



Slika 2: Uporabljen papir! [9]
Figure 2: Use paper! [9]

Identificiranje pomembnih vsebin

Prvi korak interpretacije življenjskega cikla vključuje pregled informacij iz prvih treh faz LCA, da bi identificirali podatke, ki najbolj vplivajo na potek LCI in LCIA pri vsakem izdelku, procesu oziroma storitvi. S pomočjo pridobljenih ugotovitev določamo popolnost, skladnost in natančnost študije. Pred določanjem, kateri del LCI in LCIA ima največji vpliv na rezultate posamezne alternative, moramo podrobno pregledati prejšnje faze študije. Nato pregledamo zbrane informacije in predstavitev rezultatov, da ugotovimo, ali je bil uresničen cilj in namen študije. Če je uresničen, nadaljujemo z interpretacijo rezultatov. Določanje pomembnejših vsebin je v nekaterih primerih komplicirano opravilo. Kot pripomoček za identificiranje pomembnih podatkov in določanje njihovega pomena lahko uporabimo naslednje metode:

- ▶ ocena vpliva (prispevke posameznih faz življenjskega cikla primerjamo s celotnim rezultatom);
- ▶ ocena dominantnosti (statistična orodja ali druga pomagala, kot so kvantitativno ali kvalitativno rangiranje, uporabljamo za identificiranje pomembnih elementov prispevanja);
- ▶ ocenjevanje anomalij (nenavadna ali presenetljiva odstopanja od pričakovanih ali normalnih rezultatov moramo natančno preučiti).

Pomembne vsebine so sestavljene iz:

- ▶ parametrov inventarja (so poraba energije, emisije, odpadki ...);
- ▶ kazalnikov kategorij vplivov (izraba virov surovin, emisije, odpadki ...);
- ▶ bistvenih prispevkov k LCI ali LCIA rezultatom (posamezne procesne enote ali skupine procesov, kot so transport, pridelava energije ...).

Ocenitev popolnosti, natančnosti in skladnosti podatkov

Da bi zagotovili popolnost, natančnost in skladnost podatkov, moramo opraviti:

- ▶ kontrolo popolnosti (ugotavljanje popolnosti študije);
- ▶ kontrolo natančnosti (ocenjevanje natančnosti pomembnih podatkov, ki imajo velik vpliv na rezultate);
- ▶ kontrolo skladnosti (ocenjevanje skladnosti pri sprejemanju omejitev in predpostavk, zbiranju podatkov in dodeljevanju vplivov kategorijam vplivov za vsako alternativo posebej).

Sprejemanje sklepov in priporočil

Cilj tega koraka je interpretacija rezultatov za določevanje izdelkov oziroma storitev, ki imajo najugodnejši vpliv na okolje. Pomembno je, da sprejeti sklepi in priporočila temeljijo le na utemeljenih dejstvih. Prav tako je zelo pomembno razumevanje in poročanje o morebitnih negotovostih rezultatov. V nekaterih primerih je prav zaradi negotovosti in omejitev izbrane metode, ki je bila uporabljena za LCA, napoved najustreznejšega izdelka oziroma storitve nejasna. V takšnem primeru so rezultati analize še vedno koristni. Uporabljamo jih za boljše razumevanje vpliva na naravo in posledično na človekovo zdravje, za razumevanje posameznih vplivov ter za ugotavljanje obsega posameznih vplivov glede na primerjane izdelke oziroma storitve.

2.5 Poročanje rezultatov

Ko je LCA študija končana, je potrebno iz zbranega gradiva pripraviti poročilo o poteku študije. Poročilo mora na jasen in urejen način predstaviti rezultate, podatke, metode, omejitve in predpostavke.

3 Zaključki

LCA postaja eno od najbolj zanimivih orodij za presojo vplivov na okolje. Zelo pogosta je uporaba ISO 14040 in ISO 14044 standardov, kot smernic za izdelavo LCA študije, kar povečuje primerljivost ocen in pridobljenih rezultatov.

