ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome VI (Year 2013) – FASCICULE 3 [July–September]
ISSN 2067–3809

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IMPROVEMENT OF RESOURCE EFFICIENCY IN METAL INDUSTRY

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ABSTRACT: The principle of "polluter pays" implies that industrial companies are legally and financially responsible for the safe treatment of waste and emission control, for creating the preconditions for their minimization at source, and the efficient and rational use of energy and natural resources. Opportunities to improve resource efficiency by applying preventive techniques are studied in three production facilities of metal industries, with different characteristics, the type of production process and capacity, size and mode of production. The fact that there are joint auxiliary processes, asked for careful diagnosis in determining the consumption of resources, particularly water and energy. It showed that if there is no measurement in the process units, it is difficult to determine those data. A special approach to the characterization of waste streams is required, because both sewage and treatment systems are common for all production units, and there are no records of waste streams. The objective of determination of these waste streams and resource consumption by processes is evaluation of resource efficiency and determination of emission sources in the technological processes in order to recognized possible measures of prevention or minimization. The application of preventive techniques in three selected plants clearly demonstrated that pollution prevention can be financially viable. Economic benefit from cleaner production is the main motivation for most companies. The cost of ancillary materials is huge, so any loss of raw materials represents a financial loss for companies.
KEYWORDS: resource efficiency, pollution prevention, metal industry

INTRODUCTION

The principle of "polluter pays" implies that industrial companies are legally and financially responsible for the safe disposal of waste and emission control waste, creating the preconditions for their minimization at source, and the efficient and rational use of energy and natural resources. In accordance with the principle of "polluter pays" plant operator that causes damage to the environment must ultimately provide the means to repair the damage done. Responsibility that is in our traditional practice was responsibility of a "society", are now the burden of the facility operator, which brings additional responsibilities and additional financial burden. Therefore, it is clear that industrial enterprises need expert assistance in identifying opportunities for pollution prevention in an economically profitable way. Based on the experience of other countries that have been or are in the process of transition, it is obvious that the investment funds should focus on improving manufacturing processes and preventing or minimizing pollution at source in order to reduce the need for treatment and treatment costs at the end of the production cycle, or "end-of-pipe" treatment [1].

Table 1. Characteristics of plant metal industry involved in research

Type section of the	Mark and to	Number of employees	Capacity (t / day)
Production of wire	P-1	262	250
Surface treatment of yards of soil will	P-2	252	30
Metalwork	P-3	152	3

Possibilities to improve resource efficiency by applying preventive techniques are studied in three metal industries, with different characteristics in terms of the type of production process and capacity, the company's size (Table 1).

METHODOLOGY

A "Method of Identifying Preventive Techniques-MIP" (Table 2) [11] was used to select preventive techniques. The MIP method accepts and elaborates on the steps of Cleaner production (CP) assessment methods [2], and takes the idea of form and approach to data collection methods from the Minimisation Opportunities Environmental Diagnosis (MOED)[3].

With the aim of integrating the principles of prevention in the business policy the method is amended with functions Shewhart-Deming's circle [4]. The phase „Process Analysis" is extended with analysis of the problem (Plan), and with connection with the identified problems and establishing goals to be achieved, in this case those relating to resource efficiency and reducing environmental impacts. The phase "Do" corresponds to the phase of "Improvement", however a preparation of the proposals for measures to prevent pollution is shifted in phase "Planning-Analysis", because the proposal is still not an improvement but requires analysis relating to techno-economic feasibility and the expected environmental and economic improvements. The phase "Control" measures the results of application of selected preventive measures, and monitors compliance of the results with goals set out in the planning stage. In case of deviation of the results and set goals, the correction follows through further improvements of the process in phase "Act" This phase in the CP assessment method is called "Integration".

