OPTIMIZATION OF GALVANIC WASTEWATER TREATMENT PROCESSES

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ABSTRACT

The study is focused on the possibilities for the development and practical application of preventive measures for optimization of galvanic wastewater treatment processes in Lithuania. The results of modernization of the wastewater treatment plant in JSC "Vilniaus Vingis" and optimization of the galvanic technological processes and reconstruction of the wastewater treatment plant in JSC "Vingriai" are presented.

ELECTROPLATING ACTIVITY IN LITHUANIA

In the 1980s, the machine building and instrument making industry took a leading role in Lithuania. Its production accounted for 25% of the total manufacturing and for nearly 20% of the labor force engaged in industry. The growth of all branches (e.g., electronics, electrical engineering, machine building, and metal finishing) was the most intensive. About 15% of the Lithuanian companies had electroplating divisions and more than 10^6 m^2 of material were coated by metal plating per year. A significant amount of salts, acids and alkalis were used for this purpose (Šalkauskas and Klimantavičiūtė 1990).

In the early 1990s, the electroplating industry incurred losses. For example, due to the changes taking place in the market, insufficient level of engineering and other reasons, the volume of galvanic production decreased more than 10 times. Recently, the situation started to improve. Currently, there are 22 companies in Lithuania, which operate in the area of metal finishing. The following processes are widely used: chromium, nickel, and zinc plating (including hot zinc plating), oxidation and coating by tin and lead.

A. Omelchenko et al (eds.),
Modern Tools and Methods of Water Treatment for Improving Living Standards, 197–208.

In comparison with other European countries, metal finishing activities in Lithuania have a competitive advantage in terms of labor costs (Seputis 2002). Therefore, Lithuania is able to compete with other European countries in this sphere of activity.

Currently, the non-compliance of metal finishing activity with existing Lithuanian environmental requirements is the major problem. Old and worn-out equipment for galvanic processes, including galvanic wastewater treatment processes, are the main sources of environmental problems, such as inefficient use of raw materials and energy resources, high volume of waste, sludge generation and insufficient level of wastewater treatment. Companies must solve these problems by application of preventive methods (Kliopova 2002).

CLEANER PRODUCTION METHODS FOR ELECTROPLATING PROCESSES

The typical metal finishing process is presented in Fig. 1.

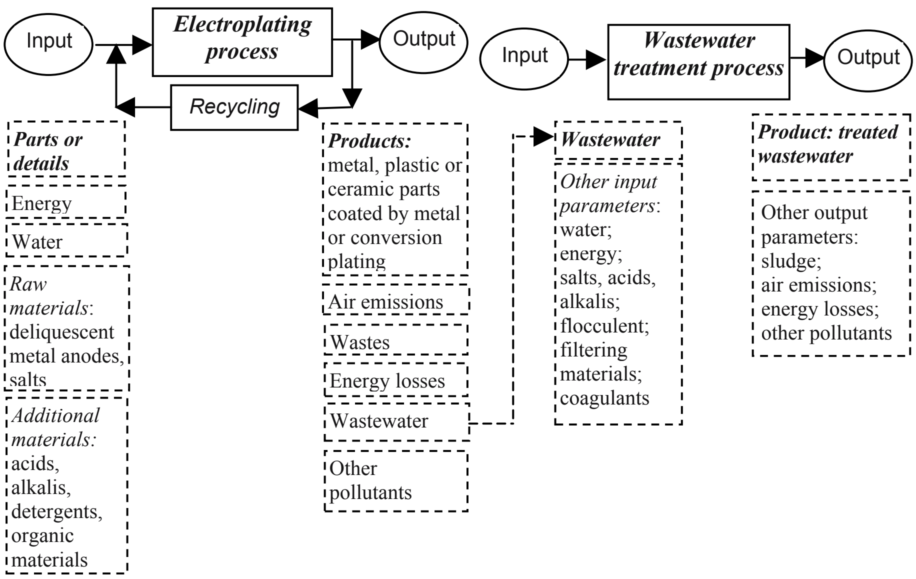

Figure1. Typical metal finishing process.

The waste volume and toxicity depends on many factors. For example, the composition of generated wastes could depend on input materials and the level of technological processes used (Staniškis et al. 2002). The large amount of pollution (wastewater, sludge, energy losses and other) could be generated due to inappropriate choice of technology, obsolete equipment and/or wrong choice of the process control equipment or system (Fig. 2).