Podjetja se čedalje pogosteje odločajo za izdelavo LCA študije, saj jim poleg vpliva proizvodnje izdelkov na okolje rezultati prikazujejo tudi procese oziroma dele procesov, ki so ekonomsko najpotratnejši. Tako lahko podjetja prilagodijo svoje procese, da postanejo ekonomsko ugodnejši.

Pri LCA študijah v papirnih industrijah, kjer so študije predpostavljale, da so papirni izdelki samo za enkratno uporabo, plastični pa za večkratno, je večina rezultatov pokazala na večje obremenjevanje okolja pri papirnih izdelkih. Vendar vemo, da temu ni tako. Papirni izdelki so še vedno okolju prijaznejši kot nekateri konkurenčni izdelki.

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POSSIBILITY OF MUNICIPAL WASTEWATER RE-USE IN PAPER INDUSTRY



MOŽNOST PONOVNE UPORABE KOMUNALNE ODPADNE VODE V PAPIRNI INDUSTRIJI

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ABSTRACT

As water scarcity is becoming a growing problem in many regions, searching for alternative water sources is of great importance, especially for high water consuming industries like paper industry. Municipal wastewater has the advantage of being broadly available and relatively stable in production and effluent quality, although microbiological safety can be a problem. Within the study presented the possibility of re-use of municipal wastewater treated with advanced oxidation processes (AOPs) in the production process of paper industry is shown. Raw municipal wastewater was treated at a lab-scale AOP-treatment plant with different AOPs and their combinations. The following AOP treatments were applied: (a) ozone (O₃); (b) O₃ + ultraviolet irradiation (UV); (c) hydrogen peroxide (H₂O₂) and (d) H₂O₂ + UV. The most effective option for colour and COD removal was the combination of O₃ and UV, while significant disinfection of municipal wastewater was achieved with all four tested AOPs. Municipal wastewater treated with the most efficient AOP combination was used for paper production. The results of the sheet former trials showed that use of AOP-treated municipal wastewater for paper production did not impair colour and strength properties of paper produced. Thus, municipal wastewater could be successfully re-used in paper industry.

Keywords: advanced oxidation processes, municipal wastewater treatment, ozonation, paper industry, wastewater re-use.

IZVLEČEK

Ker pomanjkanje vode postaja čedalje večji problem v številnih regijah, je iskanje alternativnih virov vode zelo pomembno, še posebej za industrijske panoge z visoko porabo vode, kot je papirna industrija. Komunalna odpadna voda ima to prednost, da je lahko dostopna, ima relativno stabilno proizvodnjo in kakovost iztoka, vendar pa je problem lahko njena mikrobiološka oporečnost. V predstavljeni raziskavi je prikazana možnost ponovne uporabe komunalne odpadne vode, očiščene z naprednimi oksidacijskimi postopki (AOPs), v proizvodnem procesu papirne industrije. Surovo komunalno odpadno vodo smo očistili na laboratorijski AOP čistilni napravi z različnimi AOP postopki in njihovimi kombinacijami. Uporabili smo naslednje AOP kombinacije: (a) ozon (O₃); (b) O₃ + ultravijolično sevanje (UV); (c) vodikov peroksid (H₂O₂) in (d) H₂O₂ + UV. Najbolj učinkovita pri odstranitvi barve in KPK je bila kombinacija O₃ in UV, medtem ko smo znatno dezinfekcijo komunalne odpadne vode dosegli z vsemi štirimi testiranimi AOP postopki. Komunalno odpadno vodo, očiščeno z najboljšo učinkovito AOP kombinacijo, smo nato uporabili za proizvodnjo papirja. Rezultati laboratorijskih poskusov izdelave papirja so pokazali, da uporaba AOP očiščene komunalne odpadne vode ni vplivala na barvometrične in mehanske lastnosti izdelanega papirja. Tako lahko komunalno odpadno vodo uspešno ponovno uporabimo v papirni industriji.

Ključne besede: napredni oksidacijski postopki, čiščenje komunalne odpadne vode, ozoniranje, papirna industrija, ponovna uporaba odpadne vode.

1 Introduction

Pulp and paper industry is one of the most water-dependent industries [1]. In regions with water scarcity there is not enough fresh water available to all water consumers during dry periods [2]. Paper production, which requires large amounts of water, is particularly endangered if the water supply cannot be maintained or the use of freshwater is no longer permitted by the authorities [3].