Table 2. The methodological phases and steps, MIP methods

PDSA circle	Phase of MIP method	Step no.	Description of steps	DPSIR Indicator
Plan	Assessment	I	Overview of products, regimes of work, organization and staffing	D, S
		II	Overview of production and auxiliary facilities, and the technological processes, with an understanding of their chemical and physical aspects	D
		III	Review of consumption of raw materials, auxiliary materials, energy and water by plants, and associated costs	P
		IV	Review the types and quantities of generated waste streams, and associated costs for their management, show the input-output flows and the amounts on the process diagram	P
	Analysis	V	Situation analysis, problem identification and determination of the objectives	S, I
		V	Making lists of proposed measures to prevent and / or minimize pollution	R
		VII	Analysis of technical feasibility of the proposed measures	
		VIII	Analysis of economic feasibility of the proposed measures	
		IX	Evaluation of the techniques according to the criteria and ranking	
Do	Improvement	X	Selection of measures	
		XI	Implementation of measures	
Control	Integration	XII	Monitoring of the results	
Act		XIII	Corrections and / or documenting	

In the planning stage, with the aim of identifying problems, the MIP method is based on the DPSIR method [4]. "D-driving force" can production capacity of certain product, where the "P-pressure", can be emissions of wastes. If the production and emissions are taken as functions of eco-efficiency of technologies and techniques applied, then the improved eco-efficiency can reduce pressure, although the driving force can remain the same even increased. Emission of waste contributes to a "S-state of the environment", which in dependence of environmental carrying capacity causes some "I-impact on the environment." In this way we can follow a series of "causes-impacts", and recognize the need and the "R-response of society", i.e, in the context of industrial production, the measures that a company should take to reduce emissions.

PRODUCTION PROCESS CHARACTERISTICS AND STATE OF ENVIRONMENTAL PERFORMANCE

The wire production process, in the I-1 plant, the basic material that comes to drawing in most cases comes as rolled or bonded. Such material has not always uniform structure, nor the same mechanical properties along its entire length. There is thicker or thinner oxide layer on the surface, which should be removed, and to prepare the wire for drawing.

Tabela 3. Indicators of emissions and resource efficiency in instalations I-1, I-2 and I-3 [11]

Installation		Resource efficiency indicators	Environmental efficiency indicators
Wire production	P-1	Water efficiency: 14.5 m^3/t Energy efficiency: 448.91 KWh/t Efficiency of gas consumption: 180.2 m3/t	Wastewater indicator 0.55 m^3/t; 1.6 PE/t, Specific water pollution load 1.5 kg/ t Burnt coke 0.2 kg/t Asbestos rope 21.0 t/god Organic waste, packaging waste, paper, cartridge, paper…
Surface treatment	P-2	Water efficiency: 5.7 m^3/t; Energy efficiency: 614.09 KWh/t	Wastewater indicator 3.1 m^3/t 0.23 EBS/t Specific water pollution load 100 t/god Zinc waste (ash) 75 t/god Solid Zinc 2 t/god Ferrum oxide dust 20.3 t/god Organic waste, packaging waste, paper, cartridge, paper… 56 t Wastewater sludge rich with heavy metals Fe(OH)3L
Production of barrels, hydrophors and boilers	P-3	Water efficiency: 18.35 m^3/t; Energy efficiency: 192.5 KWh/t	Wastewater indicator 11.9 m^3/t 3.6 EBS/t, Specific water pollution load 0.7 t/god Zinc waste 18 t/god Waste acid 0.6 t/god Mineral wool 0.8 t/god Waste paint 33 t/god Organic waste, packaging waste, paper, cartridge, paper, etc 20 t/god Metal Sheet waste

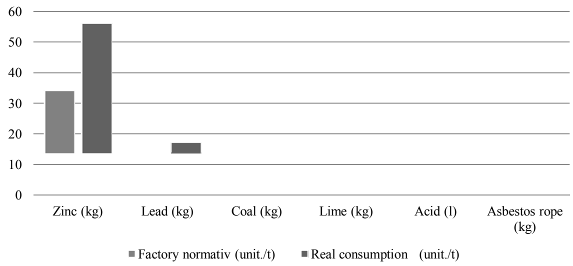


Figure 1. Factory normative and real consumption I-1[9,10]

The mechanical cleaning of blasting technology is applied at the plant P-1. The introduction of blasting technology is one of the earlier projects of cleaner production in the plant P-1, which has replaced the chemical process of preparing with mechanical wires, and thus excluded the emergence of wastewater from this process. Although the investment for the implementation of preventive measures amounted to 594 870 KM, savings on basic raw materials, water, steam, electricity, waste water neutralization, and fees for wastewater discharge, amounted 295 414 KM. The rate of return was 2 years [6].