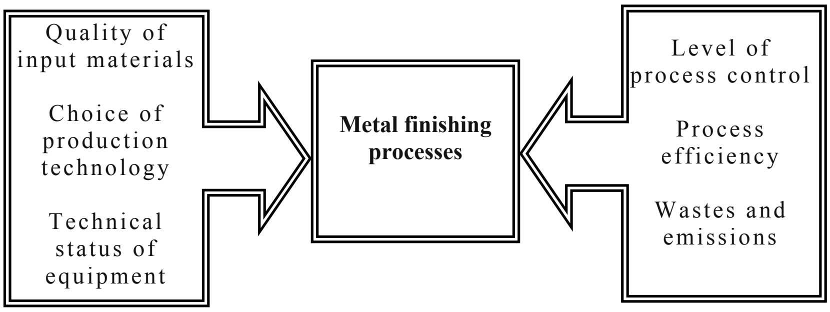

Figure 2. Assessment of the reasons for the possible environmental problems in metal finishing processes.

Due to the above-mentioned reasons it is very important to carefully evaluate the possibilities of different environmental strategies. The general principle of cleaner production (CP)/pollution prevention concept is *to evaluate technological processes for the identification of the problems' source before generation of some environmental ideas to find the best available solution*. The detection of materials which can contaminate the environment and minimization (or full elimination) of these materials constitutes the basis for preventive activity.

The material and energy balances should answer the following important questions: (i) where is the pollution generated? (ii) where do energy losses occur? (iii) what are the causes of the pollution and the energy losses? In addition, the material and energy balances are used for the economic evaluation of technological processes and for estimation of the economic costs of "production of pollutants" (Staniškis et al. 2001).

Fig. 3 presents major pollution prevention measures, which could be applied to all technological processes. CP implementation practice in the Lithuanian Machine and Instrument Industry shows that the environmental problems in galvanic wastewater treatment plants could be solved after, or simultaneously with, evaluation of the electroplating processes. The novel CP engineering techniques implemented helped to optimize some electroplating processes. They clearly demonstrated that using obsolete wastewater treatment processes is not economically or environmentally feasible due to ineffective consumption of energy, raw and other additional materials.

The most usable pollution prevention methods in Lithuanian galvanic companies and examples of their implementation are as follows:

(a) Input substitution. This method requires a number of laboratory analyses to be carried out. As examples, the implementation of electric heating systems instead of steam for bath heating, using less contaminating citrate instead of glycine in nickel-plating processes (Tarozaite and Gylene 2002) and using alkaline solution in zinc-plating processes instead of ammonia solution could be mentioned.

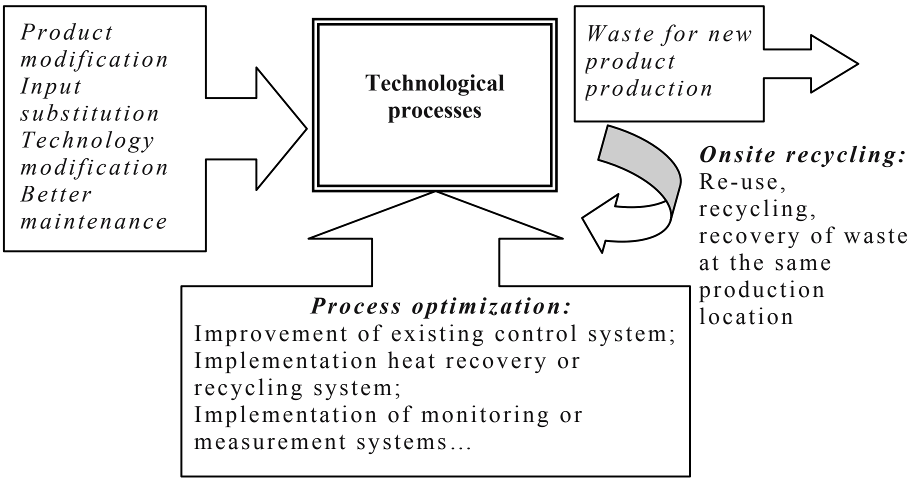

Figure 3. General cleaner production (CP) methods.