Recently there has been an increase of attention in municipal wastewater as an alternative source of water for various purposes thanks to many advantages such as broad availability, relatively stable production and effluent quality. Several recommendations and an evaluation

of potentials of cascading water use to substitute fresh water are available [4-6]. However, the use of treated municipal wastewater brings problems (potential health risks due to insufficient disinfection, conveying treated wastewater to points of consumption) that have to be dealt with. Currently, the effluents from municipal wastewater treatment plants are not generally used as a source of reclaimed water. This is due to: lack of regulation and legislation specifying the conditions for re-uses and quality requirements on re-used wastewater, together with the motivation for wastewater re-use, high costs of producing reclaimed water with adequate quality and a lack of information about the technologies and associated risks mentioned above. However, there are

few cases of municipal wastewater reuse in industry, it is mainly used for cooling and floor cleaning. In paper industry, there are some examples of the cascading use of treated municipal wastewater [7]. Since June 2012, Holmen Paper from Madrid has been replacing fresh water for production processes with treated municipal wastewater (ultrafiltration + reverse osmosis + UV). A level of 30% fresh water substitution has been reached with target use of 100% reclaimed water of the total water consumption [8, 9]. Other mills across Europe are also discussing this issue.

The main objective of this study is to show the possibility of municipal wastewater re-use in the production processes of paper industry. Raw

municipal wastewater was treated with different advanced oxidation processes (AOPs) such as ozone (O_3); O_3 + ultraviolet irradiation (UV); hydrogen peroxide (H_2O_2) and H_2O_2 + UV. Municipal wastewater treated with the most efficient AOP combination was used for paper production.

2 Materials and methods

As a source of wastewater, raw municipal wastewater was used, collected from a sequencing batch bioreactor (SBR) located in the front of the Faculty of Civil and Geodetic Engineering of the University of Ljubljana in which a part of the municipal wastewater of city Ljubljana is treated. Prior to the trials, wastewater was filtered with black ribbon filters (Sartorius-stedim, Grade 388, 10–15 μm , basis weight 84 g/m^2) to remove solid compounds. Filtered wastewater was treated with different combinations of AOPs: O_3 ; O_3 + UV; H_2O_2 and H_2O_2 + UV at a lab-scale AOP-treatment plant (Fig. 1) operating in batch mode.

2.1 Pilot plant design

The lab-scale AOP-treatment plant (Fig. 1) consisted from a plastic wastewater tank, a water pump (Iwaki Magnet Pump, Iwaki co. LTD), an air pump (KNF Neuberger), an air dryer module (Lufttrockner module LTM 110-60, AquaCare), an O_3 generator (BasiTech III, AquaCare, 500 mg/h), an O_3 reactor (Ozonreaktor OZR 75, AquaCare), an O_3 analyser (BMT 964 C, BMT Messtechnik), a rotameter (multi-parameter analyser C3040, Consort) and a UV lamp (Sterilight copper, Viqua, 12 W). For a detailed description of the lab-scale AOP-treatment plant see Krivograd Klemenčič et al. [13]. The system was operating in a batch mode

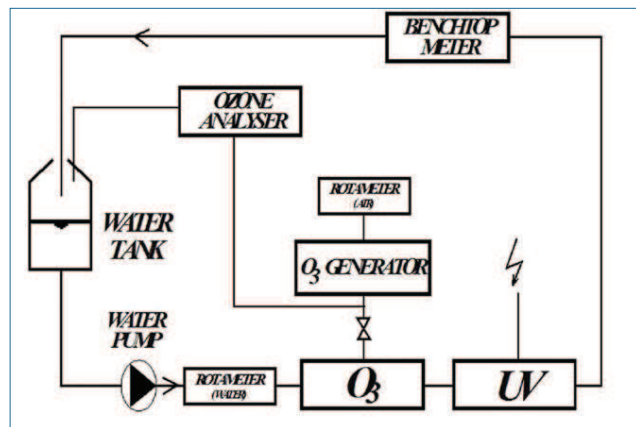


Figure 1: Scheme of the laboratory AOP-treatment plant [10]. AOP-advanced oxidation processes. Slika 1: Shema laboratorijske AOP čistilne naprave [10]. AOP-napredni oksidacijski postopki.

with a flow rate of the water stream 60 L/h maintained with the rotameter, but the residence time was increased with the wastewater returning back to the beginning of the system. Consequently the system was operating in a batch mode with the water being completely mixed.

