Piotr Przybysz,
***Kamila Buzała**

Development Directions of the Raw Material Base of the Paper Industry with regard to the Sustainable Development Concept

Institute of Papermaking and Printing,

***Faculty of Biotechnology and Food Science,**
Lodz University of Technology
ul. Żeromskiego 116, 90-924 Łódź, Poland
E-mail: piotrprzybysz@interia.pl

Abstract
Paper is one of the most common mass products used nowadays. Present paper consumption has reached almost 400 million metric tons globally. Such a huge volume of production requires stable and continuous supply of raw materials in the form of wood and recovered paper. This article presents the current situation in the field of raw materials supply for the paper industry. Firstly it needs to be underlined that in the 21st century recovered paper has already become as equally an important raw material as wood, and soon the production of paper from secondary fibre pulps may match the volume of production of paper from virgin pulps. Moreover a detailed insight into future challenges and possibilities of broadening the raw materials base for the production of paper is also given. Finally the best possible methods to ensure a constant supply of wood and recovered paper for industry are also featured.

Key words: *wood, raw material, paper industry, paper production, paper consumption.*

Introduction

The extremely high and constantly growing global demand for raw materials and energy has caused a decrease in the available supply of these resources and has resulted in an increase in their price [1, 2].

Wood as a renewable, natural raw material has many valuable properties. Hence, for centuries it has been commonly used in the building, furniture and papermaking industries, as well as in many other branches of the economy. Wood is also a very good heat carrier. Because of the fact that it is a renewable raw material and wood has exceptional properties as fuel; incineration or co-firing with the addition of this material is rewarded in the form of subsidies. These actions aim to reduce the use of fossil fuels as well as CO_2 emissions [3 - 6].

The forest is not only a source of wood but also a very important element of the ecosystem on our planet. The gradual decrease in forest territories and wasteful exploitation of forest resources has brought about a decrease in the reserves of these resources. This tendency poses a considerable risk for the Earth's ecosystem [7, 8].

Since the 19th century wood has been a basic raw material for paper production. Globally the papermaking industry uses about 15% of the total wood procurement. The dynamic increase in demand for paper products results in constantly growing orders for supply of this raw material. The limited resources and growing deficit in the availability of wood can be an important factor limiting the development of the paper industry [9, 10].

Production and consumption of paper products

In the second half of the 20th century, the development of technology and the economy as well as improvement of the living standard of society have induced a very fast increase in paper product consumption, from about 50 million tons to about 320 million tons per year. Only in the first decade of the 21st century did the consumption of paper products increase up to 394 million tons (***Figure 1***) [11].

Currently paper products are used in the form of printing, packaging, sanitary and special paper products [12].

For assessment of the raw material base, the production and global arrangement

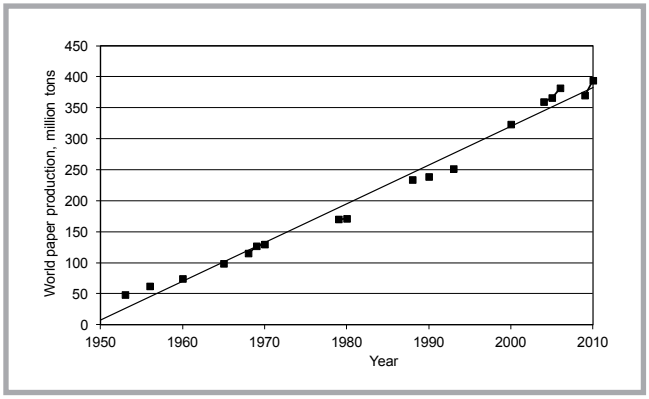

Figure 1. *Increase in world production and consumption of paper products in the second half of the 20th century and at the beginning of the 21st century.*

