Review Article
Published: 28 May, 2018

SF Journal of Environmental and Earth Science

An Evaluation of Technologies for Reduction of Wastewater from Plating Industry in Vietnam

Khac-Uan Do[1] and Jürg Walder[2]*

[1]School of Environmental Science and Technology, Hanoi University of Science and Technology, Vietnam

[2]Institute of Environmental Technology, University of Applied and Sciences Basel, Switzerland

Abstract

The plating enterprises have been arranged in every cities and provinces in Vietnam. Wastewater from plating industry containing high concentration of heavy metals has caused a serious issue for the receiving water bodies in Vietnam. This paper analyses and assessed the realized problems as well as the problems remaining in the measures for reduction and treatment of plating wastewater. Minimising chemical and wastewater could be achieved by using the way of drag-out for rack and barrel plating. Applying cascade rinsing could result in reduction of wastewater. Static rinse used in plating companies in Vietnam uses much large amounts of water than cascade rinsing. Drastic reductions in water consumption can be achieved with relatively low-cost measures. In effect, decreased water use corresponds to wastewater with lower volume and higher concentrations of chemicals. Treatment of wastewater would accordingly be more efficient and less costly. Besides the challenges and perspectives of wastewater treatment for cyanide, hexavalent chromium, other heavy metals, and sludge disposal in plating wastewater were also discussed. In conclusion, the reviewed solutions would be used as a guideline to reduce the wastewater from plating industry in Vietnam.

Keywords: Hazardous waste; Heavy metals; Plating industry; Technology; Treatment; Wastewater

Introduction

Metal plating is one of the most effective methods to protect metal from being corroded by influences from the environment. Plated metal has improved properties like high durability, high hardness, better electrical conductivity, more attractive surfaces etc, and therefore a higher value [1]. Metal plating methods have been widely used in many factories for producing e.g. electrical parts, medical implantations as well as components for construction and automotive industry [2]. It should be noted the Chromium (Cr), Nickel (Ni) and Zinc (Zn) plating technologies are common in Vietnam. Most of plating technologies were old, since 1970s or earlier in the last century [3]. The plating enterprises have been arranged in every cities and provinces in Vietnam, especially in big cities such as Hanoi, Ho Chi Minh city, Hai Phong, Nam Dinh, Dong Nai [4]. The scale of those plating enterprises is mainly small and medium sizes. There are about 57 plating plants in Hanoi in which there are 24 private plating enterprises [5, 6]. For example, in Minh Khai Lock Company (Hanoi, Vietnam), the employees are 120 people. The annual production capacity is about 1.500.000dm^2 plated products, and the turnover is 16 - 17 billion VND per year (approximately US$ 1.1 million) [5]. In Nam Dinh Galvanic Company (Nam Dinh province, Vietnam), there are about 220 employees, including engineers trained in Germany, Russian, Korea, and Vietnam. The annual production capacity is 6000 - 7000 tons of material, and the turnover is 40 - 50 billion VND per year (approximately US$ 3.5 million) [7]. There are many kinds of goods produced like locks, motor and bicycle accessories, zinc-plated steel wire fencing. It should be noted that in recent years, the industrial parks in Vietnam have developed rapidly since 1986 and there are 289 industrial parks throughout the country. Many plating enterprises have been operated in those industrial parks [8]. Until now there have been about 90% of the industrial parks which have WWTPs are operated or under constructed [9].

Wastewater from plating industry including high concentration of heavy metals has caused strong pollution and became a serious issue in Vietnam [10]. So far, there have been many projects focussed on the specific environmental problems in the plating company. They were classified into three main groups: (i) investigation of the environmental problems and build up the environmental management ISO 14001 for plating enterprises [6, 11]; (ii) improve the old waste water treatment

OPEN ACCESS

***Correspondence:**
Khac-Uan Do, School of Environmental Science and Technology, Hanoi University of Science and Technology, Vietnam.
***E-mail:** uan.dokhac@hust.edu.vn*
Received Date: 20 Apr 2018
Accepted Date: 22 May 2018
Published Date: 28 May 2018

Citation: *Khac-Uan Do, Walder J. An Evaluation of Technologies for Reduction of Wastewater from Plating Industry in Vietnam. SF J Environ Earth Sci. 2018; 1(2): 1018.*

ISSN 2643-8070

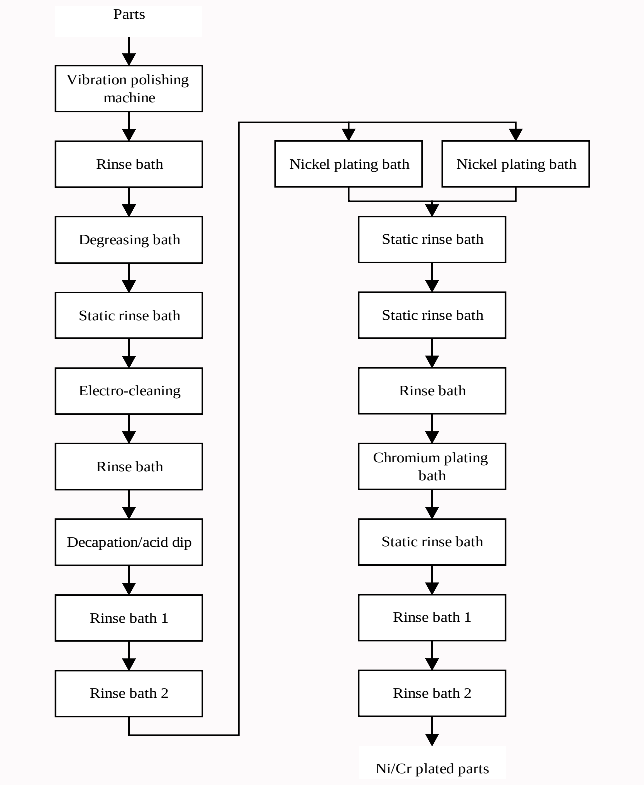

Figure 1: Flow diagram for a Nickel/Chromium electroplating process.

