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POSSIBILITIES OF SIMULTANEOUS MINIMIZATION OF WATER, ENERGY AND CHEMICAL CONSUMPTION AT DYEHOUSE IN THE TEXTILE COMPANY "LUXPOL" CO.

Nowadays environmental management is the very important part of management in industry. The heart of the environmental management is minimizing pollution at the source. At the Textile Company "Luxpol" Co. in Stargard Szczeciński near Szczecin, dyehouse is the biggest user of water and heat energy. This paper is focused on a simple way of simultaneous minimization of water, energy and chemicals consumption. There are two propositions: decrease in the volume of dyeing apparatus depending on production scheme plan, which is a kind of preventing pollution at the source, and regeneration of exhausted dyeing baths and their reuse.

1. INTRODUCTION – ENVIRONMENTAL MANAGEMENT

In recent times, an industrial pollution is one of the most important environmental threats. The principle of sustainable development has been found as a good solution to this problem. According to this idea we have to find such solutions that allow the next generations to use natural resources and live on the Earth. This means that companies ought to use such a kind of activities, procedures and technologies that their environmental impact would be as weak as possible. The sustainable development can be encouraged by means of some tools. The most important among them is environmental management.

Environmental management is defined in general as an integrated part of corporate management [1], [2]. It is vital that a company takes into account an environmental impact of its activity treating this impact and other elements of company's management as equally important [3]. Environmental management systems do not relate only to legislation requirements for environment. They also create an active conception, and informa-

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tion analysis gives new ideas of environmental impact decrease in a company. In this way, environmental management systems are ahead of the legislation. It may be said that environmental management systems can reconcile economy to ecology [2], [3].

The heart of environmental management is minimizing or preventing pollution at the source in a company. Environmental management, which is based on the principle of preventing pollution at the source, allows us to decrease a volume of waste to be treated. Figure 1 presents the hierarchy of activities in preventing principle [4].

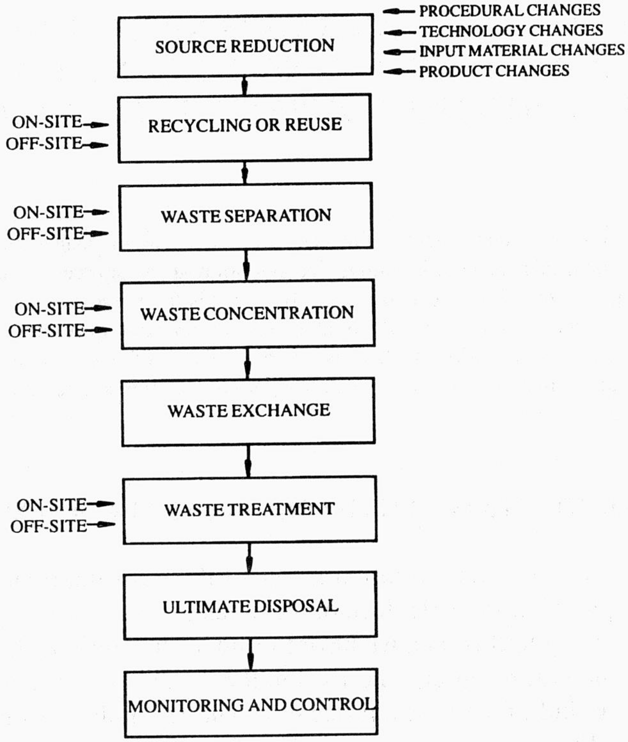

Fig. 1. Pollution prevention hierarchy

Reduction at the source is the first stage in activity hierarchy of pollution prevention. It primarily consists of technologies enabling us to reduce the volume of the wastes generated. In this stage, a company tries to change procedure, technology, input material or final product in order to eliminate or reduce the amount of waste generated in a particular process. In the second stage, i.e. recycling, a company attempts to recover a usable material from a waste stream. Recycling can take place either on-site or off-site. After completion of those two stages a company has some volume of wastes. Those wastes must be separated (e.g. wastewater streams) and treated using physical, biological and chemical methods. This results in a reduction of the toxicity and volume of waste requiring ultimate disposal. At the end, those wastes which are ultimately disposed (e.g. in landfill) must be monitored and controlled. The volume of waste is smaller in each next stage [2], [4].

