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SUSTAINABLE USE OF RECOVERED PAPER IN THE ROMANIAN PAPER INDUSTRY. PART II – ENVIRONMENTAL IMPACT

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Abstract

In the last decades, the surface of Romanian forests decreased due to an intensive harvesting and, as a consequence, the price of pulpwood significantly increased. In the same time, the regulations for environmental protection were successively hardened in Romania, so that all chemical pulp mills were closed for economic and environmental reasons. In these circumstances, Romanian paper producers shifted to recovered paper as raw material. This decision is in accordance with trends of European paper sector, where recovered paper continuously strengthened its position as raw material for paper industry. The good-looking price of recovered paper is the main reason for using it in producing paper and board. In addition, paper made from recovered paper reduces the demand of wood, uses less energy, water and chemicals, produces less toxic releases and reduces carbon dioxide emissions.
From the environmental impact point of view, using of recovered paper as raw material represents the best alternative for Romanian paper sector. Romanian paper industry is based almost exclusively on recovered paper and the utilization rate of recovered paper in producing paper and board was 88.4% in 2012. The high utilization rate can be explained by the structure of Romanian paper sector that produces paper grades for corrugated board and sanitary papers. The main goal of this paper is to evaluate the environmental impact of using recovered paper as raw material in Romanian paper industry.

Key words: environmental impact, papermaking, recovered paper, resources

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1. Introduction

Paper manufacturers are always concerned with two issues: increasing the competitiveness of papermaking by reducing costs of any kind and compliance with environmental indicators in producing paper. According to Patronizing Organization for Romanian Pulp and Paper Industry - ROMPAP, paper consumption in Romania in 2012 was 34.5 kg/capita.year, compared with an average of 130 kg/capita.year in Europe (ROMPAP, 2013). The main reason for this discrepancy is the low living standard in Romania. As a consequence, Romanian paper industry adjusted its production, regarding both the volume of production and paper grades.

The paper production stabilized in the last years at around 300,000 tones/year and the paper grades produced currently in Romania are papers for corrugated board and sanitary papers. Table 1 shows the structure of paper production in Romania (ROMPAP, 2013). As Table 1 shows, the production is strictly oriented towards two paper grades of low or medium quality like papers for corrugated board (65%) and sanitary papers also called tissue papers (35%).

No high-quality papers are produced as printing papers or coated papers. Paper and board consumption in Romania was 737,000 tones in 2012, so that the difference (419,000 tones of paper and board) was imported.

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The paper producers state that the most important advantage of using recovered paper as raw material is its acquisition cost. The price of recovered paper is 5-6 times lower compared to the price of chemical pulp. According to FOEX, the price of unbleached softwood kraft pulp was around 600 Eur/tone in the middle of November 2013. For comparison, the average price of recovered paper was 105 Eur/tone for old corrugated containers and 128 Eur/tone for old magazines and newspapers (FOEX, 2013).

Table 1. Structure of Romanian paper industry (ROMPAP, 2013)

Paper grade	*Paper production, tones*
Papers for corrugated board	206 000
Sanitary papers	112 000
Total production	318 000

Many years of experience in paper manufacture have proved that recycled fibers can be used in composition of many grades of paper as is presented in Table 2 (Vlase et al., 2012). It is obvious that excepting some sanitary and printing papers, the most common paper grades contain up to 100% recycled cellulosic fibers.

Table 2. Recovered paper pulp content of most produced paper grades at global level

Paper and board grade	*Recovered paper pulp content, %*
Sanitary	0-100
Papers for corrugated board	100
Cartonboards	80-100
Packaging	40-100
Printing	0-100

In Romania, recovered paper gained a special attention in producing papers for corrugated board and Table 2 shows that these paper grades are obtained exclusively form recycled fibers. This reality is particularly important due to the fact that these papers are among the most produced in Europe. More than 40 million tones of packaging papers were produced in 2012 in Europe, representing 43% of total paper production. Papers from corrugated board totalized 24.8 mil. tones in the same year, yielding 62% of packaging papers (CEPI, 2012).

