DEVELOPMENT OF A MODEL FOR ESTIMATING THE AMOUNT OF WASTE IN THE PRINTING INDUSTRY AND ITS IMPLEMENTATION

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ABSTRACT

Graphics industry as a service business recorded an increase in production. However, the development and output growth in the printing industry lead to the increase of hazards in the environment. No printing technique, that is used so far, is without harmful substances in its process. Starting from printing on laser printers, which are present in every office, to the most common offset print, where there are recorded hazards, but not as much as in flexographic printing. Hazards in the process of preparing, printing and finishing, come from printing inks, solvents and various printing materials (paper, cardboard, foil, textiles, ceramics, plastics).

The goal is to create a mathematical model that will, based on the input of raw materials in particular printing technique, be able to calculate how much waste of each kind is expected. Based on this, you can calculate the waste matter for each printing technique individually, which will enable control of waste records and storage. Also printers would be able to determine the capacity of the recycling and processing plant.

In addition to its prime goal to preserve the working and living environment, this research will lead to significant savings in printing houses themselves. The savings can be made in every technique and every stage of the printing process, because at each stage there is a part of the waste that is recyclable, which is not being recycled now, but mainly disposed of to landfills. This raises the hypothesis that in this way it is possible to reduce waste by 50%.

This model will be applied to the analyzed printing companies in Serbia, where there have been conducted researches on pollution in the past ten years. Waste is analyzed from the aspect of pollutants that are going into the air, water and land. Monitored values in the air are toluene, benzene, methoxy propanol, etc. Liquid waste consists of paint, adhesive and waste organic solvents such as methoxy propanol, ethyl acetate, toluene etc. When it comes to solid waste, paper, cardboard, foil waste, plastic and scrap metals are monitored.

Keywords: printing industry, model, waste.

1. Introduction

The development of computer completely changed the graphic industry. Printing techniques that were once the most common since the beginning of the 80s become obsolete, and the new ones are being developed. (Kipphan, 2001). The development and increase of production in the printing industry leads to increased hazards in the working environment. None of the printing technique that is known so far is without harmful substances in its process. Therefore, starting with the most common offset printing (DeJidas, 2005), where there are hazards identification, but not as present as in flexo printing, harmful effects are present in the most modern techniques such as digital printing. Hazards in the process of preparing, printing and finishing, originating from colours for the press, solvents and different printing materials. The prevalence of small printing shops, the lack of data and the small number of researches in this area are precisely the reason for this kind of the research. Hence, the objective of the paper is to make a mathematical model that, on the basis of input of raw materials in particular technique of the press, will be able to calculate how much of waste materials are expected and which type.

Based on that waste materials from each individual printing can be calculated, which will introduce the control into registers and storage of waste. Also, the capacity facilities for recycling can be dimensioned. The model will be applied to the analyzed printing companies on the territory of Serbia, where the research on consumption and harmful effects was conducted in the past ten years. Employers and managers need to understand that in addition to preserving the working and living environment, this research will lead to significant savings in very printing companies. The savings can be made in every technique and every stage of the printing process, because at each stage there is a part of the waste that can be recycled, which is now not being recycled but mainly disposed of to landfills. The first part of the paper analyzes the input and waste materials from offset printing. The continuation of the paper develops a mathematical model, that based on the input data (consumption of paper), is able to calculate the waste output from the process. In order to verify this model in practice, the biggest printing shops on the territory of Serbia dealing with offset printing will be analyzed. The values of the input materials will be measured, as well as the values of waste materials, and on that basis also the deviations, calculated by the model.

2. Offset printing and waste materials from the process

The most frequent waste materials from offset printing are: paper for printing, paints and varnishes, isopropyl alcohol and petroleum compounds. The term volatile compounds are used in a wide range of volatile organic compounds at ambient temperature and pressure. Many organic solvents which are used in various industries, as well as in the printing industry belong to the volatile compounds, and reducing their concentration in the atmosphere is one of the important processes that is required by the strategy of environmental standards in production. Every printing technique, as it is known, uses various chemical substances, but they are generally classified into three major classes: colours, binders and organic solvents. In a wide range of chemical substances used in the printing industry the following should be singled out: the colours based on organic solvents, heat set colours in offset printing, detergents for machine washing, wetting solution in offset printing. Isopropyl alcohol is used In offset printing as a means of dampening rollers, and for washing the pieces of equipment - oil derivatives with very low melting point.