Based on environmental literature we can state that it is very important to know what is in input and output of company's production. It may be said that input includes raw materials, and output includes products. In environmental onomastics, the product is defined not only as ready article but also as the waste generated. We can define the wastes as all the products generated in production processes which are not desired. They are by-products [1].

The aim of this paper is to present the possibilities of waste minimization in a dyehouse of the textile company "Luxpol" in Stargard Szczeciński near Szczecin. The main raw materials in a dyehouse are as follows: natural and/or synthetic fibres, water, dyes and other chemicals as well as energy. The products are the following: final goods and wastewater (which is particularly harmful for environment), also "waste" energy and solid waste [5], [6].

At the dyehouse the useful wastes can be separated in all places where they are generated. The above statement is true in the case of reuse of water, dyes and other chemicals as well as solid wastes and energy recovery.

2. COMPARISON OF RAW MATERIALS AND PRODUCTS AT THE DYEHOUSE

Tables 1 and 2 present the raw materials consumed and the products generated at a dyehouse during one month [6].

Table 1

Consumption of raw materials per a month at the dyehouse

Raw materials	Consumption
Fibre subjected to dyeing*	85 000 kg
Technological water*	4 325 m^3
Thermal energy*	3 227 GJ
Electrical energy*	87 604 kWh
Dyes*	1 333 kg
All chemicals**	7 500 kg

* Data for 1996.

** For chemicals, only the data from 1994 were available, estimated values are for 1996.

In the "Luxpol" Co., a dyehouse is the biggest consumer of water and energy. But the largest source of "waste energy", hot wastewater, is not utilized.

Table 2

The products generated per a month at the dyehouse

Wastes	Production
Dyed fibre*	85000 kg
"Waste" energy in wastewater	estimated – 515 MJ
"Waste" energy in air	–
Industrial wastewater*	90% water – 3893 m^3
Dyes contained in the wastewater*	15% using – 200 kg
Emission into the atmosphere	–

* Data for 1996.

3. THE PROPOSAL FOR MINIMIZATION OF RAW MATERIAL CONSUMPTION

This paper is focused on two ways of raw material minimization: decrease in the volume of dyeing apparatus (a kind of preventing pollution at the source) and regeneration of exhausted dyeing baths and their reuse.

3.1. DECREASE IN A DYE TANK VOLUME

According to the principle of preventing pollution at the source, the first step in environmental management is to find a way which could minimize raw material consumption.

Very high quality of products is highly important for the company. Therefore, a manager of a dyehouse has to be interested in finding such a way of minimizing the raw material consumption which does not lower this very high quality. Let us see what the situation of the dyehouse in the "Luxpol" looks like.

In the dyehouse of the Textile Company "Luxpol" Co., there are used three dyeing apparatuses (each of them is characterized by 5 m^3 volume and 400 kg inset) and laboratory dyeing apparatus (of maximum inset equal to 7 kg). The dyehouse often receives orders to dye the fibres whose mass is considerably lower than 400 kg and considerably higher than 7 kg, and dyeying takes place in a laboratory dye tank. But this bath technology used in Luxpol's dyeing apparatuses requires the bath volume equal to 5 m^3 with adequate concentration of dyes and other chemicals, which means that in this place the company generates wastes not only as a water but also as dyes and energy [6].

In this situation, it can be suggested to buy a new smaller dyeing apparatus. It seems, however, that there is another cheaper proposal. Some savings can be achieved by decreasing the volumes of dyeing apparatuses. This can be reached due to locating in the tank such an object that would fill up a part of its volume. For example, the object shaped like a cylinder or like a torus with external diameter equal to internal diameter of dyeing apparatus would act as this fulfilment. This fulfilment can be stationarily located in the apparatus or this location can allow us to remove or change the fulfilment.