2. Environmental impact of using recovered paper in papermaking

Environmental impact of using recovered paper in papermaking is usually quantified by a number of indicators, the most important being: energy use, water use, emission of greenhouse gases, discharges to water, solid waste generation (Gavrilescu et al., 2012; Iosip et al., 2012a, b; Kinsela, 2012; Muhamad et al., 2012).

One of the most important advantages of using recovered paper refers to the wood economy. Every tone of recovered paper pulp replaces one tone of virgin chemical pulp that is obtained from 4-5 m^3 of wood. This fact is very important for Romania where the forests surface rapidly reduced in the last decade. Currently, there are no chemical pulp mills operating in Romania due to the fact that the paper producers have been geared towards recovered paper and to the shortage of pulpwood.

Manufacturing pulp from recovered paper is less complicated than producing virgin chemical pulp from wood (CEPI, 2004). A chemical pulp mill includes complex processes and expensive equipments such as high pressure pulp digesters and recovery boilers. Chemical pulp manufacture needs corrosive and pollutant chemicals, high pressure steam and large volumes of process water. By contrast, recovered paper processing consists from fewer and less sophisticated technological stages and requires cheaper equipments (Bajpai, 2013; Miranda et al., 2010). Fig. 1 shows the flow sheet of recovered paper processing.

As Fig. 1 shows, recovered paper processing includes three main stages: slushing (converting the recovered paper into a suspension of individual fibers), pulp screening (that aims to separate fibers from the nonfibrous materials which differ in composition, size and shape) and de-inking (enhancing the brightness of recovered paper pulp). De-inking stage is included when pulp for sanitary paper is produced. Other stages refer to reject and sludge processing. The simplicity of the recovered paper processing technology represents the main reason which led to the implementation of this technology by the Romanian papermakers (Gavrilescu et al., 2008; Vlase et al., 2013).

Water use is a major environmental indicator, as it shows both the volume of fresh water needed and the impact of used water discharge. The specific water consumption in paper manufacture depends on the paper grade, raw material (chemical pulp or recovered paper pulp), technical level of recovered paper plant and of paper machine (Gavrilescu et al., 2008). Due to the increasing price of water in Romania, efforts have been made to reduce the overall water consumption. Two directions have been followed: the reduction of water usage in each stage of production and the increase of recirculation degree of water resulting after used water treatment aiming to replace fresh water.

In order to further reduce the costs with water, some paper mills use water taken from wells drilled in their courtyard. Table 3 shows the consumption of process water in Romanian paper mills (Gavrilescu et al., 2008; Gavrilescu, 2012). As Table 5 shows, the production of paperboards (papers for corrugated board) requires considerable less process water than sanitary papers. This difference is due to the fact that sanitary papers are obtained from de-inked recovered pulp. De-inking stage requires an additional volume of water for pulp flotation and pulp washing. Paper manufacture uses energy in the form of steam and electricity.

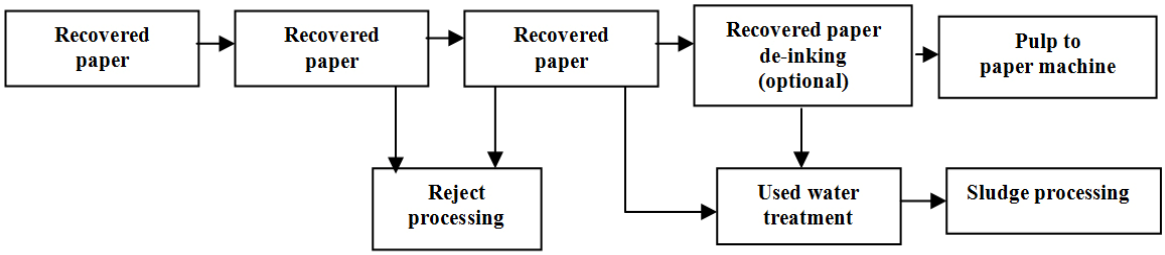

Fig. 1. Flow sheet of recovered paper processing

Energy is needed to manufacture both paper from chemical pulp and paper from recycled fibers, but much less energy is needed to produce paper grades from recovered paper. Typical energy savings by replacing virgin chemical pulp with recycled fibers in paper manufacture range between 28-70%, (Teodosiu et al., 2007).