system in a plating company [12]; (ii) design of new wastewater treatment systems for plating enterprises, focused on treating Cr, Ni, Zn in plating wastewater [4,5,11]. It should be noted that most of the solutions were just for the local pollutions in a company. There is a few project that realize studying and assessment for technologies of reduction and treatment of plating wastewater in Vietnam.

Therefore the aim of this paper is to analyse and assess the realized problems as well as the problems that are still remaining in the measures for reduction and treatment of plating wastewater in order to provide the new approaches for appropriate technologies to reduce and treat plating wastewater. The overview of the best applicable technology in plating and plating wastewater treatment would be complied in a guideline for plating industry in Vietnam.

Overview of Technology and Environmental Issues in Plating Industry in Vietnam

Plating technology in Vietnam

Electroplating processes include the main stages: Cleaning, Pickling, Plating. Rinsing stage is always used after each process. The typical flow diagrams of Cr, Ni plating was shown in Figure 1 [3]. The surface must be cleaned of all foreign matter and that it must be chemically prepared for plating. The preparatory steps are dependent on the surface and on the plating bath. Furthermore, there are variations in the preparatory steps that are necessary to accommodate alloys, heat treatments, mechanical stresses in the metal, impurities, and contaminants worked into the surface. As a consequence there are many variations of a plating cycle. The plating cycle can be broadly defined in term of limitations imposed by the basis metal. The preparation of steel, for example, is greatly different than the preparation of aluminium. The typical solutions for degreasing, pickling and sulphate zinc plating are shown in Tables 1, 2 and 3.

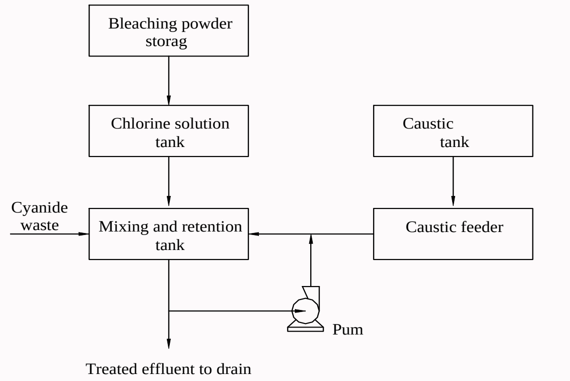

Figure 2: Treatment of cyanide wastes.

Environmental problems from plating industry in Vietnam

Solvents, acids and alkaline solutions used in pre-treatment processes often ends up in the air, in wastewater or as hazardous waste. These chemicals are causing serious environmental impacts when not handled properly. Wastewater generated from pre-treatment is primarily contaminated wastewater from rinsing baths and process cleanup water. The type of contamination depends on the origin. Most strip baths (pickling) from stripping and cleaning of metals are acidic in nature and consist of solutions of sulphuric, nitric and hydrochloric acid. Alkaline wastewater from alkaline cleaners and rinsing water usually contains soaps, oils and suspended solids. Alkaline cleaners consist of sodium hydroxide, phosphates, silicates, carbonates, some organic emulsifiers and synthetic wetting agents. Characteristics of wastewater of typical plating plants in Vietnam were presented in Table 4 [4]. Wastes typically generated during electroplating are associated with the metal-bearing solutions. The most commonly electroplated metals and alloys include: brass (copper-zinc), chromium, and zinc. The character and strength of electroplating wastes vary considerably depending on plating requirements, types of rinsing and the number of pre-treatment operations located in the plant. Electroplating operations produce air emissions and aerosols. Aerosols arising from electroplating fluids and process gases can be a source of air emissions, which may contain metals or other substances present in the baths. Aerosols and vapours may lead to a bad working environment in the production area [13,14]. Wastewater from the electroplating process is primarily rinsing water and the contamination consists of metal ions and in some cases cyanide depending on the composition of the process bath. Wastewater is normally treated on-site by conventional hydroxide precipitation. Wastewater containing hexavalent chromium must be pre-treated to reduce the hexavalent chromium to its trivalent stage. Wastewater containing cyanide must be oxidized separately. The wastewater treatment results in sludge. The content of heavy metal in the wastewater has thereby been reduced and instead transferred to a concentrated sludge phase of metal hydroxides. The produced sludge phase must be deposited. Cyanide, mainly in the form of sodium or potassium cyanide, is usually used as a complexing agent for cadmium and precious metals plating and for other solutions as copper and zinc baths. Cyanide salts are desirable since they are good oxide solvents, and in zinc plating they yield a brighter, less porous electroplating. Cyanide is very toxic to fish and other aquatic life, as well as humans [15]. Even low concentrations in wastes are extremely dangerous and are to be avoided. Other wastes generated from electroplating include spent solutions which become contaminated during use, and therefore, diminish performance of the processes.