It seems that it would be profitable to keep one of the apparatuses with the volume of 5 m^3 because the dyehouse receives some large orders to dye fibre with mass of 10 000 kg, 20000 kg and more. We propose to use the other two dyeing apparatuses for various inset masses, i.e. 100 kg, 150 kg, 200 kg, 250 kg and 300 kg. The bath volumes necessary to dye those quantities of fibre allow us to achieve big savings. In order to estimate the water consumption, we should to analyse a company's production for one month. We propose to analyse the production in two dyeing apparatuses with decreased volume for the inset mass of 100 kg and 200 kg for September, 1996.

The bath ratio required for those dyeing apparatuses can be expressed as

$$\frac{5\,000\ \mathrm{dm}^3}{400\ \mathrm{kg}} = 12.5\,. \qquad (1)$$

Then the water volume necessary for dyeing the fibre load of the inset mass equal to 100 kg is as follows:

$$12.5 * 100 = 1250\ \mathrm{dm}^3\,. \qquad (2)$$

It appears from this that on each load of the fibre dyed the following water volume can be saved:

$$5000\ \mathrm{dm}^3 - 1250\ \mathrm{dm}^3 = 3750\ \mathrm{dm}^3\,. \qquad (3)$$

Water demand for fibre load with mass of 200 kg is:

$$12.5 * 200 = 2500\ \mathrm{dm}^3\,. \qquad (4)$$

Such a decrease of water demand enables us to save the following water volume:

$$5000\ \mathrm{dm}^3 - 2500\ \mathrm{dm}^3 = 2500\ \mathrm{dm}^3\,. \qquad (5)$$

In September 1996, about 35 of dyeing processes with the inset mass of 100 kg have been put in motion. Then the water savings would have been:

$$35*3750\ \text{dm}^3 = 131\,250\ \text{dm}^3 = 131.25\ \text{m}^3. \tag{6}$$

The dyeing apparatus with the inset mass of 200 kg would have been used in 46 dyeing operations. The water savings would have been:

$$46*2500\ \text{dm}^3 = 115000\ \text{dm}^3 = 115\ \text{m}^3. \tag{7}$$

The total savings in water volume as a result of this modernization would have been:

$$1.131.25\ \text{m}^3 + 115\ \text{m}^3 = 246.25\ \text{m}^3 \text{ per month.} \tag{8}$$

This value makes 5.7% of technological water volume used on average in one month in 1996. This minimization of water consumption could have decreased the amount of dyes used in the process. Average monthly dye demand was 1333 kg in 1996. The savings of dyes would have been 76 kg per month.

The decrease in hot water demand causes the decrease in total energy demand. Those heat savings can be estimated according to the following formula:

$$Q = m*c_w*\Delta t \tag{9}$$

where:

Q – heat needed to warm up 1 m^3 of water in a range of Δt in °C [kJ];
m – amount of water saving [kg];
c_w – water specific heat [kJ/kg * °C];
Δt – rise in water temperature [°C].

The mass of water without chemicals can be taken as m = 246 kg and water is warmed up from 30 °C to 110 °C, therefore the water temperature rise is Δt = 80 °C.

Then:

$$Q = 246000*4.19*80 = 82.4 \text{ GJ per month.} \tag{10}$$

The expected savings for September 1996 are presented in table 3.

Table 3

The comparison of raw material savings for September 1996

Raw material	Average consumption per month	Savings	Decrease in consumption
Technological water	4325 m^3	246 m^3	5.7%
Dyes	1333 kg	76 kg	5.7%
Energy	25815 GJ	82.4 GJ	0.3%

The dyehouse should be stocked with the changeable fulfilment for dyeing fibre with the maximum inset masses equal to 100 kg, 200 kg, 250 kg and 300 kg. Table 4 compares the most important parameters of single bath for maximum masses of dyed inset chosen.

Table 4

Saving indexes of single bath for maximum masses of dyed inset chosen

Dyed inset mass [kg]	100	150	200	250
Volume of water needed to bath preparation [dm^3]	1250	1875	2500	3125
Unit technological water savings [dm^3]	3750	3125	2500	1875
Unit dye savings [kg]	1.16	0.96	0.77	0.58
Unit energy savings [MJ]	1257	1048	838	628

Changing the volume of dyeing apparatus causes the pause in production, therefore it cannot take place too often. But the above analysis proves that the adaptation of volume of dyeing apparatuses to a production scheme gives savings.