Table 5. Specific consumption of process water in Romanian paper mills

Paper grade (recovered paper based)	***Consumption of process water, m^3/t of paper***
Paperboards	2-7
Sanitary papers	10-15

Specific energy consumption depends on the paper grade, technological level of paper mill, management of energy conservation and on the season (summer or winter). Energy is also required for collecting, sorting and transporting of recovered paper to paper mills, but recent studies in Romania showed that the contribution of these stages to overall energy consumption is very low, if compared with energy consumption for recovered paper processing and paper manufacture (Iosip, 2012). Table 6 shows specific consumption of energy in Romanian paper mills.

The figures presented in Table 6 show that sanitary papers require larger quantities of electrical energy and steam if compared with papers for corrugated board. The main causes are related to the lower grammage of sanitary papers and the necessity of a de-inking stage that increases the electricity and steam consumption. During wintertime the specific energy consumption can be 10-20 % higher than during summer season. In order to reduce the energy consumption, some Romanian paper mills are equipped with dedicated boilers for burning sludge from waste water treatment plant and rejects generated during recovered paper processing (Matcasu and Botez, 2012).

Replacing chemical pulp with pulp made from recovered paper influences CO_2 emissions of the paper industry sector. No detailed calculations were performed regarding the greenhouse gases (GHG) emissions of the Romanian paper sector. Assessment of the impact of paper recycling on GHG emissions is not a simple task because it should take into account the followings:

- fossil fuel-related GHG emissions from recovered paper processing and paper manufacturing;
- carbon sequestration in forests;
- methane emissions from landfilled recovered paper;
- avoided emissions associated with the burning of used paper as bio-fuel;
- GHG emissions of other alternatives to recycling for recovered paper.

Table 6. Average specific consumption of energy in Romanian paper mills

Paper grade (recovered paper based)	***Energy consumption***	
	Electrical energy, kWh/t	***Steam, t/t***
Recovered paper processing		
Paperboards	200	-
Sanitary papers	250	0.3
Paper machine		
Paperboards	580	1.30
Sanitary papers	550	1.40
Total consumption		
Paperboards	780	1.30
Sanitary papers	800	1.70

In Romania, recovered paper is only used as a raw material in the paper sector. The waste paper that is not collected is landfilled and other alternatives for paper recycling are not in force. In these circumstances, GHG emissions refer to emissions related to paper manufacture, carbon sequestration in forests and landfilling of waste paper.

Regarding the recovered paper processing and paper manufacturing, recent studies showed that the intensity of carbon dioxide emission is drastically reduced for papers made from recycled fibers, as is shown in Table 7 (Vlase et al, 2012).

Paper recycling recovers used paper from the waste stream, directly reducing the amount of paper landfilled. Unfortunately, in Romania, large quantities of waste paper still end up in the landfills, where the decomposition of paper produces methane, a greenhouse gas with 21 times the heat-trapping power of carbon dioxide. It was found that every tone of used corrugated board boxes that end up in the

landfill generates 1.12 tones of carbon dioxide (NCASI, 2009).

Table 7. Comparison of CO_2 emission intensity in producing paper grades using virgin fibers and recovered fibers

Paper grade	***CO_2 emission intensity (t/t of paper)***
Paper made from virgin fiber pulp	0.9 - 1.5
Paper made from recovered paper pulp	0.15 - 0.4

Thus, for recycled papers, any increase in greenhouse gas emissions due to manufacturing is more than outweighed by reductions in emissions from landfills (Skovgaard et al., 2008). Efforts must be made to increase the collection rate of recovered paper in Romania and paper mills are the main actors involved in this action.