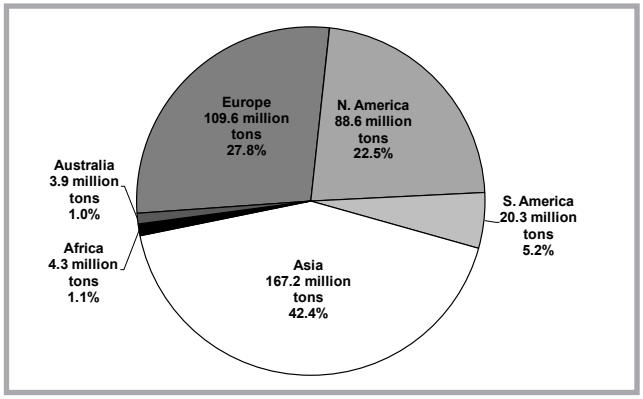

Figure 2. *Arrangement of paper industry in 2010.*

Przybysz P, Buzała K. Development Directions of the Raw Material Base of the Paper Industry with regard to the Sustainable Development Concept.
FIBRES & TEXTILES in Eastern Europe 2014; 22, 4(106): 18-23.

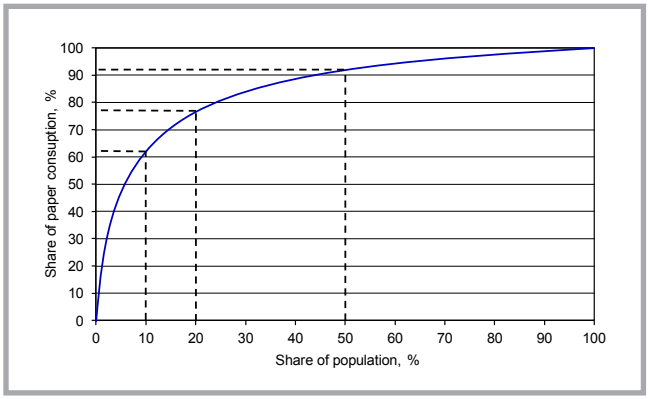

Figure 3. *Share of people in the world in relation to the paper consumption.*

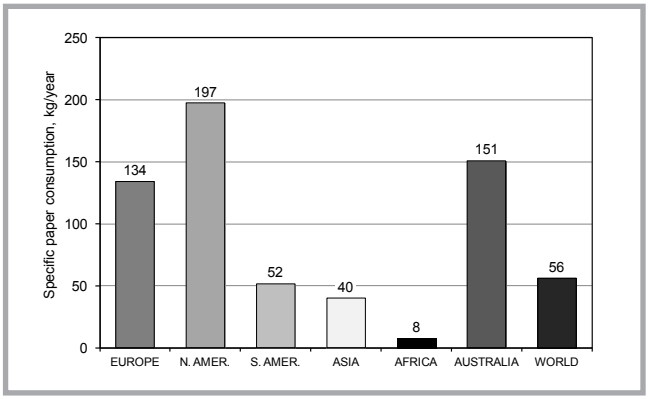

Figure 4. *Specific paper product consumption in different world areas in 2010.*

of the paper industry has to be taken into consideration (***Figure 2***). The arrangement of paper mills depends on, among others, the demand for paper products, the infrastructure, costs of the labour force and their qualifications, and many others.

At the end of the first decade of the 21st century, the global production and consumption of paper was at a level of about 394 million tons. Over half (50.3%) of this production took place in Europe and North America, while in Asia it was about 42% of the total paper production. On the other hand, a relative low share in world paper production could be found in countries of South America (5.2%) and Africa (1.1%). On these continents, paradoxically very rich in vegetable raw materials (especially in case of South America), paper production is only at the level of 6.3% of the total world paper production, being an effect of limited sales markets and poorly developed economies and energy infrastructures, among others [13, 14].

The very uneven distribution of the papermaking industry's capacity in the world is confirmed by the fact that almost half of the world paper production (49.5%) is concentrated in 3 countries (China, USA, Japan), and the first ten countries produce over 70% of world paper production [15].

The uneven distribution of paper consumption in the world is very precisely described by the graph, showing the percentage share of people in the world in relation to that of paper consumption (***Figure 3***).

This graph shows that about 10% of the world population, mainly from highly developed countries, consumes about 60% of all paper produced, and similarly 20% of the world population is responsible for the consumption of 80% of paper. Besides the volume of production, an important factor is also that of paper consumed, which is expressed by specific paper consumption i.e. fells per inhabitant. The value of this parameter globally is at the level of about 56 kg. This factor strictly depends on the level of civilisation development of each country, varying from 8 kg in Africa up to 200 kg in North America and Western Europe (***Figure 4***).