3.2. REGENERATION OF EXHAUSTED DYEING BATH

Considerable minimization of technological water, energy and chemicals consumption can be reached by a reuse of dyeing baths. The exhausted dyeing baths before being recycled ought to reach such concentrations of both dye and other chemicals as primary dye and chemical concentrations in a dyeing bath. The addition of lacking dye quantity makes the bath useful. This operation will be justified if the mass of the dyeing fibre load is bigger than the nominal inset mass for the given dyeing apparatus. In this case, the dyeing process should be gone on two times at least. The Textile Company "Luxpol" has dyeing apparatuses with nominal inset mass of 400 kg, but sometimes it takes orders to dye fibres with the mass of 10 000 kg, 20 000 kg and more. The multiple use of dyeing bath decreases the losses of raw materials.

The regeneration of exhausted dyeing bath will be possible if the quantities of each component of dyestuff in the exhausted bath are precisely defined. If those quantities are known, the exhausted bath will be completed with lacking quantities of dye components. In this new regenerated dyeing bath, each component of dye has to have the concentration conformable to the prescription of dyeing.

The research conducted in the Department of Water Environment Engineering (TUS) confirmed that photocolorimetric method was very useful to determine the concentration of each dyestuff in exhausted dyeing bath [7]. The research was carried out for some dyes used at the Textile Company "Luxpol" in their dyeing bath. The trade marks of the dyes were: MARINE and GRANAT 58 [7].

The tests have been carried out with each component of a dyestuff. The auxiliary chemicals have been added to each sample. Such a kind of sample was investigated and a characteristic wavelength of light for maximum light absorption was determined. The concentration of particular dyestuff was determined for this wavelength of light. Temperature and pH in each sample were measured in order to conduct each research under defined conditions. For each dyeing bath it was plotted a standardization curve representing each component of dyestuff with the auxiliary chemicals. The standardization for the given wavelength of light defined an extinction being a function of a dye concentration in the solution:

$$E = f(c) = a * c + b \tag{11}$$

where:

E – extinction of single dyestuff solution,

c – concentration of dyestuff,

a, b – coefficients.

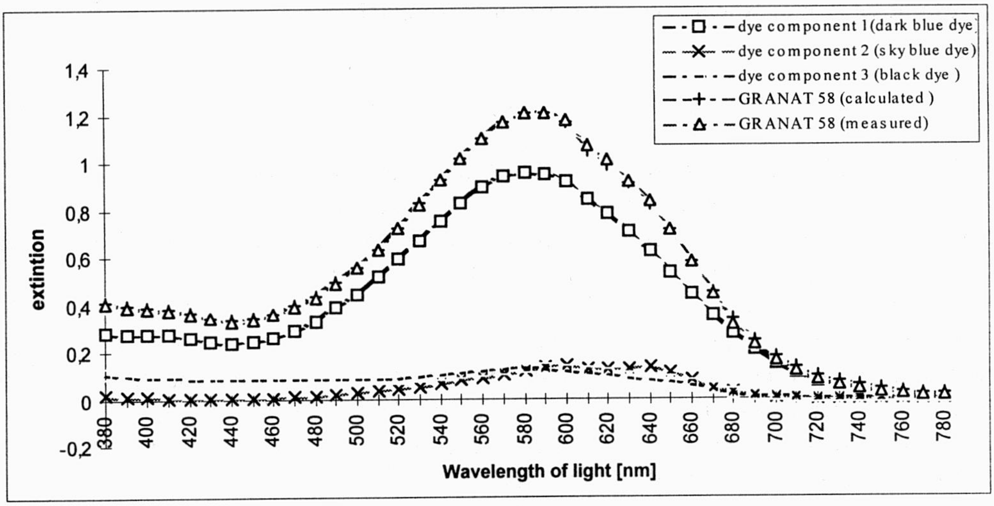

Fig. 2. The spectrum of dyeing bath components of dyeing bath GRANAT 58

In the next step, we solve the system of equations describing the dyestuff concentrations in the exhausted dyeing bath:

$$E^1 = a_1^1 * c_1 + a_2^1 * c_2 + a_k^1 * c_k,$$

$$E^2 = a_1^2 * c_1 + a_2^2 * c_2 + a_k^2 * c_k, \tag{12}$$

$$E^n = a_1^n * c_1 + a_2^n * c_2 + a_k^n * c_k$$

where:

E^1, E^2, E^n – extinction of exhausted dyeing bath for the determined wavelength of light for each dye component,

c_k – the concentration of the k-th dye component,

a_k^n – coefficient for n-th wavelength of light and k-th dye component in bath.