If waste paper is recycled, the carbon stored in the paper product is prevented from going back to the atmosphere, keeping the fibres that originated from sustainable forestry in the value chain. For this reason, carbon sequestration in paper products is significantly prolonged by their recycling.

In most studies dealing with the effect of paper recycling on GHG emission, the influence of recycling on forest carbon sequestration is ignored. It is known that one half the dry weight of wood is carbon. By using recovered paper large amounts of pulp wood are saved what brings benefits regarding carbon sequestration in forests. Few data regarding the true contribution of recovered paper on forest carbon sequestration are available in the literature. In one study, the net benefits for paper recycling compared to waste paper landfilling were found to range from 2.57 to 5.03 tones CO_2 per tone of paper (USEPA, 2002). Of this, 3.34 tones CO_2 were due to anticipated increased forest carbon sequestration, meaning that forest carbon sequestration was accountable for the estimated benefits of paper recycling.

Discharges to water are one of the main problems of the Romanian paper mills. This is due to the large water consumption in producing paper and due to the fact that recovered paper is highly contaminated. According to Romanian legislation, the limits of discharges to receiving surface waters are listed in Table 8 (NTPA 001, 2002). The limits of discharges are expressed in terms of concentration (mg/L), and correspond to those included in the EU Water Framework Directive 2000/60/EC adopted in 2003 (EC Directive, 2002b).

Waste waters of the most Romanian paper mills are discharged directly to the surface waters after both primary and biological treatment at the site. In few cases, the waste waters are discharged to a municipal treatment plant after a primary clarification stage for suspended solids removal. In order to obtain a more accurate picture of the level of waste waters load, the discharges are expressed in mg/L and kg/t of paper as well. The second unit of measure is preferred by the paper producers because they consider that kg/t reflects more accurately the environmental impact of paper mill.

Table 8. The limits of discharges to receiving surface waters according to Romanian legislation (NTPA 001, 2002)

Parameter (selection)	***Emission limit value***
Temperature, ^oC	35
pH	6.5-8.5
Suspended solids, mg/L	35
BOD, mg/L	20
COD, mg/L	70
NO_3^-, mg/L	25
Total Phosphorus, mg/L	1.0
Chlorides, mg/L	500
Ca^{2+}, mg/L	300
Al^{3+}, mg/L	5
Cd^{2+}, mg/L	0.2
Total Chromium, mg/L	1.0
Cr^{6+}, mg/L	0.1
Hg^{2+}, mg/L	0.05

Emissions from paper mills to water strongly depend on the quality requirements of the paper grade and on the class of recovered paper from which paper is made. Other factors of influence refer to additives used, process management and to technical level of involved installations. For example, the emissions to water are considerably higher if paper is produced from de-inked pulp.

Due to the great number of factor influencing the emission to used water, the discharge largely varies from mill to mill. Specific data are not available regarding the emissions to used water of Romanian paper mills. The Romanian environmental authorities ask to paper producers to fit within the limits stipulated in NTPA 001/2002. Due to the fact that Romanian mills producing paper from recovered paper have a good technical level, framing within the above-mentioned limits is not difficult. Practical data regarding the emissions to water in producing paper from recovered paper are included in Best Available Techniques and these are presented in Table 9 (BAT, 2001).

Table 9. Average water emission data after used water treatment plant (biological treatment included)

Parameter	***Non-deinked pulp***		***Deinked pulp***	
	mg/L	***kg/t***	***mg/L***	***kg/t***
BOD_5 before treatment	1800	12.3	770	8.3
BOD_5 after treatment	10	0.06	9	0.09
COD before treatment	3200	22.0	1900	21
COD after treatment	150	0.77	290	3.1
N_{tot}	5.6	0.03	7.8	0.08
P_{tot}	1.5	0.01	n.a.	n.a.
TSS	25	0.13	n.a.	n.a.
Discharge volume, m^3/t	-	5.7		11

n.a. – not available

Table 9 shows that the waste waters entering the treatment plant have high organic loads, mainly in terms of BOD and COD. After treatment plant, BOD is strongly diminished, while COD values are still high, mainly if de-inked pulp is used.