Statistical data presented for different world regions show average values and do not express differences within each world region.

Regarding continuous civilisation development on our planet, it should also be taken into consideration that an increase in demand for paper products is going to take place, especially in less developed countries, which represent the majority of the world's population [16, 17]. Assuming that the growth of specific paper consumption on a global scale is to rise up to a moderate level of 100 kg annually, it can be forecasted that by the middle of the 21st century paper production and paper consumption will have doubled [18].

Raw material base for the papermaking industry

Despite the stable increase in demand for paper products, the main factor which in the future will hinder the development of the production of these products is a limited raw material base for the paper industry with respect to fibrous and vegetal raw materials. On a global scale, pulps made from vegetal raw materials make up about 90% of the weight of final products (***Figure 5***, see page 20).

Virgin as well as secondary fibres pulps are used for paper production. Virgin pulps are made directly from vegetal raw material, mainly from wood, whereas secondary fibres pulps are produced from recovered paper.

On a global scale, in 2010, the production of 394 million tons of paper products required the use of 186 million tons of virgin pulps (made mainly from wood) and 160 million tons of secondary fibre pulps.

Virgin pulps

Virgin pulps are the basis of the raw material base for the papermaking industry. These pulps have been produced from vegetal raw materials since the 19th century, mainly from wood (over 90%) and non-wooden raw materials like straw, bamboo, bagasse and others (10%) [19]. It can be stated that wood is the basic raw material for virgin pulp production and this situation is not going to change in the nearest future [20, 21].

The production of virgin pulps from vegetal raw materials (mainly from wood) is constantly increasing. In the second half of the 20th century annual world production increased from 40 million tons up to 186 million tons.

Currently the most popular and valuable pulp type is cellulose sulphate, produced by chemical treatment of vegetal raw materials. The pulping process yield is below 50%, which means that 1 ton of cellulose pulp is obtained from 4 - 5 m^3 of wood. 85% of all virgin pulps produced is from cellulose sulphate.

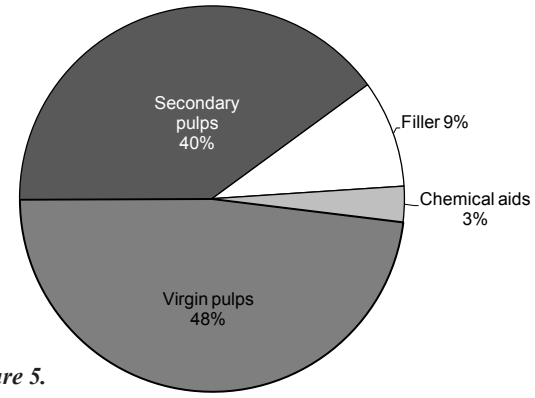

Figure 5.

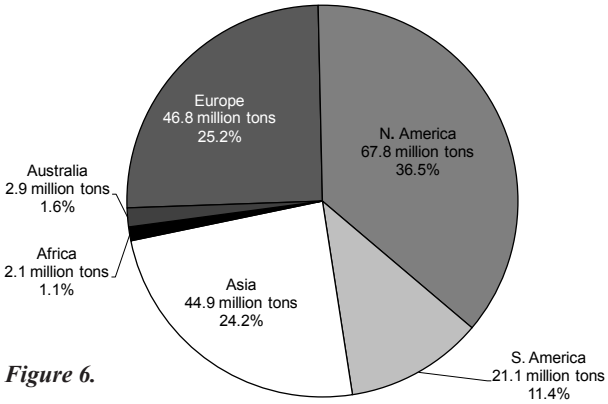

Figure 6.

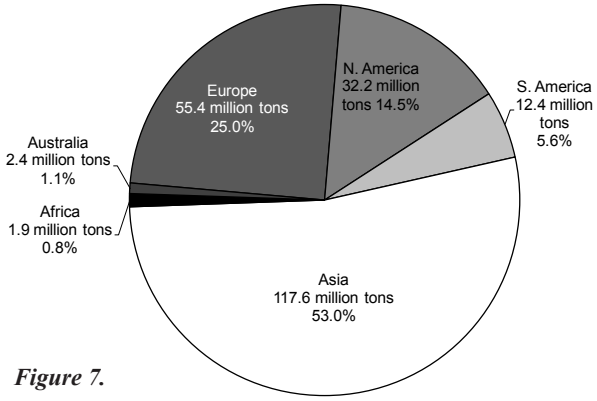

Figure 7.