Based on this system of equations it was possible to find the concentration of dyes in exhausted dyeing bath. Figure 2 presents the diagram of parameters characteristic of dyeing bath GRANAT 58 [7].

Taking into account the results of those laboratory experiments we can estimate the raw material savings which will be achieved in dyehouse if a company puts regeneration of dyeing bath into practice. Due to this modernisation a company can decrease the consumption of technological water, energy, dyes and other chemicals (particularly auxiliary chemicals). In order to estimate the savings, we can analyze a production scheme for September 1996.

At this time about 200 dyeing baths would have been prepared based on the regenerated bath. They would have been itemized as follows:

- 150 baths for dyeing apparatus with the volume of 5 m^3,
- 20 baths for dyeing apparatus with the volume decreased to 2.8 m^3,
- 30 baths for dyeing apparatus with the volume decreased to 1.4 m^3.

This modernization would has saved the following water volume:

$$150 * 5 + 20 * 2.8 + 30 * 1.4 = 848 \text{ m}^3 \text{ per month;} \qquad (13)$$

and the following energy amount:

$$Q = m * c_w * \Delta t, \qquad (9)$$

$Q = 848000 * 4.19 * (110 - 30) = 284{,}249{,}600$ kJ/month = 284.25 GJ/month.

Those saved values give:

- ($848 \text{ m}^3/4325 \text{ m}^3$) * 100% = 19.5% of monthly technological water consumption,
- (284.25 GJ/25815 GJ) * 100% = 1.1% of monthly thermal energy consumption.

Based on monthly technological water consumption we can estimate savings in dye consumption (assuming 15% of dye being left in exhausted bath):

$$19.5\% * 15\% * 1126.2 \text{ kg} = 31.5 \text{ kg}. \qquad (14)$$

4. RESUME

The volumes described in this paper have been estimated as an example for September 1996, but they give the order of magnitude of raw material savings. The savings will be made when the proposal of a partly closed water loop is realised. Table 5 presents the expected monthly savings for the presented modernization at dyehouse in the Textile Company "Luxpol" Co.

Table 5

Value of monthly savings

Raw material	Value of savings	Decrease in consumption
Technological water	1094 m^3	25%
Energy	370.8 GJ	1.4%
Dyes	96 kg	8.5%
Other chemicals	785 kg	19%

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MOŻLIWOŚCI SYMULTANICZNEGO MINIMALIZOWANIA ZUŻYCIA WODY, ENERGII I CHEMIKALIÓW W BARWIARNI ZAKŁADÓW PRZEMYSŁU DZIEWIARSKIEGO „LUXPOL" S.A.

Zarządzanie prośrodowiskowe uważa się dziś za bardzo ważny element zarządzania w zakładach przemysłowych. Jedną z jego głównych zasad jest minimalizowanie ilości powstających zanieczyszczeń już w miejscu ich powstawania. W przedstawionym artykule opisano proste sposoby symultanicznego minimalizowania ilości zużywanej wody, energii i barwników w barwiarni Zakładów Przemysłu Odzieżowego „LUXPOL" S.A. w Stargardzie Szczecińskim. Pierwsze z opisanych rozwiązań zapobiega powstawaniu zanieczyszczeń w miejscu ich tworzenia się i polega na zmniejszaniu objętości aparatów barwiących w zależności od planu produkcji na dany okres. Drugie rozwiązanie polega na regeneracji wyczerpanych kąpieli barwiących i ich powtórnym użyciu w produkcji. Jest to przykład powtórnego użycia zużytych materiałów.