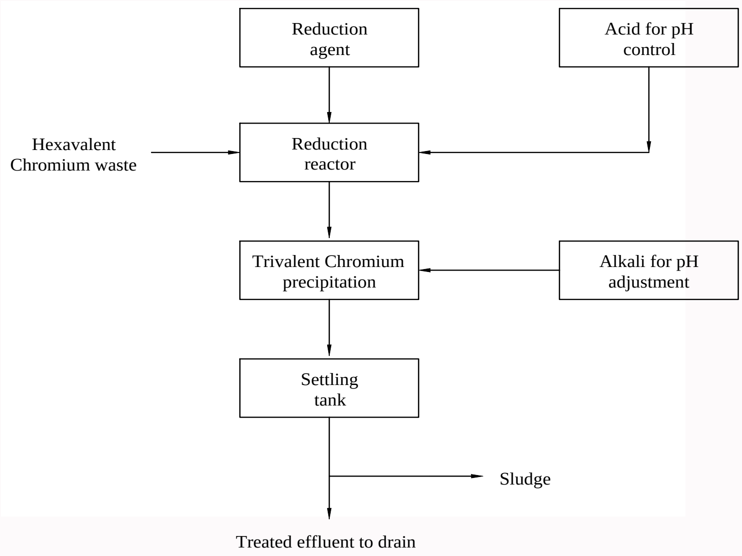

Figure 3: Treatment of hexavalent chromium wastes.

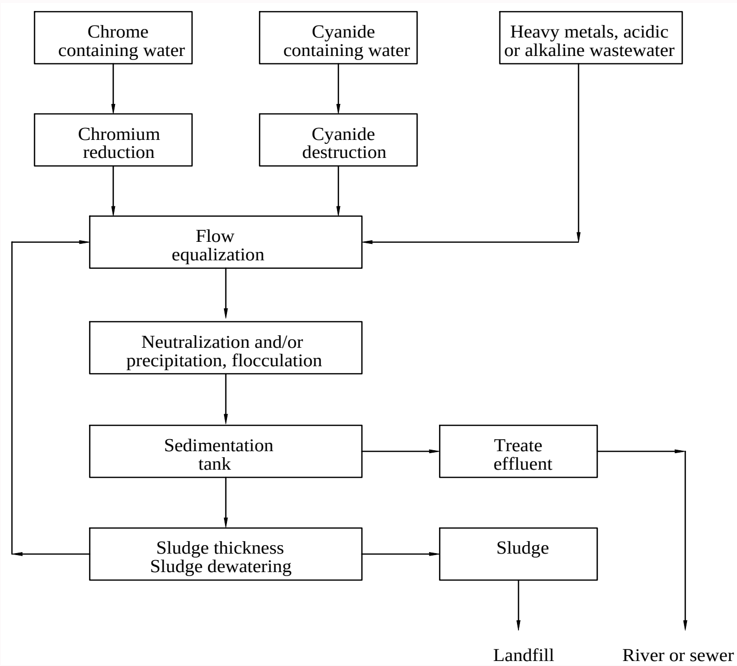

Figure 4: Treatment of electroplating wastewater.

Spent solutions may be discharged periodically.

The two major sources of wastewater in the electroplating operations come from batch solutions and rinse water. They are distinctly different in volume and characteristics. Batch solutions from vats are highly concentrated and are discharged intermittently. Rinse waters, made up of preliminary and final rinses, are more diluted but form the bulk of the wastewater of the plating shops. However, the preliminary rinses being more concentrated than the final rinses are often blend together with batch solutions for treatment before discharge to the sewer. The final rinses are treated for reuse in some plating shops. The volume and characteristics of various wastewater streams vary considerably from one plating plant to another and within the same plant from day to day. Generally, the drains inside the plants are interconnected mainly due to facility layout of the plant and partly to ignorance of the consequences. The ranges of concentration of metals in wastewater are on Table 5 [6]. The electroplating wastes may be acidic or alkaline depending on the type of baths used. They may be highly acidic with a pH of 1 or highly alkaline with pH of 12. Total dissolved solids from 131 mg/l to 19500 mg/l and total suspended solids range from 1mg/l to 3160mg/l [7].

Assessment of Reduction Technologies of Wastewater for Plating Industry in Vietnam

Minimising chemical and wastewater

There are numerous reasons why the company will benefit from minimising its chemical and water use, including (i) Chemical waste levels in the industry are often high. Typically 10 - 20% of the materials from a zinc plating electrode end up as waste. Equivalent

Table 1: Typical components of degreasing solution [3].

Components of degreasing solution, g/l	Solutions			
	1	2	3	4
NaOH	5 - 15	20 - 50	8 - 12	-
$Na_3PO_4.12H_2O$	15 - 35	5 - 15	20 - 50	15 - 35
Na_2CO_3	15 - 35	-	-	15 - 35
Surface active substances	3 - 5	3 - 5	-	3 - 5
Na_2SiO_3	-	10 - 30	10 - 30	-
Temperature, ^0C	60 - 80	50 - 70	40 - 70	60 - 80
Degreasing time, minute	3 - 20	2 - 5	3 - 10	5 - 20

Table 2: Typical components of pickling solution [3].