Figure 5. *Basic paper components.*

Figure 6. *Distribution of the production of virgin pulps in different world regions.*

Figure 7. *Utilisation of recovered paper in different world regions.*

Besides cellulose sulphate pulp, there is the TMP (Thermomechanical Pulp) variety, obtained by mechanical treatment of wood and so-called CTMP (Chemithermomechanical Pulp) received by applying both mechanical and chemical treatment.

The distribution of the production of virgin pulps in different world regions is shown in the ***Figure 6***.

This figure presents that 62%, that is 2/3, of world virgin pulp production comes from North America (USA and Canada) and from some European countries (mainly Sweden and Finland). 24.2% of these pulps is produced in Asian countries (mainly China, Japan and Indonesia). It is an interesting fact that a low share of virgin pulp production originates from South America (11,4%) and Africa (1,1%), namely from regions with great resources of vegetal raw materials.

The biggest producer of virgin pulps is the USA (49.2 million tons), followed by China and Canada with production at a level of 20 million tons, and then Brazil, Sweden, Finland and Japan (10 - 13 million tons).

In the group of the biggest virgin pulp producers there is also Russia (about 7.5 million tons) and Indonesia (about 6.5 million tons). In the remaining countries the value of annual production does not exceed 3 million tons.

Secondary fibre pulps

The rapid increase in paper production in industrialised countries caused a local shortage of wood widely used for virgin pulp production in the second half of the 20th century, which was the reason why in the fifties of the 20th century recovered paper became more and more important as raw material for paper production.

Pulps produced from paper for recycling, unlike virgin pulps, are called *secondary fibre pulps*, also known as *recycled fibre pulps*.

It can be assumed that from one ton of recovered paper it is possible to obtain, on average, about 0.8 tons of secondary fibre pulp. The same amount of pulp can be produced from about 4 m^3 of wood. Therefore it can be said that recovered paper processing has a very important ecological aspect [22, 23]. Moreover the development of organised collections of paper for recycling has also taken place. From the sixties of the 20th century, an increase in the production and consumption of secondary fibre pulps could be observed. In 2010 it reached the level of 160 million tons and it is getting closer to the value of virgin pulp consumption and production.

To determine the consumption of recovered paper in specific world regions, it is necessary to determine local consumption as well as the export – import balance of this raw material. Taking all these parameters into consideration, it can be said that on a global scale, more than a half of paper collected for recycling (117.6 million tons) is processed on the Asian continent (***Figure 7***). Approximately one fourth of this recovered paper comes from North America and Europe.

On a global scale, European countries consume over 25% of recovered paper, while in North America consumption is at the level of 14%. The remaining paper for recycling is consumed in South America (5.6%), Australia (1.1%) and Africa (0.8%).

The undisputed market leader in recovered paper consumption is China, which

consumes 117.6 million tons of paper for recycling, whoch makes about 53% of the world consumption of this raw material. Over 10 million tons yearly are used in the USA (28.9 million tons), Japan (19 million tons) and Germany (15.5 million tons).

Trends in the intensification of papermaking raw material acquisition in relation to the idea of sustainable development

The basic condition for the further development of the papermaking sector is the assurance of suitable material resources in the form of wood and paper for recycling.

The papermaking sector, like other industrial sectors, according to current formal and legal standards, follows sustainable development rules. These rules encourage and force the industry to diminish its influence on the environment. This concept of action demands that the industry should economise on the use of primary raw materials and utilise of fossil fuels. The industry should also limit pollutant emission into water and air as well as the amount of solid waste.

The papermaking industry has broadened the rules of sustainable development by introducing the concept of the "supported paper cycle". According to this all actions undertaken by the papermaking industry should be integrated into the constant cycle of environmental transformation (***Figure 8***). Generally speaking, it is connected with the balancing the growth and consumption of vegetal raw materials.

