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Profitability of in-plant modifications in pollution control

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Abstract

This case study was developed in view of setting up a demonstration project on "revealing the profitability of clean technology in small-scale electroplating unit". The research was conducted in a small-scale electroplating shop located in Bangkok. A set of simple in-plant control measures such as dragout recovery, spray rinsing technique and rinse water agitation were implemented. Quantitative data, obtained from the monitoring of wastewater before and after process modifications, have indicated a substantial reduction both in quantity and strength of wastewater generated. Water consumption was reduced by approx. 35% of total rinsing water, which is 19% of total process water consumption. Average metal concentrations in wastewater was reduced 73% for Cr-, 71% for Ni- and 54% for Cu-plating rinse water.

Keywords: Small-scale electroplating unit; In-plant modification

1. Introduction

Electroplating processes create a considerable amount of extremely toxic wastewater containing heavy metals which require treatment. The most important toxic contaminants found in plating wastes are acids, cyanides and heavy metals such as chromium, zinc, copper, nickel and tin. Alkaline cleaning agents, grease and oil are also found in these wastes [1].

Until very recently, the small- and medium-scale electroplating industries have been the focus of increasing concern owing to their very significant contribution to the deterioration of the environment. Among their identified problems include unaffordable capital and operating costs for pollution control facilities, lack of trained personnel to properly operate the system, and lack of sufficient space for such facilities.

With the advent, however, of shifting emphasis from end-of-pipe treatment to cleaner production technologies, prospects for factory owners to substantially reduce their

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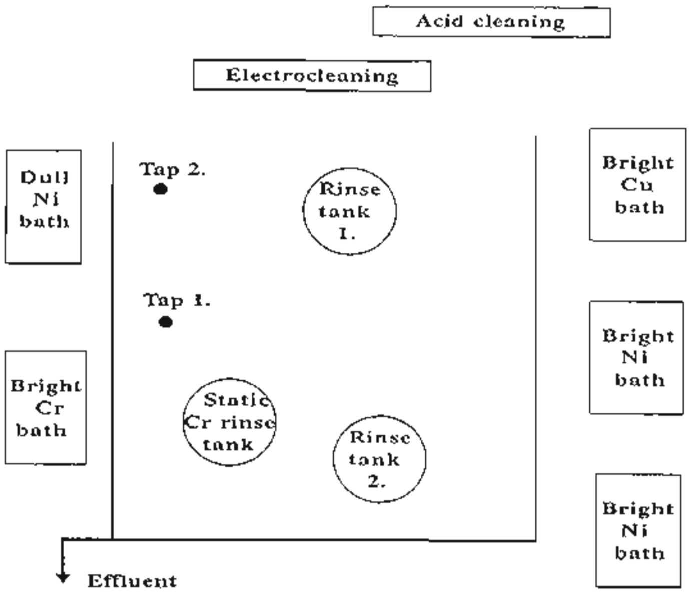

Fig. 1. Layout of the electroplating shop.

pollution loads is realizable by simply exploring various options ranging from waste minimization to in-plant modifications, resource recovery and reuse and the like [2].

2. Status of the chosen research site

The selected plant is one among the many small electroplating shops in Bangkok, dealing with Cr, Ni and Cu plating of metal parts. It is a family-owned shop and located in North-Bangkok. The shop has ten workers, working 8 h a day within an area of about 4 m × 15 m.

The electroplating shop has two conventional types of non-cyanide based, chrome plating processes:

$$\text{Dull Ni} \rightarrow \text{Bright Cu} \rightarrow \text{Bright Ni}$$

$$\rightarrow \text{Cr (for parts requiring more thickness, e.g., car bumpers)}$$

$$\text{Bright Ni} \rightarrow \text{Cr}$$

This shop serves different kinds of clients to plate their materials and spare parts. Most of the metal parts being electroplated are heater stands, car bumpers, exercise machine parts, spare parts of motor cycles and furniture parts. The layout of the electroplating shop can be seen in Fig. 1.