Components of pickling solution, g/l	Solutions		
	1	2	3
H_2SO_4	50 - 70	-	-
HCl	-	100 - 150	-
H_3PO_4	-	-	120 - 160
Temperature, ^0C	40 - 60	40 - 60	60 - 70
Pickling time, minute	10 - 20	10 - 15	5 - 10

figures from a bright nickel electrolyte and from a chromium electrolyte are 25 - 30% and 70% respectively. Such levels of waste mean that you are spending more on chemicals than you should be. You can make substantial savings by reducing your chemical use [16]; (ii) Waste disposal costs are rising at rates faster than the rate of inflation. Landfill charges for sludge disposal alone are as much as £83/tonne, while current waste disposal policy and pressures on land suggest that charges will rise in the future. You can reduce your waste disposal charges by minimising the quantities of waste produced [17]; (iii) Water costs are rising faster than the rate of inflation, yet it is relatively easy to save water. You can reduce your water costs by up to 40% by implementing simple, no-cost or low-cost measures. In other words, you can achieve striking results without excessive capital outlay. Even more substantial reductions are possible in the medium and longer term [18]; and (iv) Companies are required to reduce their environmental impact and comply with increasingly stringent legislative requirements. Taking action now could make compliance easier both now and in the future [19].

Many plating companies can make substantial cost savings by minimising their consumption of chemicals and water, and improving their end-of-pipe treatment facilities. Chemical and water consumption within the industry varies widely, and there are many instances of waste. Water supply and effluent disposal costs are rising and there is growing pressure on companies to reduce costs and improve both profitability and environmental performance. A waste minimisation programme is a good way of achieving these objectives. The first step in any waste minimisation programme is to assess what is currently happening on site. The Guide outlines a simple mass balance technique that allows companies to understand the material flows within their processes, determine where wastage is currently taking place, and identify opportunities for waste minimisation [20]. Drag-out is one of the most significant causes of chemical loss from plating and other treatment baths. Yet these losses can be reduced by up to 40% using simple procedures that involve little or no expenditure. Other techniques for reducing chemical waste include better purchasing and stock control, improved measurement and control of operating conditions, and improvements in the life of process bath chemicals. Water savings of 15 - 20% [17] can be achieved for zero cost, simply by good housekeeping. Limited investment can increase these savings to 30% [17]. Examples of no-cost and low-cost measures include installing flow controllers and providing better control of hose use. More capital-intensive measures include counter current, spray and fog rinsing. Where effluent treatment is required, the options range from standard precipitation techniques to more sophisticated approaches such as ion exchange, electrochemical recovery, evaporation, reverse osmosis and ultra filtration. In many cases, these techniques not only recover chemicals and metals, they also produce clean water for recycling within the process. The Guide emphasises the need for companies to adopt a systematic approach. In other words, they should consider minimisation throughout the site rather than focusing only on end-of-pipe solutions. Immediate action could be beneficial now and in the longer term [21].

Determination of the drag-out

The consumption of chemicals in processes of surface treatment is mainly caused by the drag-out of bath solution. Knowing the amount of the drag-out helps to maintain the process stable and is necessary for minimizing waste water and dosage of additives. Mostly, the values of the drag-out only are estimated. Sometimes they are unknown. However, it is very easy to find out how much bath solution is dragged out. During the surface treatment with process solutions, a film of the bath solution remains on the parts and on the rack/barrel. The bath solution also remains in cavities and gaps, and is transported into the next baths. Due to this transport, the chemicals of the process get lost. The consumption of additives related to the drag out can be higher than the consumption related to the chemical reaction on the part surface. For instance, the consumption of blue passivation is caused to 90% [22] by drag-out.

In electroplating processes, especially if high layer thicknesses are deposited, the amount of drag-out is minor to the amount being consumed by electrochemical reaction. Yet, conductivity salts and inert additives are consumed nearly exclusively by drag-out. The amount of drag-out depends on several factors (geometry of the parts and racks, drain times, temperature of the bath solutions, special devices of the plating line) and can differ strongly from one line to another. General values of the drag-out are 20 - 200 ml/m^2 for rack application and 100-400 ml/m^2 for barrel application [22]. But for calculations of the consumption or for instructions of additive dosage these values are indeed too inexact.

To measure the amount of drag-out in a processing line, a bath is needed containing ingredients easy to analyse at a high concentration. A hydrochloric pickling or a chromium bath for example is very well suited, since in the following rinse it is easy to analyse the dragged in HCl or chromium. The following steps have to be done [23,24,25] as (i) Clean the rinsing bath after the chosen active bath, fill it with fresh water and disconnect it from any circuits; (ii) Determine the exact volume of the rinse by measuring width, length, and level; (iii) Mix the bath and its rinse well and take a 100ml sample of each; (iv) Run 10-50 racks or barrels through the line, using different parts for representative statistics; and (v) Take samples (100ml) of the rinse regularly and analyse them.

If the concentration of the chosen active bath (e.g. pickling, chromium bath) is high enough, it can be considered to have a constant concentration for easier calculation.

Table 3: Solutions for sulphate zinc plating [3].