(b) Technology modification. This method is associated with large investments for market research, purchase of new technology and implementation. The implementation of electrochemical burnishing processes instead of chemical burnishing or tin/lead plating processes, elimination of hazardous cadmium in plating processes and implementation of powder dyeing technology instead of some electroplating processes exemplify this method. These modifications to electroplating processes make a direct impact on galvanic wastewater treatment. Therefore, technology modification is the most usable CP method in wastewater treatment processes. For example, after the modernization of electroplating processes in JSC "Baltic Vairas" it was decided to eliminate Ni- and Cr-plating and to optimize the phosphotation process (Bagdonas 2003). The optimization of the wastewater treatment plant was the next modernization step: a new coagulant was selected for better precipitation of sediments.

(c) Modernization of worn-out technological equipment. For example, new galvanizing baths with measurement and control systems, and new press filters instead of vacuum filters for sludge dewatering (dehydrating) have been implemented. The last innovation improved the galvanic sludge dewatering process by approximately 15 % (the water volume in sludge was decreased from 70% to 55 - 50 %) (Bagdonas 2003).

(d) Process optimization. This method could be exemplified by the following measures: (i) installation of a conduction sensor or meter allowing control of solution concentration and implementing recycling systems in electroplating processes (Kliopova 2002) (ii) installation of a control reservoir with a pH meter in the filtrate drainage line allowing quality control of the wastewater filtering process and minimization of some accidents (Kliopova 2002); (iii) installation of an automatic chemical dosage system allowing minimization of consumption of raw and additional materials in the wastewater treatment process. Due to optimization of the galvanic wastewater treatment process, the quality of treated water could be suitable for re-use in the galvanic technological processes.

EFFICIENCY OF CLEANER PRODUCTION MEASURES IN LITHUANIAN GALVANIC COMPANIES

The environmental and economic efficiency of the implementation of pollution prevention techniques was analyzed by taking into account the results of CP innovations implemented in the Lithuanian Machine and Instrument Industry during 1998 - 2002. Ten companies from this branch of industry took part in different CP, CP financing and Environmental Management System (EMS) implementation programs that were organized by APINI. Five companies chose the galvanization department as the potential subject for CP evaluation. A summary of the results of environmental evaluation of six implemented CP innovations is presented in Table 1.

Table1. Environmental benefits of CP implementation in Lithuanian galvanic companies (1998-2002).

Environmental sector	**Environmental benefit, units/year**
Electricity saving	890 MWh
Heat energy saving	4,443 MWh
Minimization of chemical consumption	26.7 t
Water saving, wastewater minimisation	26,000 m^3
Minimisation of wastewater pollution:	110.2 kg (P (3.5 kg), Ni (7.5 kg), Cr (9/6 kg), Zn (11.3 kg), Cu (4.5 kg), Fe (70.7 kg), Cd (3.1 kg))
Waste minimisation, including sludge	31.5 t
Minimisation of air emissions in production facilities and wastewater treatment plants	8.6 t
Minimization of environmental fees	30,000 LTL

Total investments in modernization and optimization were about 3,000,000 LTL (868,600 EUR), and total profit - about 1,200,000 LTL (347,500 EUR) (Kliopova 2002).

Innovations costing up to 55,000 EUR are usually implemented using the company’s resources. For implementation of bigger projects, the companies began looking for external financing: for example from banks and environmental funds. At present, there are a lot of possibilities to receive subsidies or loans on favorable terms to finance environmental projects, especially for CP projects, which have real economic effect.

Since 1998, APINI has collaborated with NEFCO (Nordic Environment Financial Corporation), which funded a CP investment credit line in the Baltic States. The main objective of these NEFCO activities is to finance implementation of CP projects on favorable terms (Kliopova 1999).

APINI specialists prepare CP investment projects in accordance with NEFCO requirements, carry out monitoring of CP project implementation, and evaluate real environmental and economic benefits after project completion. At present, four CP projects in galvanic and wastewater treatment have been funded through NEFCO’s loans.

CASE STUDIES

Modernization of the wastewater treatment plant in the galvanizing department at JSC “Vilniaus Vingis”

Project description

Worn-out wastewater treatment equipment at the metal coating workshop constituted the main problem in the television equipment manufacturing company “Vilniaus Vingis”. After the implementation of a rinsing water recycling system in the electroplating processes in 1997, water consumption, wastewater volume and pollution by zinc and nickel decreased. Therefore, it was not economically feasible to use the old wastewater treatment plant due to ineffective use of energy and production facilities.