During the process the work pieces are washed directly under the tap. There are two rinse tanks used for the whole operation system. Tank No. 1 is used for rinsing after dull Ni and bright Cu plating process and tank No. 2 is used for rinsing workpieces after the

Table 1
Composition of wastewater

Concentration (mg/l)	Minimum	Maximum	Quantity (m^3/day)
Cu^{2+}	74	1100	0.2–1.3
Cr^{6+}	50	2340	0.9–3
Ni^{2+}	10	2482	0.9–3

Ni plating process. Therefore, the wastewater contains mainly three components: Cr^{6+} in the form of $Cr_2O_7^{2-}$ Ni^{2+} and Cu^{2+}, as shown in Table 1. The analysis of wastewater from the shop showed a wide fluctuation in quantity and quality [3]. The wastewater samples were collected in separate plastic buckets. However, during the actual process operation, the tap is kept open continuously. Thus, more diluted wastewater can be expected than in the analyzed data. In general, the whole process consumes about 3–5 m^3 per day of water. At present, wastewater from this plant is simply discharged directly to the nearby sewer system without any treatment.

3. Implementation of in-plant control measures

The initial in-plant control waste auditing revealed that this plant generates essentially four types of wastewater, which originate from: (a) Cr plating; (b) Ni plating; (c) Cu plating and; (d) electroplating (alkaline) and acid cleaning. The major focus of the work was on control and treatment of the first three metal bearing wastestreams. The last wastestream which mainly contained suspended solids, acid and alkali, contributes 40% of total wastewater generated at this plant. Therefore, considering its non-hazardous nature and high volume, it seems to be more appropriate to be discharged directly to the sewer after neutralization.

The layout of the electroplating shop with process modifications is presented in Fig. 2. The major orientation of this modification can be summarized as follows:

(a) Wastewater segregation: Cr, Ni and Cu bearing wastewater were segregated and collected separately [4,5]. These wastewaters were then treated and concentrated solutions (Cr, Ni, Cu) were recovered for reuse or recycling. Four more buckets installed in series at both taps 1 and 2 served the following purposes: (a) segregation of different metal bearing wastewater, (b) reduction of rinse water consumption, and (c) recovery of drag-out solution.

(b) Control of positioning and withdrawal of work-pieces: The workers were asked to orient parts so that only a small surface area came into contact with liquid surface as it leaves the plating solution, as well as to hold the workpiece for sometime above the plating bath after emerging from the bath in order to reduce the volume of drag-out.

(c) Simple drag-out recovery: This was implemented by using a plastic bucket to capture drips of plating solution as the workpieces were taken out of the tank, before rinsing. This bucket was used as a drag-out tank at the same time in which the workpieces were sprayed with a small amount of water before rinsing. The solution was then returned to replenish the plating bath.

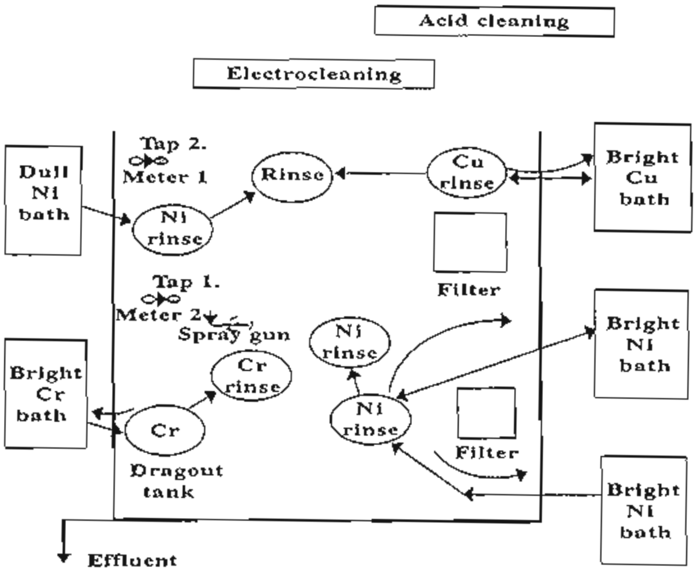

Fig. 2. Electroplating shop with process modification.

(d) Rinsing effectiveness: This was improved by using 'spray rinsing technique' (a spray gun was installed at tap 1). Jet rinse with high velocity and small amount of water was used, and spray effluent was trapped by the drag-out bucket to recover drag-out. Fresh water was introduced at the bottom of rinse tanks by nozzles to provide 'agitation' during rinsing so as to improve the rinsing effectiveness.

(e) Water consumption monitoring: Water meters were installed at both tap 1 and tap 2 for monitoring the water consumption.