Components, g/l	Solutions						
	1	2	3	4	5	6	7
$ZnSO_4.7H_2O$	200 - 300	430 - 500	240 - 360	200 - 220	-	575 - 718	200 - 215
ZnO	-	-	-	-	17.5	-	-
$Al_2(SO)_3.18H_2O$	30	30	30	-	-	30	40 - 50
$Na_2SO_4.10H_2O$	50 - 100	-	-	70 - 80	-	-	40 - 50
pH	3.5 - 4.5	3.5 - 4.5	4.2	3.5 - 4.5	1.9 - 3.5	3.5 - 4.5	3.0 - 4.4
Tem. ^0C	25	40	25	25	25	40 - 50	25
Application	Barrel lating	Wire plating	Rack and barrel plating	Barrel plating	Rack and barrel plating	Wire plating	Barrel plating

Table 4: Characteristics of wastewater of typical plating plants in Vietnam [5,13].

No	Name of plating companies	Dischargem^3/day	pH	Temp. (^0C)	Ni (mg/l)	Cr (mg/l)	CN^- (mg/l)	COD (mg/l)	Zn^{2+} (mg/l)	Fe (mg/l)
1	Thang Long Goshi Accessories Company	100	5.0 - 7.5	25 - 26	0.02 - 0.23	100 - 500	< 0.1	320-384	-	-
2	Minh Khai Lock Company	70	6.3 - 7.5	21 - 23	1.2	0.08	-	42	2.5	1.47
3	Viet Tiep Lock Company	70 - 80	4.0	20 - 22	50.2	6.0	0.16	50	-	-
4	Thong Nhat Electromechanics Company	55 - 60	5.8	24	0.62	0.109	-	28.5	-	-
5	Thang Long Metal Company	40	10.8	24	16.00	8.8	0.039	112	-	-
6	Dong Da Motorbike-Bicycle Company	70	8.2	25	1.31	1.4	0.03	4.8	-	-
7	Giai Phong Mechanical Company	50	7.7	24	-	-	-	32.5	-	-
8	Trinh Van Dat's plating enterprise	3-5	4-7	21-27	0.01-20.1	0.2-5.7	-	170	14	-
9	Industrial Mechanical Co-operative 8 March	4-5	3-11	22-27	0.2-16.7	0.02-12.7	-	154	16	-
10	Toan Thang's plating enterprise	1-4	5-12	24-28	-	-	-	187	20.5	-
11	Hoa Binh's plating enterprise	2-4	5-10	21-23	5-1706	-	-	150	18.6	-
12	Quang Tien's plating enterprise	3-4	6-11	21-23	0.01-12.5	0.6-11.2	-	-	-	-
13	Le Xuan Tien's plating enterprise	4-5	2,6-12	23	1-22.3	0.43-16.7	-	300	-	-

Knowing the concentrations of the rinse after different number of racks/barrels, the exact volume of the rinse and the concentrations of rinse and active bath at the beginning, the drag-out can be calculated as follows:

$$V_{d,n} = \frac{C_{r,n} - C_{r,o}}{C_b} . V_r \quad [22]$$

where: $V_{d,n}$ = volume, which is dragged out at rack number n,

$C_{r,n}$ = concentration of the rinse after n racks,

$C_{r,0}$ = concentration of the rinse at the beginning,

C_b = concentration of the bath at the beginning (considered as constant),

V_r = exact volume of the rinse.

Dividing the dragged out volume by the number of racks (n), which have been run through the line, yields in the average volume being dragged out by each rack. If all analysed concentrations are calculated, the average drag-out of this special line can be found out.

The amount of the drag-out is often unknown or merely estimated. However, sometimes it is responsible for 90 % of the chemical consumption, and it can influence the quality of the plated parts extremely. The reference value for draining time is 20 seconds (withdrawal and drain) as described in Table 6. The Reference value for draining time is 24 seconds with 3 rotation periods of 8 seconds on the Table 7 [26].

Reduction of wastewater by rinsing solutions

Close packed parts, as in barrel plating, take some time to rinse. Experiments with barrel rinsing have readily shown what goes on. If a barrel is allowed to rotate in a running rinse while conductivity readings are taken, it will be seen that conductivity will increase for some time. During a typical study this time was two minutes, revealing the time necessary to rinse flow can be halted. This assures proper rinsing in the minimum amount of time [27]. Also, it was found with this approach that rinse flow rates could be increased to shorten the rinsing time. With automatic control a combined process step is possible that consists of a holding rinse. The controlled rinse will allow water to flow until the equilibrium concentration is established and then shut off the water to maintain this concentration. Following cleaning, some steels can be held in the inactive alkaline rinse to protect the metal until further processing is required. After pickling, metals may be held in an acid rinse to maintain an active surface and to avoid rusting and so that adherent plating will be attained [28].

It is believed that troubles can develop from rinse water that is too clean. Rinse waters usually consist of calcium bicarbonate plus contaminants. The calcium bicarbonate can act as a neutraliser both for acids and alkalis and the rinse can become alternately acid and alkaline if it is allowed to run to sufficient dilution. It is possible that metals can lose activity under such conditions or, conversely, that the metals may corrode [29]. Multiple stage rinsing is particularly suitable to achieve a high rinsing rate with a small amount of rinsing water. The main effect of saving is reached with the transition from the first into the second stage. A smaller rinsing quantity of water can be achieved by selection of the correct rinsing system. The effect of water saving decreases with an increasing number of rinsing stages [30]. However, the volume of water required decreases to the point where direct make up for water losses from process solutions at ambient temperatures can be considered. The achievable recovery rate is, at a given volume of evaporation, directly related to the concentration of process chemicals in the first rinse station.