Modernization of the wastewater treatment plant was completed in September 1999. Comparison of the old and the new implemented technology, and the benefits obtained from implementation are presented in Tables 2 and 3.

Table2. Technical evaluation of modernization of the wastewater treatment plant.

Old technology	New implemented technology
Chromium, acidic and alkaline water was collected into separate tanks.	Wastewater is collected into one tank.
Reagents were supplied into the chromium neutralization reactor by means of a pump. Neutralized water from the reactor was supplied to the intermediate tank and then to another tank in order to settle heavy metals.	Reagents (NaOH, $Fe(OH)_2$, flocculants) are supplied to the reactor by gravitation flow. Solution for neutralization is removed from collection tank in portions. After the full neutralization, wastewater is transferred by gravitation flow to the intermediate tank for sludge separation using a vacuum filter.
Neutralized water was treated by sand filters.	One polyester filter is used instead of 8 sand filters.
Sludge was separated from liquid by old pressure filters. Dried sludge was placed in containers.	One vacuum drum filter BOR is used instead of a 3-step filtration processes.
Coagulant for chromium neutralization was generated by 4 generators using iron shavings.	Two coagulant generators are used instead of 4 old ones.
The wastewater treatment plant occupied a 4-story building (1090 m^2). Process execution in the multi-story building required large quantities of pipes of various diameters and valves.	In order to vacate space for production processes, the treatment plant was moved to other premises with total area of 200 m^2. Yearly pipe maintenance expenses were eliminated.
Electrical consumption of the old water treatment plant was 550 kWh.	Electrical consumption of the new water treatment plant was reduced by up to 40 kWh.
Pure alkali was used for metal sedimentation. Besides, steam was used for dissolving alkali.	Alkaline solutions from electroplating processes are re-used for metal sedimentation in wastewater treatment.

Environmental evaluation

The comparison of treated wastewater quality is presented in Fig. 4. Economical evaluation of the project is characterized by the following: (i) total project cost - 290,000 EUR (including NEFCO loan of 243,000 EUR), (ii) yearly cost saving: in 1999 (3 months)-9,000 EUR; in 2000-83,000 EUR; in 2001-85,500 EUR; in 2002-86,500 EUR, (iii) Environmental savings constitutes forty percent of the total cost saving, (iv) Real payback was received in 3.4 years.

MODERNIZATION OF THE GALVANIZATION TECHNOLOGICAL PROCESS AND THE WASTEWATER TREATMENT PLANT AT JSC "VINGRIAI"

Project description

The company had the following electrochemical processes: treatment of aluminum; electroplating with chromium, zinc, cadmium and nickel and

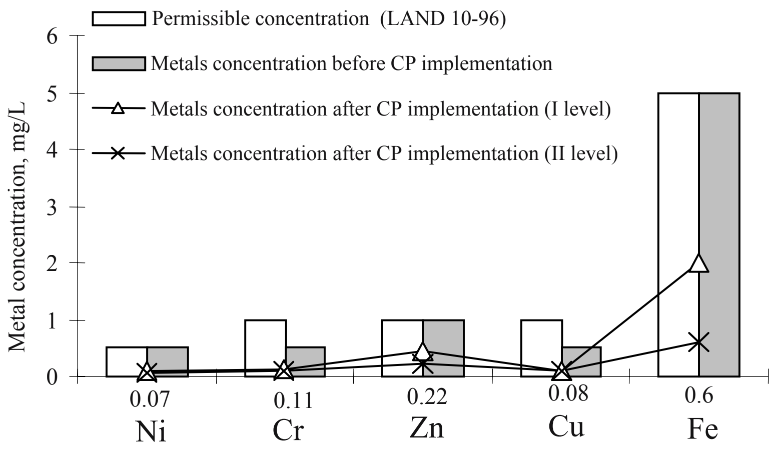

Figure 4. Reduction of metal concentration in galvanic wastewater due to implementation of new technology.

oxidation. The electroplating technology, galvanic baths and galvanic wastewater treatment equipment were obsolete and worn out. Therefore, the company inefficiently used all types of energy, raw and additional materials. Additionally, it was not environmentally feasible to use the old electrochemical equipment for metal coating with zinc, nickel or cadmium or the old wastewater treatment technology.