Recovered paper processing generates important quantities of solid wastes that originate from contaminants and other detrimental substances such as:

- additives used at previous paper production process (fillers, coating components, functional and process chemicals);
- substances added according to application (printing inks, coatings, foil laminations, adhesives);
- material mixed with the paper during its life cycle and subsequent collection (wires and strings, textile and wood fragments, sand and stones, paper clips);
- cellulosic material (fiber fines) lost at screening and cleaning of recovered paper pulp.

Contaminants have to be removed to meet manufacturer requirements concerning product quality. The level of recovered pulp purity will depend on the paper grade produced. High contaminated recovered paper is only suitable in producing of lower paper grades. Recovered paper processing can lead to low pulp yields, as a proportion of cellulosic material is lost due to the removal of contaminants and short fibers.

In paper mills, large quantity of rejects is generated during slushing, screening and cleaning of recovered paper pulp. Depending on the paper grade, the overall reject rate varies from 5-8 % for used corrugated containers to 25-40 % and even more for old magazines and newspapers (Sánchez, 2009). The most reliable indicator of rejects generation is specific consumption of recovered paper that ranges between 1.07 - 1.40 t/t of paper. In other words, 70 - 400 kg of rejects are generated in producing one tone of paper. The higher value refers to the paper made from de-inked pulp. The rejects composition strongly differs from mill to mill. The main components are wires (from bales), plastics and cellulosic material.

Paper and board detrimental to production represents another category of solid waste. These consist from paper and board grades which have been treated in such a way that they are harmful for paper production and/or paper quality. Examples refer to specialty papers like: coffee filters, dust bags, pressure-sensitive labels, thermal printing papers, wallpapers, barrier papers. As a rule, detrimental paper grades have to be eliminated during recovered paper sorting, but practice shows that small quantities of these enter in the process. An important category of solid waste is sludge generated during treatment of process water and waste water. There are three categories of sludge: sludge from process water clarification, de-inking sludge and used water treatment sludge (Abubakr et al., 1995). Sludge properties depend on the grade of paper being produced, recovered paper characteristics, fiber losses during the production process and on efficiency of used water treatment plant.

Table 10 shows the main characteristics of sludge generated in producing paper for corrugated board in a Romanian mill (Matcasu and Botez, 2012).

Table 10. Main characteristics of sludge generated in producing paper for corrugated board in a Romanian mill

Parameter	***Value***
Moisture, %	50.0
Ash, %	22.2
Carbon, %	10.0
Hidrogen, %	1.27
Nitrogen, %	0.19
Sulphur, %	0.05
Combustion heat, kJ/kg	4320

As Table 10 shows, the sludge is firstly characterized by high content of moisture and ash. The values of these parameters are very important since moisture and ash strongly influence burning capacity of sludge. A combustion heat of 4320 kJ/kg is not satisfactory for incineration of sludge, and for this reason a supplementary fossil fuel must by used.

According to their composition rejects are incinerated or/and landfilled. The practice of Romanian paper mills proves the following ways of rejects valorization (Gavrilescu and Bobu, 2009):

- binding bale wires are sold as used iron;
- organic material (plastics, cellulosic material, sludge, wood and textile fragments) is incinerated in a dedicated boiler;
- non-organic reject (sand, stones) is landfilled.

Some Romanian paper mills are endowed with boilers able to incinerate high moisture content organic materials. In order to increase the combustion heat of organics, the boilers are fuelled with a mixture of plastics, dehydrated sludge and other organic rejects. Plastics are a valuable fuel regarding available heat, the values range between 23.0 MJ/kg for polyvinylchloride and 44.0 MJ/kg for polyethylene (Gavrilescu, 2008). Burning of rejects presents advantages and drawbacks as well. The main advantage refers to the boiler steam that is send to the paper machine. In this manner, fossil fuel is saved, by thus enhancing the competitiveness of the paper mill. In addition, rejects incineration reduces the expenses with waste landfilling. The drawbacks of rejects incineration refer to the emission to pollutant gases and to the generation of ash.