Rinsing criterion: $R_i = \frac{c_{i-1}}{c_i}$, [14] c_i: concentration in bath i

Rinsing criterion overall: $R_{overall} = \frac{c_0}{c_n}$, $R_{overall} = R_1 * R_2 * R_3 ... R_n$ [14]

c_0: concentration in process bath, c_i: concentration in last bath

Empirically estimated rinsing criterions for different purposes: (i) after pre-and after-treatment of surfaces: 500 – 1500; (ii) after deposition of metal (without chromium): 2000 – 5000; (iii) after deposition of chromium: 30000 – 50000.

For a one-step rinsing process: $R_i = \frac{Q_i + V_i}{V_i}$ [14]

Q_i: fresh water volume, V_i: drag-out volume of process bath for a rinsing cascade:

$Q = V * (\sqrt[n]{R_{overall}} - 1)$, [14]

Q: fresh water volume, V: drag-out volume of process bath

Specific fresh water consumption of rinsing cascades for different rinsing criterion (fresh water demand in l/hour per drag-out of a process bath) shows on the Table 8.

The zero-discharge (closed-loop or squared) water balance is often seen as the ultimate criterion of the rinsing technology for a surface process low in emissions. This is where the water returned to the process solution from the first rinse station equals the water lost in evaporation and drag-out. Process solutions operated at higher temperatures and with multistage rinsing offer possibilities for this. By the introduction of multi-stage rinsing systems partly combined with rinsing water recycling system, decreases of wastewater of up to 90% can be obtained [29]. Generally the installations of multi-stage rinsing techniques is associated with higher space requirement and higher investments (costs for additional tanks, workpiece transport equipment and control). The decrease of water consumption, recovery of process chemicals and the smaller effluent discharge, which requires a smaller wastewater processing facility and less treatment chemicals, reduces the total costs.

Challenges and perspectives of plating wastewater in Vietnam

There is a variety of methods available for the treatment of the electroplating wastes, but two widely used systems employed by the plating workshops are batch and continuous treatment. Batch treatment system is mainly practised in the small electroplating workshops. In the batch treatment system, all wastes are collected in a tank, usually for on shift, and then treated as a single batch. The continuous treatment system, on the other hand, monitors the volume of incoming wastewater and adjusted the chemicals to the wastewater as it passed through the system. Membrane technologies could be combined with the current wastewater treatment plants to enhance their treatment efficiencies [30-32].

Cyanide treatment

The method commonly used by electroplating workshops for cyanide waste treatment is cyanide destruction by chlorination under alkaline condition, or referred to as alkaline chlorination. Destruction of the cyanide by alkaline chlorination method may be accomplished by direct addition of gases chlorine or chlorine dioxide in the presence of caustic soda, sodium hypochlorite or bleaching powder. When chlorine is added to the wastewater containing free cyanide and sufficient alkali is added to raise the pH to 10 or higher, free cyanide is oxidized to cyanate with cyanogen chloride as an intermediate product. This reaction is normally instantaneous or takes less than 10 minutes [2]. With excess chlorine, cyanate could be further oxidized slowly to carbon dioxide and nitrogen. This second stage of reaction takes 30 minutes to an hour. The overall reaction with excess chlorine in the presence of NaOH for complete conversion of cyanide to carbon dioxide and nitrogen gas is as follows:

$$NaCN + 5\,Cl_2 + 12\,NaOH \rightarrow 10\,NaCl + 2\,Na_2CO_3 + N_2 + 6\,H_2O$$

Theoretically, 2.75 parts of chlorine and 3.08 parts of alkali (NaOH) are required to oxidize each part of cyanate. Additional 4.09 parts of chlorine and 3.08 parts of alkali for each part of cyanide are required to convert cyanate into carbon dioxide and nitrogen gas. However, chlorine requirement in practice for the complete destruction of cyanide higher than 6.82 parts [16]. Figure 2 shows the schematic flow diagram of cyanide waste treatment in the electroplating workshops:

Table 5: Typical substances in plating wastewater [15].

No	Substances	Concentration, mg/l
1	Cyanide	1.0 - 150
2	Chromium (VI)	0.25 - 2600
3	Nickel	0.07 - 125
4	Zinc	0.12 - 140
5	Iron	0.17 - 300

Table 6: Withdrawal and dwell times for jig/rack [27].