According to the idea of the "supported paper cycle", the papermaking industry is aiming to get into a natural cycle of environment transformation without disturbing it. Because of the fact that the basic raw material for paper production is wood, the industry makes great efforts to protect and develop a possible raw material base in the form of forests. Hence within these actions there is the procurement of wood from certified forests, the establishing of plantations of fast growing trees, and many other actions [24]. Harvested wood is used, in possibly a maximal way, for paper production. Wastes from this process, after utilisation, come back to the environment in the form of carbon dioxide and water. Paper coming from recovered paper and produced according to the "supported paper cycle" follows this idea in a very strict way, as a result of which the remaining paper for recycling comes back to the environment in the form of carbon dioxide and water either through utilisation or natural disintegration.

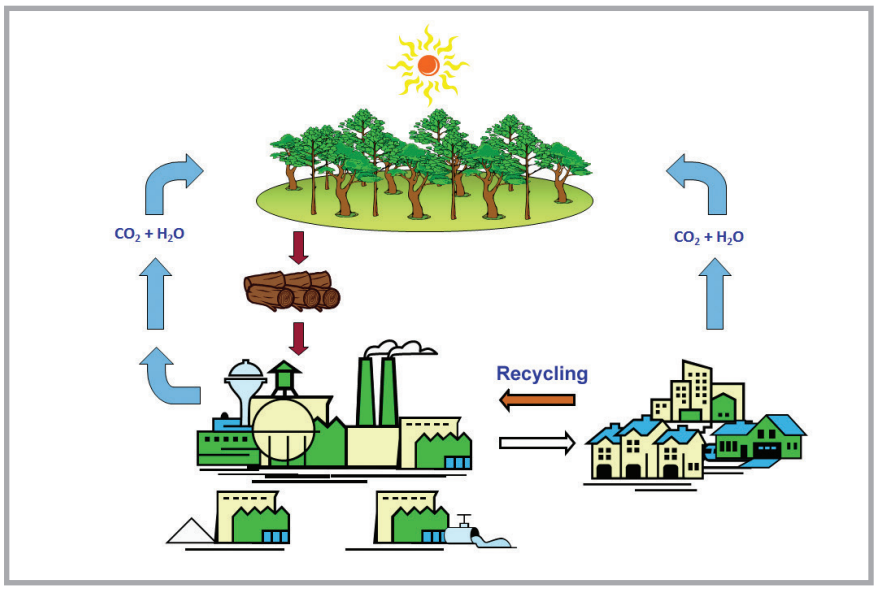

Figure 8. *Scheme of functioning of the 'supported paper cycle'.*

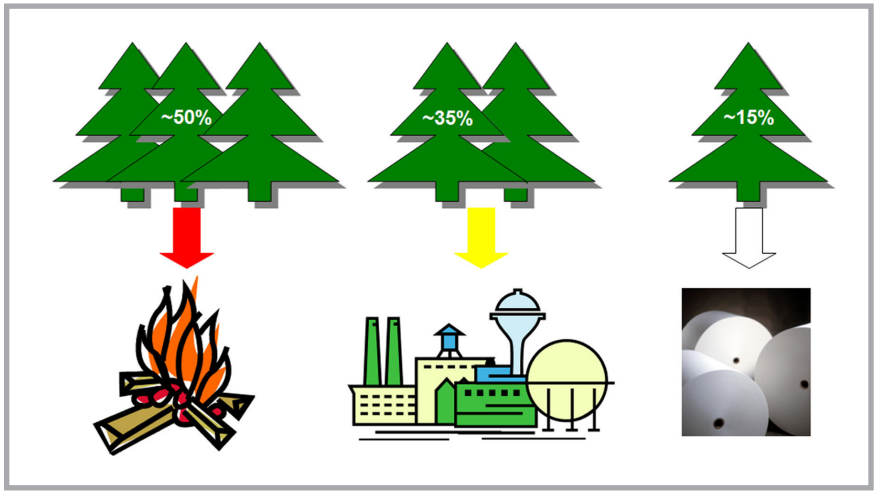

Figure 9. *Worldwide consumption structure of wood.*

The papermaking industry together with forestry, according to the idea of the "supported paper cycle", undertake some actions in order to broaden the raw materials resources available. These actions include, among others:

- efficient management of worldwide wood resources and other vegetal raw materials,
- intensification of forestry,
- establishment of fast-growing tree plantations,
- intensification of efficient use of vegetal raw materials,
- changes in production structure,
- intensification of utilisation and efficient use of recovered paper.