Indicators of specific consumption of plant P-1 (Table 3) refer to the total consumption of all consumers, because there is no possibility of measuring the unit production process. Comparison with the specific values determined in other plants of the same *technology is not possible, because the literature reports on spending by individual technological processes and expressed as the amount of water consumed in relation to the surface-treated metals, while in the facility P-1 data on production capacity recorded in the tons of galvanized construction. For example, Nordic Council report on the consumption of 50 L/m2 galvanized surfaces [7], and the French regulations concerning metal finishing require consumption of 40 L/m2, 5 stages of rinsing [8].*

Given the impossibility of comparing the values of indicators, analysis of the burden of production in financial terms. Water consumption and energy cost burden products with 120.7 KM / t, which accounts for about 20-30% high-carbon wire cost and low carbon wire cost. Since the galvanization dominant consumer of water, energy and basic raw materials, the analyzes of the possibilities of application of preventive measures, was focused on one of the galvanizing lines capacity of 1665 t / yr. Measurements showed that the consumption of raw materials is greater than the prescribed factory normative (Figure 1).

The installation I-2 provide metal finishing services by coating metal with zinc, as well as production and finishing of tin plates for transmission lines, and production and finishing of iron profiles for transmission line construction. In the technological process of hot coating, the waste material is generated while cleaning the zinc bath.

Wastewater from the zinc bath contains solid and ash zinc which is approximately 40% of the zinc used for production on annual basis. The company is located on the river bank, thus periodical increases of groundwater level are observed causing flooding of production halls. In order to prevent flooding, pumping wells were constructed to decrease level of ground water. Water is pumped in the sewage system.

The analysis of water, energy and zinc cost share in the unit price shows that these costs make product price less concurrent on the market and that costs must be reduced. One of the reasons for high electricity consumption is its use in the peak consumption period when several consumers are connected at the same time to the system. It is determined that water in the cooling process is used uncontrollably. Cooling bath has continuous flow required to maintain low temperatures, while flow required to keep the temperature down is not controlled. The bath with the acid solution (HCl) is changed 2 times per month which requires large quantities of water for preparation, while technological water after cooling is discharged unused. Beside potential use for preparation of acid solution, technological cooling water can be reused for rinsing after treatment with HCl. Pumped ground water is discharged unused while drinking water is used for technological purposes.

In the installation P-3, the problem with increased number of returned final product from the tin barrel line is observed. Total of 2.4% of final products (479 pieces) is returned annually, which increases need for refinishing thus increasing consumption of raw material (paint and diluent) and energy (naphtha and electricity), and generating additional quantities of wastewater. In the production of barrels, hydrophors and boilers, majority of technological operations is common. All production steps were analysed, from purchase of raw materials to dispatch of final product, and concluded that cause for damage on the barrels is inadequate storage space.

Final products are stored on open space under influence of climatic factors which causes problems with paint fixation. From environmental aspect, greater impact on environment is generated in zinc coating and painting processes. Beside these main operations, auxiliary operation of galvanisation with cadmium for anticorrosion protection is applied. Cadmium is very toxic and costly metal.

ENVIRONMENTAL AND ECONOMIC BENEFITS OF IMPLEMENTED MEASURES

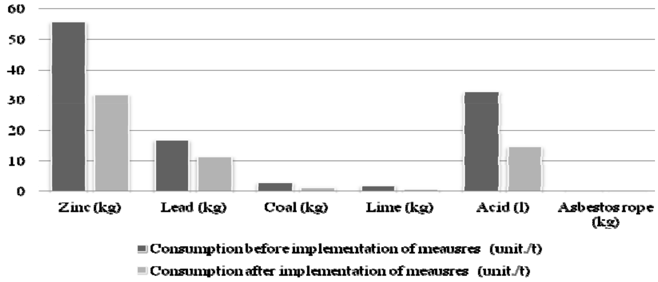
In the installation I-1, zinc coating process line of 1665 t/y capacity, two gas measurement devices are installed (in the preheating line and annealing line) as well as two water meters (in the washing line after treating with basic solutions and zinc coating line) (Table 4).