Process	Minimum time withdrawal (seconds)	Minimum time dwell (seconds)
Plating	10	10
Cleaning/ pickling	8	7
Passivation	10	10
Seals/lacquers	10	5

Chromium treatment

The most effective and economical way of chromium treatment is to reduce hexavalent chromium, Cr^{+6} to trivalent state, Cr^{+3} in an acidic condition, and subsequent precipitation with an alkali. Ferrous sulphate along with sulphuric acid is commonly used for this purpose. Other reducing agents used are sulphur dioxide and sodium bisulphite. Maximum reduction occurs in the pH range of 2.0 to 2.5. The reduction takes about an hour. The reduced trivalent chromium is precipitated by the addition of an alkali, such as lime or caustic soda. Lime is commonly used, since it is cheaper than caustic soda. The step-wise reaction for precipitation by hexavalent chromium with ferrous sulphate and lime are [33]:

$$H_2Cr_2O_7 + 6FeSO_4 + 6H_2SO_4\ Cr_2(SO_4)_3 + 3Fe_2(SO_4)_3 + 7H_2O$$

$$Cr_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Cr(OH)_3 + 3CaSO_4$$

$$Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow CaSO_4 + 2Fe_2(OH)_3$$

Theoretically, 16.03 parts of copperas ($FeSO_4.7H_2O$), 6.01 parts of sulphuric acid and 9.48 parts of lime are required for the complete

Table 7: Withdrawal and dwell times for barrels [27].

Process	Minimum time (seconds)		
	Withdrawal	Dwell	Stationary periods (*)
Plating	5	24	3 x 8
Cleaning/pickling	5	24	3 x 8
Passivation	5	16	3 x 8
Seals	5	24	3 x 8

(*) barrel is rotated two or three time through 900 with an 8 seconds dwell period.

Table 8: Specific fresh water consumption of rinsing cascades for different rinsing criterion.

Steps	Rinsing criterion, R							
	25000	20000	15000	10000	5000	2000	1000	500
1 step	24999	19999	14999	9999	4999	1999	999	499
2 steps	157	140	122	99	70	44	31	21
3 steps	28	26	24	21	16	12	9.0	6.9
4 steps	12	11	10	9	7.4	5.7	4.6	3.7
5steps	6.6	6.2	5.8	5.3	4.5	3.6	3.0	2.6

removal of part of chromium. Figure 3 shows the schematic flow diagram of chromium waste treatment.

Treatment of other metal bearing wastes

The most commonly used method of treatment for nickel and zinc wastewater is by chemical precipitation. Almost all the metals precipitate completely in the pH range of 9.5 to 10.5 [33]. Lime is commonly used as a coagulant for the removal of the heavy metals. Figure 4 shows the typical treatment processes of electroplating wastewater.

Sludge disposal

Sludge generated from the treatment processes contains 1% to 3% dry solids [34]. Dewatering of sludge is required to reduce transportation and disposal costs. Centrifugation and vacuum filtration have been used for sludge dewatering. The dry solid concentration by using these two facilities ranges from 15% to 25% [35]. Filter press and belt press are two most effective mechanisms for sludge dewatering. The filter cake produced from these two methods contains 25% to 35% of dry solids. As the dewater sludge contains high concentration of heavy metals, the residue may be regarded as hazardous waste. Many countries are now required to use special landfills for disposal of potentially harmful sludge [36]. Secure landfills are sited and designed to preclude the risk that toxic chemicals will leach into surrounding environment and groundwater. The sludge generated from electroplating workshops may have to be stabilized by chemical fixation or cementation to avoid leaching of heavy metals prior to the ultimate disposal in secure landfills.

Conclusions

Vietnam is facing the challenge of trying to keep pace with increasing environmental pollution associated with rapid urbanization and industrilization. The plating enterprises have been arranged in every cities and provinces in Vietnam. Chromium (Cr), Nickel (Ni) and Zinc (Zn) plating technologies are common in Vietnam. Most of plating technologies were old, since 1970s or earlier in the last century. Wastewater from plating industry containing high concentration of heavy metals has caused a serious issue for the receiving water bodies in Vietnam. To achieve the goals about reduction and treatment of plating wastewater in Vietnam, several solutions could be used (i) minimising chemical and wastewater could be achieved by using the way of drag-out for rack and barrel plating; (ii) applying cascade rinsing could result in reduction of wastewater. Static rinse used in plating companies in Vietnam uses much large amounts of water than cascade rinsing. Drastic reductions in water consumption can be achieved with relatively low-cost measures; and (iii) the challenges and perspectives of wastewater treatment for cyanide, hexavalent chromium, other heavy metals, and sludge disposal in plating wastewater should be taken into accounts when applied the solutions for reduction of wastewater from plating industry in Vietnam.

Acknowledgements

This research was done at the Institute of Environmental Technology (IFU) in the University of Applied and Sciences Basel (FHBB, now renamed as FHNW, Switzerland). The funding of United Nations Industrial Development Organization (UNIDO) and Swiss Agency for Development and Cooperation (SDC) and the support of Hanoi University of Science and Technology (HUST, Vietnam) were high acknowledged.