Efficient management of worldwide wood resources

The increasing demand for wood worldwide induces an intensification of logging and hence the management of this very valuable renewable raw material. However, the current situation is very far from perfection. On a global scale, over 50% of logged wood is incinerated i.e. the least effective use of this raw material. The papermaking industry consumes, at the moment, about 15% of logged wood (***Figure 9***).

The basic aim with regard to this situation is the limitation of the excessive use of wood for energy purposes.

Besides the improper structure of wood consumption, the next parameter which limits effective wood consumption for paper production is the inadequate arrangement of the paper industry on our planet. The production capacity is mostly concentrated in North America – 23%, Europe – 28% and Asia – 42%. The share of other continents in paper production does not exceed 10% (South America – 5%, Oceania 1%, Africa – 1.1%) [3]. This results in the fact that huge wood resources, especially in South America and Africa, are not, to great degree, used at all or not used in an effective way.

It can be forecasted that efficient, according to environment protection rules, forest management of rainforests in South America as well as in south-west Asia and Africa should ensure long-term raw material resources for increasing paper production in these world regions.

Intensification of forestry

In order to ensure the growing production capacity of the papermaking industry necessary for meeting the large demand for paper products, some actions aiming to intensify forestation have to be undertaken [25]. These are connected with an increase in forestation in particular countries as well as with the improvement of forestry. The improvement process is associated with the latest developments in chemistry, biology and genetics, also including meticulous forest conservation and the introduction of new, more productive tree species.

The attestation proving the usage of rational rules of forest management in accordance with requirements of environment protection is the FSC certificate (*Forest Stewardship Council*). Products made from wood coming from certified forests are marked with this certificate (***Figure 10***).

Establishment of fast growing tree plantations

The aspiration to broaden raw materials resources for the papermaking industry has induced the establishment of fast growing tree plantations. There are very productive plantations in tropical countries, where a particular modification of the gum and acacia trees are grown. In a favorable climate and soil conditions the annual growth of the gum tree in a tropical zone exceeds 20 m^3 per hectare,

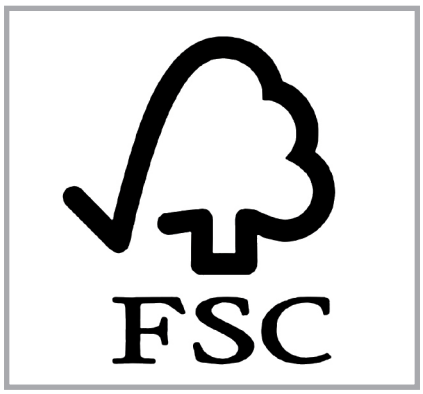

Figure 10. *Sign of FSC certificate.*

while that of trees in a temperate climate zone is at the level of 4 - 5 m^3 [26].

Attaining the possibility to obtain such high amounts of raw materials was the reason for building pulp plants close to plantations. On average such mills produce about 300 - 500 thousand tons of pulp annually. Wood logging from plantations enables the continuous work of these plants. In such a case, wood procurement is balanced with planting new trees.

It can be estimated that about 30% of worldwide pulp production comes from such plantations [27].

Utilisation of an increasing amount of recovered paper

The collection and rational use of paper for recycling, which comes from used paper products, has contributed in a significant way to developing a solution for the issues mentioned above. These factors are, in developed countries, the driving force of the continuous development of the recycling system functionality and efficiency [25].

A mature, systematic approach to the comprehensive association of rational utilisation of recovered paper and environmental protection can be related with the "responsibility rule" for industry and trade for the whole product chain from 'cradle to grave' [26]. According to this concept the final product is treated as potential waste, therefore in the design phase as well as during production, the final product should be adapted to enable easy processing or utilisation.