Combustion of plastics is a highly pollutant process. During combination of oxygen, plastics carbon is converted to carbon dioxide, hydrogen to water, sulfur to sulfur dioxide, nitrogen to cyanides or molecular nitrogen, and chlorine to hydrochloric acid. Many other harmful volatile compounds were detected in the flue gases (Simoneit and Medeiros, 2005).

Paper sludge consists of printing inks, fillers and coating pigments, short fibers, and adhesives. Inorganic compounds represent more than 55% of the sludge solids and they consist of fillers and coating pigments such as clay and calcium carbonate. The

proportion of cellulosic fiber is low. The combustion value of sludge (dry matter) depends on the ash content and is between 4700–8600 kJ/kg, (Hamm, 2006). The moisture drastically reduces the combustion capacity of paper sludge. Burning of sludge is beneficial because the landfill volume required for ash disposal is about four times lower of that required for sludge. In addition, boiler ash generated at sludge incineration can be used in cement industry. Sludge ash contains heavy metals and if their concentration will arrive at hazardous levels, the ash will require a particular processing, (Shin et al, 2005).

In Romania, Government Ordinance 746/2004 stipulates the limits of pollutant emissions in air of boilers and other combustion plants used for incineration of all kind of solid wastes (municipal waste and sludge). The restrictions refer both to emissions of particulates and volatile compounds and are listed in Table 11.

The values listed in Table 11 are in concordance with the Directive 2000/76/EC of the European Parliament and of the Council on the incineration of solid wastes (EC Directive, 2000a). It is compulsory for the Romanian paper makers to accomplish the emission limits included in Table 11 at burning of solid wastes generated in their paper mills.

Table 11. Air emission limit values at solid waste incineration

Pollutant	***Concentration, mg/Nm^3 at 11 % oxygen***
Particulates	10
VOC as C	10
HCl	10
HF	1
SO_x	50
NO_x	200
Cd	0.05
Hg	0.05
Heavy metals, total	0.5

Incineration of plastics and sludge mixture can release flue gases having higher concentration of the pollutant than those listed in Table 11. To avoid this risk, the ratio between plastics and sludge entering in the boiler has to be optimized and burning parameters must remain permanently under control.

3. Conclusions

Romanian paper producers consider that the low price is most important advantage of using recovered paper as raw material. To avoid the use of expensive chemical pulp, the manufacturer extended the number of paper grades that are produced from recovered paper. Excluding some sanitary papers, the paper grades produced in Romania contain 100% recycled cellulosic fibers.

Water consumption is a major environmental indicator in producing paper, as it shows both the volume of fresh water needed and the volumes of waste water discharge. Two directions have been followed by the Romanian paper sector in order to reduce the overall water consumption: the reduction of water usage in each stage of production and the increase of recirculation degree of water resulting after waste water treatment plant. In order to further reducing of costs with water, some paper mills use water taken from wells drilled in their courtyard.

Sanitary papers require larger quantities of electrical energy and steam if compared with papers for corrugated board, the main cause being the de-inking stage that supplementary consumes electricity and steam. During wintertime, the specific energy consumption can be 10-20 % higher than during summer season. In order to reduce the energy consumption, a number of Romanian paper mills are equipped with dedicated boilers for burning sludge from waste water treatment plant and rejects generated during recovered paper processing. In order to increase the combustion heat of organics, the boilers are fuelled with a mixture of plastics, dehydrated sludge and other organic rejects.

The practice of Romanian paper mills proves the following direction of rejects valorization: binding bale wire is sold as scrap iron; organic materials (plastics, cellulosic material, sludge, wood and textile fragments) are incinerated in a dedicated boiler; inorganic rejects (sand, stones) are landfilled.

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