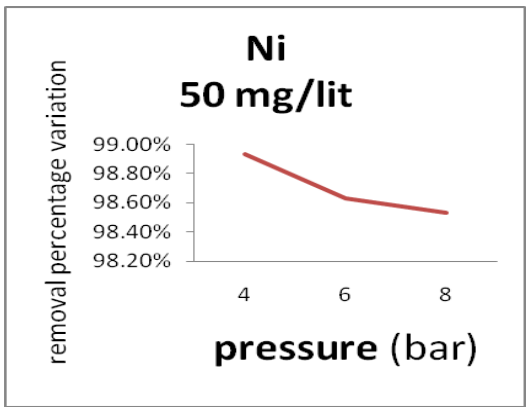

Fig-4 removal percentage efficiency based on pressure variation in 50 mg/lit concentrate for Ni

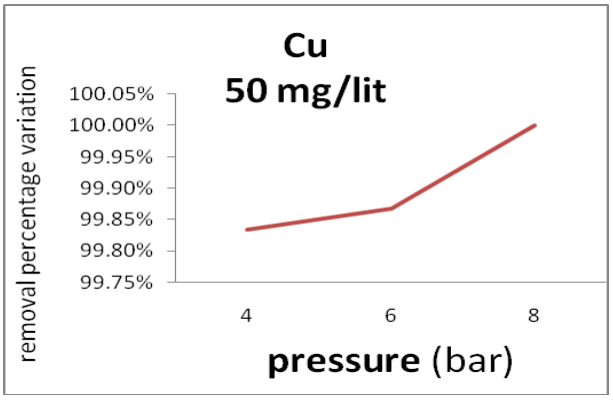

Fig-5 removal percentage efficiency based on pressure variation in 50 mg/lit concentrate for cu

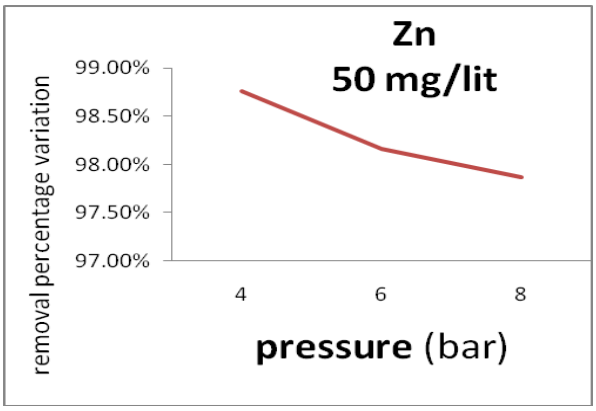

Fig-6 removal percentage efficiency based on pressure variation in 50 mg/lit concentrate for zn

3-2 The Effect of density factor in the removal of efficiency

The increase of density will cause that the results of removal efficiency decrease and when the density amount of ions increases , the aggregation ions will be increased in membrane level because of electro static repellent decrease and osmosis pressure . will be increased and as a result the efficiency removal of heavy metals in membrane will be decreased .

3-3 the comparison of removal efficiency and the reason of it is difference with regard to the kind of metals

According to the comparison of removal efficiency in heavy metals and with regard to the table of experimental results , it is observed that copper has the best and the most removal efficiency and zinc and nickel is the last one. The reason for this difference is that even though the solvent of metals depend on the amount of pH and all experiments had been conducted in natural pH , copper can be solved in high densities and because experiments in 25 and 50 ml g/lit densities had been done , copper had dissolution property in this area while nickel and zinc had dissolution property in less than 10mlg/lit density dissolution amount also had the direct relation ship with the amount of molecule germ and copper in natural pH generally had more sediment than nickel and zinc .copper is also more solution , it is more resistance but the amount of solvent in nickel and zinc is less and it causes they do not deionise and omit later. Some researchers also used some fixed factors ,the

same as I used in my experiment such as pH and temperature and there were different results which victor pauer and Edit csfslavy did this experiments in the temperature between 10 to 30 centigrade and variable pH between 2 to 11*[6]*.it is also necessary that the amount of in system for control of membrane function and prevention of eclipse and the decrease of membrane life were calculated. On the other hand , calculation of system efficiency in contact with removal of heavy metals was also evaluated which is called recovery. The way of calculation for amount of flux in concluded experiments equal**:**

$$\text{Flux} = \frac{Q\,p}{\text{membrane surface}} * 60 \frac{1}{m2.hr}$$

Q_p : treated waste water Q

The way of calculation for amount of Recovery in concluded experiments equal:

Q_p : Treated waste water Q

Q_f : input waste water Q to system

$$\text{Recovery \%} = \frac{Q\,p}{Qf}$$

IV. Suggestions

1. with regard to research results for nano filtrations membrane with high efficiency , removal of heavy metals and the it is operation in low pressures will be done so that we can use them in usage and the usage of this way in industrial scale as a choice for investigation by erecting and fast establish and simple exploitation will be recommended.
2. with regard to heavy metals in infusion in many industry , research and experiment for the removal of different industrial infusion (for example plating, iron melt , steel and etc)and it is comparison with each other , we can lead to the appropriate and optimum usage in this technology. The investigation of other ways for waste water filtration such as active black mud , nano filtration for real infusions because of the practical use of waste water directly in nano filtration system for the membrane impairment and use of SBR simultaneously which are almost inactive will be suggested to the other researchers.

Acknowledgment

The authors would like to thanks of Ahvaz Jundishapur University of Medical Sciences for their financial support.

Funding/Support

This study was supported by Ahvaz Jundishapur University of Medical Sciences.IRAN

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