Evaporable compounds have a significant impact on the environment, which is primarily manifested in the influence on the atmosphere. Locally speaking this is the formation of toxic compounds. The toxic effects of organic solvents on people are reflected through a coma and respiratory problems, irritation of mucous membranes and eyes, gastritis, hypotension, cardiac depression, brain damage, liver and kidney damage at a later stage. Regionally speaking, it comes to the formation of photochemical smog. Namely, volatile compounds with nitrogen oxides are the main precursor that, under favourable meteorological conditions and insulation, stimulates the synthesis of harmful substances in the lower atmosphere including, for example, ozone. Finally, globally speaking, dissociation of organic solvents and oxidation to carbon dioxide contributes to the formation of the greenhouse effect and climate changes, which are more visible.

3. Development of model for determining the quantities of waste

3.1. Paper consumption

When printing the graphic products, it is starting from the consumption of paper (COBRPP, 1986). For the calculation of the required amount of paper it is necessary to define the dimensions of the finished product D_f (m^2). Part of waste paper must be counted as a need for the printing process, which contains the necessary data for printing and finishing process (various types of markers), which will be marked with D_p. Also, when installing the pages, a part that will be cut within the final graphics processing in the design of the finished product D_c must be included. In machines preparation, depending on the type of machine and the number of colour machines and prints, a certain amount of waste paper is created (proof sheets and running of the machine) D_s. It is necessary to include a certain number of waste materials that will appear in the case of machine failures during the work process, paper jams and other unplanned situations on the machine D_m. Thus, it is obtained that the total area of waste paper is equal to:

$$D = D_p + D_c + D_s + D_m$$

Part of the paper used for labels for quality control of the printing, to label the final graphic processing, as well as space for the machine grippers in the printing process require surface D_p. This area requires a minimum of 5mm at the sides, 6mm at the top and 13mm at the bottom side and it is calculated by the following equation.

$D_p = (5+5) \cdot A + (6+13) \cdot B$, where: A - width of the sheet, B - the length of the sheet.

The easiest way to show how to calculate D_c can be seen in the case of making of the book. When the pages of the book are placed next to each other depending on the way how they will be set later in the book, it is necessary to leave room for the final trimming of a book. The minimum waste paper will be calculated on the sheet of size B1, where 16 sheets can be set, or 32 pages. The minimum space between the sheets is calculated as:

$D_c = n_p \cdot (a+b) \cdot 2 \cdot 3$, where:$n_p$–number of pages in a sheet, a - length and b - width of pages. In preparation of the machine, depending on the type of machine and how many colours the machine prints in a single pass, and the number of colours on the printout, waste paper for proofing (D_s), is calculated, with the help of factors t_a, which is determined empirically. Values t_a, are given in Table 1.

Table 1: Values t_a, depending on several factors, is obtained experimentally

Machine	**t_a in sheets**
One colour	50-100 (per colour - pass)
Two colour	50-100 (per colour - pass)
Four colour	150-250

$D_s = t_a \cdot A \cdot B \cdot s \cdot d$, where t_a –waste sheets in preparation of the machine and the reading is based on machine type and job complexity, s-the number of rotations (operations) on the machine and d – number of working days.

During the operation of the machine there may be some delays and failures that also provide a certain amount of waste material D_m. It is calculated from the equation below.

$D_m = f \cdot A \cdot B$, where:f-the percentage of waste material in sheets, read from the Table 2.

Table 2: Values f depending on the machine and the number of prints (BPIF, 2012)

Machine	Up to 10 000 prints f	More than 10 000 prints f
One colour and two colour	3% 0,03	2% 0,02
Four colour	8% 0,08	6% 0,06

By replacing the obtained expression in the initial equation, we get the final shape of the model for the of waste paper surface.

$$D = N_p \cdot [(5+5) \cdot A + (6+13) \cdot B + n_p(a+b) \cdot 2 \cdot 3 + f \cdot A \cdot B] + t_a \cdot A \cdot B \cdot s \cdot d$$

3.2. Consumption of other substances

First it is necessary to determine the amount of colour, and based on that the consumption of other raw materials used in the processes of preparing, printing and finishing.

The consumption of colour [kg] per sheet can be calculated according to the equation:

$B = \frac{2n_p 0{,}75(a \cdot b)10^{-6} f_p}{f_b}$, where: f_p – printing coverage area is determined based on the number of colours on the printout (Savic, 2011); 0,75 correction factor of the printed surface dimensions (borderless). Factor of the consumption of colour f_b is determined experimentally (Novakovic, 2012).

Other agents here are calculated as shown below. According to the consumption of colour, the number of printouts and number of different tasks, solvent oil consumption (P17) is calculated as follows:

$V_{P17} = f_{P17} \cdot B/\rho_{P17}$, where: f_{P17} – factor of substances consumption P17, (Savic, 2011); B – mass of the colour consumption, ρ_{P17} – specific weight of substances P17.