4. Results of the implementation of in-plant control measures

4.1. Water consumption

Records of water consumption before and after the implementation of process modifications are presented graphically in Figs. 3 and 4.

From Figs. 3 and 4, it can be seen that after the implementation of process modifications, the water consumption recorded at tap 1 and the portion used for rinsing purpose at tap 2 has decreased considerably. (39.4% at tap 1 and 34.6% for tap 2). The total water consumption shows an average reduction of 18.7%. However, it was found that there was no significant reduction in total water consumption at tap 2. This could be explained by the fact that major portion of water from tap 2 was used for washing and cleaning of the workpieces. It was found that water used for cleaning purpose represented approx. 78.5% of water consumption at tap 2 and about 40% of the whole process water used at both taps. As stated earlier, the wastewater produced by this

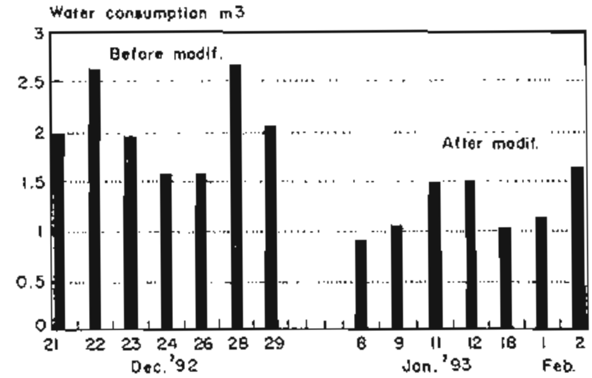

Fig. 3. Water consumption at tap 1.

cleaning process contains mainly suspended solids and has alkaline characteristics. In this study it can be considered as a non-polluting stream because it does not contain any heavy metal or toxic substances. After neutralization it can be discharged direct to the common sewer.

4.2. *Concentration of heavy metals in wastewater*

The variation of concentration of heavy metals in wastewater generated before and after process modification is illustrated in Figs. 5 and 6.

From Fig. 5 it can be seen that chromium concentration in the wastewater generated has decreased significantly after process modifications. There was about 73% reduction in the average Cr concentration observed in the wastewater generated. Also, Fig. 6 indicates the decrease in Ni concentration in wastewater after process modification. The

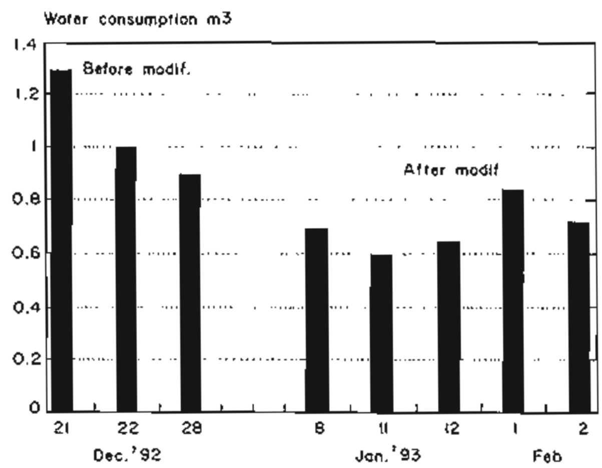

Fig. 4. Water consumption for rinsing at tap 2.

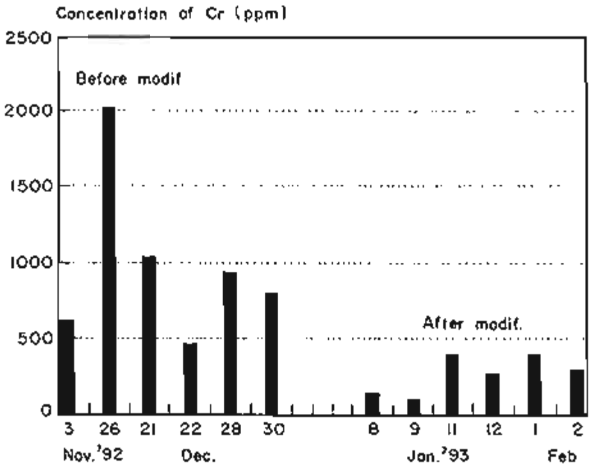

Fig. 5. Cr concentration in wastewater.