Table 4. Introduced prevention and minimisation measures [11]

Measure	I-1	I-2	I-3
Product change	-	Reducing zinc coating temperature to average temperature of 447 °C and obtaining the same quality of product with thinner coating, thus reducing overall zinc consumption	-
Technological measures	Two measurement devices for gas and two for water installed in the zinc coating line.	Installation of thermostat in cooling baths and automatic valve for adjustment of water flow from the public water supply system.	Construction of covered storage space for protecting the barrels
		Installation of pumps in the groundwater draw-down system with the purpose of cooling the construction after zinc coating with pumped water	
		Installation of device for regulation of engaged power i.e. peak energy consumption	
Reuse and recycling	Excess of heat from zinc bath used for drying of wire after fluxing process.	Extraction of zinc ash by sieving to obtain zinc to be reused in the process.	-
		Reuse of cooling water for acid preparation and neutralisation processes	-
Good housekeeping	Recording of auxiliary material consumption to achieve their rational use.	Planning of the production with the purpose of taking advantage of lower energy tariff and avoiding simultaneous connection of several energy consumers	-

Continuous 15-day measurements of energy and water use indicated consumption of 11,4 m^3/t. The zinc coating process was technically improved by introducing an additional pipe for excess heat removal above the zinc bath.

This heat was conveyed to the drying chamber. Resources management and cost analysis system was introduced. Consumption was measured daily using installed devices. Other measurements such as acid, coal, azbest rope consumption were recorded by *weighting. Data obtained were recorded in tables per cost centres for easier analysis and tracking the costs. With above mentioned measures, the company reduced consumption of water for 71%, gas for 10%, zinc for 57%, and lead for 31%. Total savings were 526,747 KM with immediate return of investment (Picture 2).*



Picture 2. The effects of prevention measures at the zinc coating line of capacity of 1665 t/y at the I-1 installation

In the installation I-2, changes in product are introduced by reducing temperature of zinc coating to average temperature of 447°C. This measure at the same time increased resource efficiency by rationalisation of zinc and acid consumption. These technological measures (Table 4) reduced water and energy consumption as well. By implementing group of measured, the I-2 installation reduced consumption of energy for 9%, water for 83% and waste zinc for 85%/ton of end product. This resulted in savings of 391,839 KM with investment pay-back period being less then 1 month.

In the installation I-3, construction of covered storage space enabled better paint fixation for the barrel and reduced number of barrels returned by the customers. This resulted in reduction of raw material, auxiliary materials, energy and water (Table 6). Pay-back period for this investment was 4 years and 9 months.

Total savings obtained in all three installations amounted to 924,227.80 KM, while total investments amounted to 33,400.00 KM (Table 5). These results were achieved at the time when water and sewerage tariffs were subsidized meaning that costs were not calculated based on the real costs of water production while wastewater treatment plan was not in function. In case the installation had wastewater treatment costs and that cost of auxiliary resources were based on economic calculation, annual savings would be greater. Implementation of these measure produced not only economical but also environmental benefits expressed through reduction in consumption per unit product and reduction of emission to environment (Table 6).

Table 5. Overview of investments and savings [11]

Installation	Investment	Savings
I-1	1.000.0	525.747.0
I-2	1.000.0	391.839.0
I-3	31.400.0	6.641.8
Ukupno	33.400.00	924.227.80

Table 6. Savings in energy. water and reduction in waste generated [11]

Installation	Energy	Water	Waste
	kWh/y	m^3/y	t/y
I-3	2.479	155.4	0
I-2	4.559	22.050	123
I-1	0	13.647	0
Total	7.038	35.852.4	123

CONCLUSIONS

The fact that common auxiliary processes exist asked to pay special attention while doing diagnosis on resources consumption, especially water and energy. It is demonstrated that these data are hard to obtain unless measurement per process line is performed. Special approach was also required in characterization of waste flows since wastewater discharge systems are usually common for process and sanitary wastewater. Recording of the waste flow qualities is also not present. The purpose of waste flow determination and determination of resources consumption per process is to evaluate resource efficiency and recognise parts of the process where flows are generated. This makes selection of prevention and minimisation options easier. The use of prevention techniques in three installations selected clearly showed that pollution prevention can be financially sustainable. Economic gain from cleaner production was the main motivation for majority of companies. Cost share of auxiliary materials is significant so any waste of material represent big financial loss for a company.

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