In a similar manner the consumption of oil treated with hydrogen is calculated (P21).
$V_{P21} = f_{P21} \cdot B/\rho_{P21}$, where: f_{P21} – factor of substances consumption P21, (Savic, 2011); ρ_{P21} – specific weight of substances P21.

A mixture of non-aromatized hydrocarbon (RG-31) is calculated as follows:
$V_{RG31} = f_{RG31} \cdot B/\rho_{RG31}$, where: f_{RG31} – factor of substances consumption RG-31, (Savic, 2011); ρ_{RG31} – specific weight of substances RG31.

Isopropyl alcohol consumption is calculated according to the equation:
$V_{IA} = f_{IA} \cdot B/\rho_{IA}$, where: f_{IA} – factor of the isopropyl alcohol consumption (Savic, 2011);, ρ_{IA} – specific weight of isopropyl alcohol

4. Application of the model for determining the quantity of waste

4.1. Calculation of waste material

To check the model we considered the company Rotografika from Serbia that will be analyzed, which deals with offset printing. This company has four-color machines for printing from the sheet of B1 format (1000x707mm), and the initial sizes of paper are (1034x747mm). Based on the model the amount of waste material is calculated. A part of the waste paper used to label the print quality control D_p, is:

$D_p = (5+5) \cdot 1034 + (6+13) \cdot 747;\ D_p = 0{,}024533\ m^2$. Waste paper which is obtained in the finishing of printed (graphic) products Dc is: $D_c = 16 \cdot (250+176) \cdot 2 \cdot 3;$
$D_c = 0{,}040896\ m^2$. The amount of paper that is a waste material in the preparation of machines D_s is equal to: $D_s = 200 \cdot 1034 \cdot 747 \cdot 4 \cdot 360;\ D_s = 222450{,}6\ m^2$. The amount of paper that is a waste material in the preparation of machines D_m is equal to:

$D_m = 0{,}06 \cdot 1034 \cdot 747;\ D_s = 0{,}046344\ m^2$.

Using the input data that the daily consumption of paper in Rotografika is 47769 kg, i.e. 17196.8 t annually, and that the average weight of paper is 80gr/m^2, by calculating the total consumption of paper, the surface of waste paper is obtained according to the model. $D = 214960500 \cdot [0{,}024533 + 0{,}040896 + 0{,}046344] + 222450{,}6;$
$D = 24249230{,}5 m^2$.

Knowing that the average weight of paper is 80gr/m^2, the result is that the total mass of waste paper is 1939938,4kg or 1939.94 tons.

The consumption of colour per sheet can be calculated according to the equation:

$B = \frac{2 \cdot 16 \cdot 0{,}75 \cdot (250 \cdot 176) \cdot 10^{-6} \cdot 1{,}0}{568{,}8};\ B = 0{,}0018565$ kg.

For the total number of sheets in the production, the paint consumption of 399082 kg is obtained. Based on this, the amount of other waste chemicals is calculated.

$V_{P17} = 0{,}01 \cdot 399082/0.88$; V_{P17}=4535 liters. $V_{P21}=0{,}011 \cdot 399082/0{,}88$; V_{P21}=4989 liters.
$V_{RG31}=0{,}036 \cdot 399082/0{,}8$; V_{RG31}=17958 liters. $V_{IA}=0{,}1 \cdot 399082/0{,}786$; V_{RG31}=50774 liters.

4.2. Measurements of waste material

The company Rotografika measured the mass of waste paper of 2000 t, while calculated according to the model was 1939.94 t. Partial deviations have occurred, but are in very narrow tolerances. The model can be even more precise, so we will take the exact number of working days and the exact number of tasks, as well as the diversity of tasks. Measurements from the printing shop show that the annual colour consumption of 400,000 kg, and the calculated consumption is 399082 kg. Therefore, here measured deviations of the calculated ones are minimum. Measured amounts of other waste chemicals are: V_{P17} =5000 liters; V_{P21} = 5645 liters; V_{RG31}=17900 liters; V_{IA} = 50500 liters. It is notable that in the first two substances we recorded significant deviations from calculated in the model, while the other two substances have minimal deviation. This is because the first two substances are used for manual washing, so obviously the exact measured quantities are not taken, but it's done arbitrarily.

5. Conclusions

Based on what has been said it is evident that the developed model gives quite precise amounts of waste material from offset printing shops. Deviations are possible due to the fact that tasks are not always the same, but in general it is possible, based on the amount of input paper, to determine all waste materials in the printing company. This is a very useful information for both employers and supervisors, because the employer can predict the recycling material and prepare for a situation where savings could be made. Also, supervisors can determine the exact amount of waste material, to control the disposal of this waste material and thereby reduce environmental pollution. In future research the model will be developed, working on its higher use and testing its accuracy.

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