The company employed the following measures to solve its environmental problems:

(i) Reconstruction of ventilation and lighting systems in the galvanic department

(ii) Implementation of new electrochemical metal burnish and phosphotation technology instead of coating by zinc, nickel or cadmium. Wastewater volume was decreased by 33%, and wastewater quality improved

Table3. Environmental performance and monitoring method.

Environmental sector	Real benefits (2002)	Method for evaluation
Electricity saving	294,500 kWh (72%)	Electricity meter
Steam saving	10.12 MWh (100%)	Proportion of alkali saving
Compressed air saving	368,000 m^3 (88%)	Theoretical engineering calculation method
Hot water	127 m^3 (100%)	Water meter
Chemical savings (HCl, NaCl, alkali)	5.3 t (67%)	Chemical dosage system
Other material savings (quartz sand, steel shavings)	12 t (75%)	Quartz sand is not used in the new process; 50 kg of steel shavings are used for one cassette
Less sludge	7 t (13,5 %)	Sludge is supplied to the special tanks with mass indication
Heat saving for heating premises	184 MWh	Heat meter and theoretical calculation

(iii) Implementation of a new automatic electroplating process control system
(iv) Modernization of the wastewater treatment plant
(v) Recycling of 70% of the treated wastewater to the electroplating technological processes and for equipment cooling

Modernization of the wastewater treatment process was conducted though the following actions:
(i) The concentrates were collected in the different reservoirs and supplied to the main reactor using an automatic dosage system
(ii) Galvanic wastewater was supplied directly to the reactor
(iii) Metal plates were used for coagulant production
(iv) Sludge was dehydrated by a press filter
(v) An automatic pH control system was installed.

Environmental evaluation

The comparison of environmental indices before and after CP project implementation is presented in Tables 4 and 5.

Economic evaluation of the project is characterized by the following:

(i) The projects real investments were about 300,000 EUR (including NEFCO's loan of 200,000 EUR).
(ii) Cost savings – 162,000 EUR/year.
(iii) Planned payback period is about 2 years.
(iv) The cost of treatment of galvanic wastewater was decreased by more than 60%.

Table 4. Environmental effect (summary table).

	Pre-project Units/year	**Post-project Units/year (2002)**	**Savings Units/year**
Total volume of metal coated:	32,768 m^2	12,030 m^2	
Volume of wastewater after the galvanizing process	6,000 m^2	2,370 m^3	
Environmental indices:			
Electricity consumption, kWh/year	1.98 GWh	0.54 GWh	1.44 GWh
Compressed air consumption, m^3/year	254,971	38,463	216,508
Hot water consumption, m^3/year	2,270.4	29.5	2,240.9
Cold water consumption, m^3/year	21,414	995.4	20,418.6
Chemicals (alkalis, acids, salts, liquid glass), kg/year	24,851	10,010	14,841
Wastes (sludge, filtering materials, iron), kg/year	5,785	2,187	3,598
Indirect effect from electricity saving, t CO_2 /year	1,704	465	1,239 t
Minimization of metal concentration in the wastewater	38.8 kg	3.6 kg	35.2 kg

CONCLUSIONS

Optimization of galvanic wastewater treatment processes by implementation of various CP measures allows improvement of environmental performance in metal finishing companies: electricity

Table 5. The results of the environmental analysis of the galvanic wastewater and air emissions after CP implementation.

Me and pH	Concentrations in wastewater after the galvanizing process, mg/L	Concentrations after the treatment process, mg/L	Air emissions from electroplating department after modernization of ventilation system, t/year	
Cu	2.0	0.05	NaOH	0.011
Cr	25.0	0.30	Na_2CO_3	0.004
Zn	7.0	0.22	Na_3PO_4	0.004
Fe	10.0	3.00	HCl	0.002
pH	9.5	7.80	H_2SO_4	0.049
			Cr anhydrides	0.0002

consumption could be decreased up to 72%, consumption of chemical materials and sludge generation could be reduced up to 67% and up to 30%, respectively, the quality of the wastewater treatment process is significantly improved.

These results have a direct impact on the production costs. For example, it was estimated that the cost of the wastewater treatment process at JSC "Vilniaus Vingis" decreased by approximately 50%. At the same time, the product became more competitive on the market. New contracts on metal finishing have been signed after the modernized wastewater treatment plant started to operate. These contracts increased the productivity of the galvanic department by 1.5 times. Implementation of new environmentally more benign electroplating technologies in JSC "Vingriai" created opportunities to find new customers and extend the company's activity.

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