This idea is widely understood by producers and converters of paper. Under the influence of this idea, during the production process of paper and converting, the amount of chemical substances and materials introduced, which could hinder or make paper products impossible to reuse, is limited. This is related, among others, to the exclusion of ink, which contains heavy metals, and certain types of adhesives or coating which hinder or make paper impossible to recycle [27, 28].

The obvious effect of this concept is the high level of collection of recovered paper, which on a global scale is currently at a level of over 55%. In Europe, among the 19 countries organised as the CEPI (*Confederation of European Paper Industries*), this factor is above 70%, while statistically every ton of paper contains secondary fibres pulps which have been manufactured from 0.5 tons of recovered paper.

Summary

Paper is widely used in the economy, technology and everyday life because of the possibility to modify its properties, as well as the relatively low price.

The mass scale use of paper is also possible because it is produced from available vegetal raw materials. Renewable raw material, the possibility to recycle and multiply the use of fibres for paper production and biodegradation are reasons for the common use of paper in other industrial products used in developed societies. Paper is also an ecological mass product of the 21st century.

The consumption of paper increases in parallel with the level of civilisation and national income. In the first decade of the 21st century global paper consumption increased by about 78 million tons, reaching the level of 394 million tons in 2010. Currently the main producer and main consumer of paper are the highly developed countries in North America and Western Europe, in which specific paper consumption is about 250 kg per inhabitant annually. In general the abovementioned countries comprise about 20% of the Earth's inhabitants but use about 80% of manufactured paper. In spite of the high consumption of paper these countries not only fulfill their needs but they are also the biggest exporters of virgin pulps and paper (among others, Canada, Sweden and Finland) and recovered paper (among, others, the USA and Germany). Because of the high specific consumption of paper, recovered paper has

an increasing share in the raw material balance of highly developed countries. In these countries, where an improved recycling system is present, paper collection is at the level of 70% of paper consumed. Nowadays secondary fibre pulps comprise about half of pulps consumed, and the share of which is increasing.

On the basis of the material collected, it can be stated that a substantial part of countries with low paper consumption have a significantly large potential of wood resources, which concerns mainly South America, Middle Africa and Southeast Asia, requiring the conducting of rational forest management for existing resources. This trend is already increasing because the biggest and most modern plants are built in South America and Southeast Asia. At present China is the leader in papermaking industry development, based on wood from Southeast Asia and recovered paper from the USA and Western Europe.

On the basis of the analysis of the global potential for wood, paper for recycling and other fibrous raw material resources it can be stated that these reserves will meet, during the coming decades, increasing demands for paper products.

Assuming that specific paper consumption increases on a global scale from the current level of 55 kg per inhabitant to 100 kg, it can be forecasted that both the production and consumption of paper will double. It can be predicted that the biggest increase in paper production will take place in countries with low paper consumption and a high, natural raw material base in the form of wood. The production will mainly concentrate on both packaging and graphic paper grades.

On the other hand, in countries with high specific paper consumption (above 200 kg) the increase in paper production will be limited and will be based mainly on effective utilisation of recovered paper. Moreover because of the high level of technology and high qualifications of employees, the increase in paper production will concern, above all, fine graphic paper grades and specialty papers.

Acknowledgements

The authors gratefully acknowledge the financial support given by Grant No. N309 706340 from the National Science Center (NCN).