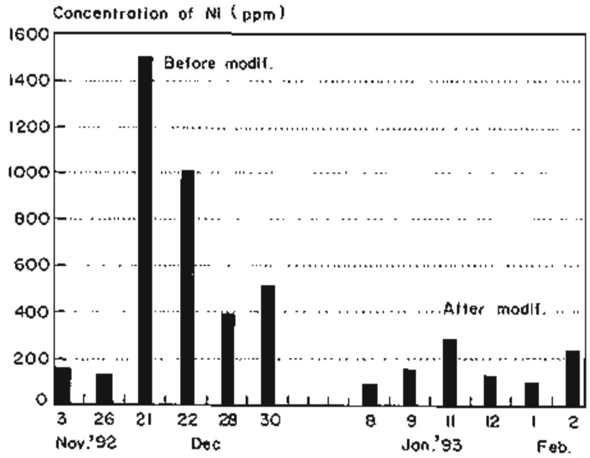

Fig. 6. Ni concentration in wastewater.

Table 2
Savings through wastewater reduction

	Quantity reduced	Cost/unit (Baht)	Savings (1 mon.; Baht)
Water reduction	15.6 m^3	9 B/m^3	140.4
Reduction of wastewater requiring treatment	15.4 m^3 = 20.2 ton	157 B/ton	3171.4

25 Baht = 1 US$.

Table 3
Savings due to metal concentration reduction

Reduction of pourback of dragout solution	Reduction of concentration in wastewater [a]	Reduction in wastewater generated (m^3)	Amount of material saved	Equivalent to	Cost/unit [b]	Savings per month (Baht)
Cr^{6+} reduction	720/5 mg/l of Cr^{6+}	22% * 15.6 = 3.43	495.8 g Cr^{6+}	476.7 g of CrO_3	950 B/kg of CrO_3	906
Ni^{2+} reduction	445.8/5 mg/l of Ni^{2+}	34% * 15.6 = 5.3	472.6 g Ni^{2+}	1130 g of $NiSO_4 \cdot 7H_2O$	3360 B/kg of $NiSO_4 \cdot 7H_2O$	7594
Cu^{2+} reduction	370.9/5 mg/l of Cu^{2+}	12% * 15.6-1.87	139.4 g Cu^{2+}	273.9 g of $CuSO_4 \cdot 5H_2O$	550 B.kg of $CuSO_4 \cdot 5H_2O$	302

[a] Divided by a dilution factor of 5. The dilution factor was introduced to compensate for continuous dilution of the actual waste stream due to open taps used for rinsing and cleaning.
[b] Cost based on the pure chemicals of laboratory grade.

average reduction in concentration was estimated to be about 71.3% for Ni and 54.6% for Cu.

From the results obtained after implementing the proposed process modifications it can be realized that it was 'not feasible to achieve a zero discharge' of heavy metals form electroplating operations. However, substantial reductions were possible in both the volume and the metal concentration of wastewater. In addition, it was noted that rinsing water bearing heavy metals and wastewater produced form cleaning process before plating should be strictly segregated, since the cleaning water does not contain any heavy metal, but only suspended solids, and it represented about 40% of total plating process water. This could significantly reduce the cost of treatment of wastestreams bearing toxic metals.

5. Cost evaluation

5.1. Saving due to wastewater reduction

Average water consumption:
$4.17\ m^3/d * 20\ d = 83.4\ m^3/mon$
$= 83.4\ m^3 * 1.3\ ton/m^3$
$= 108.4\ ton/mon.$
Water reduction:
$18.7\% * 83.4\ m^3 = 15.6\ m^3.$

The estimation of savings due to the amount of wastewater are presented in Tables 2 and 3.

5.2. The total cost saving

The total cost saving due to water and wastewater reduction is:

$$(140.4 + 3174.4 + 906 + 7594 + 302)\ \text{Baht} = 12117\ \text{Baht per month}$$

6. Summary

This case study was developed in view of setting up a demonstration project on "revealing the profitability of clean technology in small-scale electroplating unit". The research was conducted in a small-scale electroplating shop, located in Bangkok. The implementation of these simple in-plant control measures are demonstrated in a 30 min video tape, copies of which can be obtained at cost from the Environmental Engineering Program, AIT.

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