References

1. Hoang Tran Minh. Electroplating, Science & Technnology Publishing House, Hanoi. 2001; pp. 33-36.
2. JB Mohler. Electroplating and related processes, Chemical Publishing Co., Inc. New York. 1969; pp. 211-212.
3. Hoang Tran Minh. Handbook of electroplating, Science & Technnology Publishing House, Hanoi. 2002; pp. 102-104.
4. Manh Vu Van. Study of Cr and Ni treatment in plating waste water. Choosing of the appropriate processes to be applied in a plating company. Hanoi University of Technology. 1997; pp. 24-25.
5. Loc Nguyen Van. Electroplating technology, Education Publishing House, Hanoi. 2001; pp. 12-18.
6. Duong Do Kim. Investigation of plating and environmental problems in Hanoi. Promotion of solutions for those problems. Hanoi University of Technology. 2002; pp. 62-63.
7. Thang Tran Van. Model and optimization of Chromium VI reduction process in industrial plating wastewater treatment, Hanoi University of Technology. 2003; pp. 25-26.
8. Thuy PT, PT Tuan and NM Khai. Industrial Water Mass Balance Analysis. International Journal of Environmental Science and Development. 2016; 7: p. 216-220.
9. Pham TT, et al. Industrial water mass balance as a tool for water management in industrial parks. Water Resources and Industry. 2016; 13: p. 14-21.
10. Do KU, Dang KC, Robert K. Research solution for changing the hot dip galvalizing wastewater characteristics based on the principle of envirinmental technology assessment. J. Sci. Tech. 2006; 55: 121-125.
11. Duc Hoang Minh. Build up the model of the environmental management ISO 14001 for plating enterprises. Hanoi University of Technology. 2004; pp. 18-21.
12. Cham Mac Bich. Study to improve the old waste water treatment system in a plating company, Hanoi University of Technology. 2003; pp. 28-32.
13. Thao Mac Cam. Design of waste water treatment systems for plating enterprises with different outputs, Minh Khai Lock Company, Hanoi. 1998; pp. 21-22.
14. Ludwig Hartiger. Handbook of effluent treatment and recycling for the metal finishing industry, Finishing Publications LTD, Stevenage - United Kingdom, 1994, (2nd Edition). pp. 206-209.

15. Krishna B Misra. Cleaner Production - Environmental and Economic Perspectives, Springer - Verlag Berlin Heidelberg 1996. Printed in Germany. pp. 14-15.

16. Kenneth F. Cherry. Plating Waste treatment, Ann Arbor Science Publishers Inc, United States of America. 1982; pp. 114-116.

17. David Hemsley. Minimising chemical and water waste in the metal finishing industry, National Environmental Technology Center, United Kingdom. 1999; pp. 125-126.

18. Charles L McEntyre. Wastewater and waste reduction, EPA Pollution Prevention/Waste Minimization Conference Atlanta December, 13 - 15, 1994; pp. 61-62.

19. Amulya Kumar N Reddy. Technology, development and the environment: a re-appraisal, United Nations Environment Programme, Printing and Packaging Corporation Limited, Nairobi Kenya. 1979; pp. 21-22.

20. Department of Environment - Waste Technical Division, Licensing of metal recycling Sites, London. 1995; pp. 21-23.

21. Farrokh Najmabadi, Sanjaya Lall. Development Industrial technology - Lessons for Policy and Practice, The World Bank Washington D.C. 1995; pp. 5-8.

22. Surtec Technical Letter. Determination of the drag - out, Surtec GmbH, Zwingenberg, Germany. 2003; pp. 24-26.

23. National Pollutant Inventory. Emission Estimation technique Manual for Electroplating, Commonwealth of Australia - Environment Australia, Canberra. 2001; pp. 31-33.

24. Michael Haischild, Henrik Wenzel. Environmental Assessment for Products, Published by Chapman & Hall, London, United Kingdom. 1998; pp. 45-47.

25. Katherine Bajusz and Felix Schuppisser. A clean line - Technology Transfer in wire production, IFU- FHBB Institute of Environmental Technology. 2001; pp. 81-82.

26. European Commission. Institute for Prospective Technological Studies, Reference Document on Best Available Techniques for surface Treatment of Metals and Plastics, Draft. 2004; pp. 23-29.

27. European Committee for Surface Treatment - Integrated Pollution Prevention and Control (IPPC), Surface Treatment of metals and plastic materials using electrolytic or chemical process. 2002; pp. 16-17.

28. Johannes Fresner and Thomas Dielacher. Towards Zero Emission in Galvanizing, University of Technology and Joanneum Research, Graz Austria. 2003; pp. 25-28.

29. US Environmental Protection Agency. Emission Factor of Electroplating. 1996; pp. 121-122.

30. Do KU, Dang KC. An assessment of potential application of membrance technology in municipal wastewater treatment in Vietnam. Vietnam Urban Env. 2008; 7: 39-42.

31. Tran HT, Chu XQ, Do KU. The MBR technology for treatment of oily contaminated wastewater: Application feasibility in Vietnam. Vietnam Science & Technology Review. 2015; 2: 52-58.

32. Duong CH, Nguyen CN, Do KU, Le TS. Membrane processes and their potential applications for fresh water provision in Vietnam. Vietnam J. Chem. 2017; 55: 533-544.

33. Christopher Forster. Wastewater treatment and Technology, Published by Thomas Telford Publishing, London. 2003; pp. 215-220.

34. Do KU, Dang KC, Jurg W, Maurice J. Reduction of wastewater from hot dip galvalizing industry based on the principle of environmental technology assessment. Vietnam J. Chem. 2008; 46: 355-361.

35. Do KU, Mai AK, Jurg W. An approach of cleaner production concepts for minimization of sludge from wastewater treatment systems. J. Sci. Tech. 2011; 4: 96-103.

36. KU Do, BD Bui. A novel approach of cleaner production concepts to evaluate promising technologies for sludge reduction in wastewater treatment plants. SF Journal of Environmental and Earth Science. 2018; 1: 1-9.