References

1. Confederation of European Paper Industries: Annual Statistics 2011. CEPI 2012.
2. Diesen M. Papermaking Science and Technology, Book 1- Economics of the Pulp and Paper Industry. Paperi ja Puu Oy, Helsinki, 2008.
3. Myths and Realities, electronic document at http://www.paperonline.org/myths-and-realities.
4. European Declaration on Paper Recycling 2011 – 2015, European Recovered Paper Council ERPC; 2010.
5. Farahani S, Worrell E, Bryntse G. CO2 free paper? *Resources, Conversation and Recycling* 2004; 42: 317.
6. Ince PJ, Durbak I. Pulpwood Supply and Demand: Development in the South, Little Growth Elsewhere. *Journal of Forestry* 2002; 100, 2: 20-25.
7. Forsström J, Keränen J, Hytönen E, Soria A, Szabó L. *Development of a Model of the World Pulp and Paper Industry.* European Commission Report No. EUR 22544 EN, 2006.
8. *Renewable energy progress and biofuels sustainability*. European Commission Report No. ENER/C1/463-2011-Lot2, 2012.
9. Jaakko Pöyry Ltd. World paper markets up to 2020. Know-how wire magazine, January, 2006.
10. FinPro Company: Twenty-five year development plan for paper industry. China Pulp and Paper Modernization Project, 2011.
11. Fornalski Z. Paper and Board Production and Consumption 2011 in Poland. *Polish Paper Review* 2012; 68, 9: 523.
12. Przybysz P. Zarys procesu wytwarzania papieru. PROGRESS, Łódź, 2012.
13. Forsström J, Keränen J, Hytönen E, Soria A, Szabó L. *Development of a model of the world pulp and paper industry.* Technical Report Series - EUR 22544 EN, Seville, 2006.
14. Nyrölä J. The pulp and paper business in emerging markets. Presentation at Capital Market Day, 2003.
15. IBISWorld, The Global Paper and Pulp Mills Industry Market Research Report, 2012.
16. Clark D. Przemysł papierniczy wobec wyzwań w zmieniającym się świecie. *Polish Paper Review* 1999; 55, 11: 711.
17. Raczyńska Z. Produkcja i zużycie papieru w Europie oraz surowce papiernicze – prognoza na początek XXI wieku. *Polish Paper Review* 2000; 56, 4; 191.
18. Confederation of European Paper Industries: Pulp & Paper Industry Main economic developments. Advisory Committee meeting, 2010.
19. Przybysz K, Wandelt P, Przybysz Z. Światowy przemysł papierniczy na przełomie wieków. Cz.I Produkcja pierwotnych mas włóknistych. *Polish Paper Review* 2002; 58,7: 375.
20. Ratajczak E, Szostak A. Surowiec drzewny – prognoza potrzeb i podaży do 2010 roku. *Polish Paper Review* 1998; 54, 6: 345.
21. Surewicz W. Światowe tendencje rozwoju techniki i technologii w procesach wytwarzania papierniczych mas włóknistych z surowców pierwotnych. *Polish Paper Review* 1999; 55,11: 727.
22. Cainelli G, Mazzanti M, Zoboli R. Environmental performance, manufacturing sectors and firm growth: structural factors and dynamic relationships. Environmental Economics and Policy Studies Online publication, 2013.
23. Gamper-Rabindran S, Finger SR. Does industry self-regulation reduce pollution? Responsible Care in the chemical industry. Journal of Regulatory Economics 2013; 43, 1: 1-30.
24. Reducing GHG Emissions in the Pulp & Paper Sector – Manufacturer's Perspective Climate Leaders Annual Meeting, December 2, 2009.
25. Wandelt P. Europejski sektor przemysłów przerabiających drewno wobec wyzwań przyszłości. Polish Paper Review 2000; 56, 3: 155.
26. Avó M, Altmann R. Future of the pulp and paper sector from a Brazilian perspective. O'Papel, online publication, 2009.
27. BralCelpa Brazilian Pulp and Paper Association. Forest Plantations: opportunities and challenges for the Brazilian pulp and paper industry on the path of sustainability. In: *Industry Meeting for Sustainability*, 2012; http://www.bracelpa.org.br/bra2/sites/default/files/rio20/ING_BRACELPA_RIO20.pdf.
28. Surewicz W. Światowe tendencje rozwoju techniki i technologii w procesach wytwarzania papierniczych mas włóknistych z surowców pierwotnych. *Polish Paper Review* 2000; 56,1: 36.
29. Przybysz P. Pozysk makulatury przez przemysł papierniczy w Polsce. *Polish Paper Review* 2011; 67, 6: 367.
30. Przybysz K, Przybysz P. Rozwój koncepcji ochrony środowiska w przemyśle papierniczym. *Polish Paper Review* 2010; 61, 10: 615.
31. Przybysz K, Przybysz P. *Ocena funkcjonowania systemu recyklingu makulatury w Polsce w latach 2000-2010*. PROGRESS, Łódź, 2012.
32. Leberle U. *Innovation scenarios - A pulp and paper industry perspective.* Joint Session of the ECE Timber Committee and the FAO European Forestry Commission, 2011.

Received 04.07.2013 Reviewed 20.01.2014