2.2 Chemical analyses

The following parameters of raw municipal wastewater were analysed: pH, electric conductivity (EC), colour at 436 nm, 525 nm and 620 nm, chemical oxygen demand (COD), biochemical oxygen demand in 5 days (BOD_5) and total suspended solids (TSS). pH and EC were measured with the HACH HQ40d Multimeter, colour was measured with a portable spectrophotometer (Hach DR 2800), COD was analyzed according to ISO 6060, BOD_5 according to SIST EN 1899-2 and TSS according to SIST ISO 11923.

During the AOP experiments, 10 mL of sample was taken from the circulation loop in the batch system at regular time intervals of 40 minutes (10 cycles) for COD and colour measurements at 436 nm, 525 nm and 620 nm. For each experiment, 7 samples were taken. Before each experiment, COD and colour were measured as initial state.

2.3 Sheet former trials

The influence of re-using treated municipal wastewater on paper quality has been estimated on the basis of a hand sheet. Hand sheets were produced from short fibre and long fibre pulp in equal shares, refined together in a laboratory refiner at a consistency of 3.5%. Refining energy input into the pulp was 150 kWh/t . After refining, the freeness of pulp was raised from 20 $^{\circ}SR$ to 31 $^{\circ}SR$ (Schopper Riegler). Before producing the hand sheets, stock was again diluted down to a consistency of 0.5% and introduced into the Rapid

Köthen sheet former. Original process water (white water 1) was used to show the current situation in paper mills, with these results serving as the basis. The exclusive use of AOP-treated municipal wastewater is the worst case scenario (Sc), whereas the mixed scenario represents a possible water reuse. Based on the results presented below, the following processes and settings have been used for the AOP-treatment: ozone (total dosage 380 g/m^3) + UV (total dosage 800 Wh/m^3).

The following properties of the hand sheets were measured: colour as $L^*a^*b^*$ -values according to the CIE LAB System and bending stiffness according to DIN 53 121, breaking elongation, tensile strength as well as the modulus of elasticity according to DIN EN ISO 1924-2.

3 Results and discussion

3.1 Characteristics of raw municipal wastewater used for experiments

Raw municipal wastewater used for experiments (Tab. 1) had already been partially degraded as it was collected from a sequencing batch bioreactor (SBR), thus having relatively low COD and BOD_5 values. It was slightly coloured and contained a portion of suspended solids which were removed prior to the AOP-treatment.

Table 1: Characteristics of municipal wastewater used for experiments. Preglednica 1: Karakteristike komunalne odpadne vode uporabljene za poskuse.

Parameter	Unit	Measured value
pH	-	8.17
Electric conductivity	$\mu S/cm$	1144
TSS	mg/l	80
BOD_5	mg/l	60
	mg/l	126
Colour		
436nm	m^{-1}	7.73
525nm	m^{-1}	5.56
525nm	m^{-1}	4.26

3.2 AOP experiments

The most efficient combination for colour removal (Fig. 2) was O_3 + UV (86%). The second best was O_3 alone (76%–77%). The least effective for colour removal was the combination of H_2O_2 + UV (31%–33%). By comparing O_3 and O_3 + UV treatments, it can be seen that UV light contributed to better decolouration, which however did not apply to the H_2O_2 and H_2O_2 + UV treatments.

The most efficient option for COD removal (Fig. 3) was the combination of O_3 + UV (25%). The second best was the combination of H_2O_2 + UV (19%). The least effective for COD removal was the H_2O_2 (12%). By comparing O_3 and O_3 + UV treatments, it can be seen that UV light contributed to better decolouration. This was also true for H_2O_2 and H_2O_2 + UV treatments.

All AOPs tested have been proven efficient for the disinfection of municipal wastewater, and even low doses of ozone resulted in a significant removal of microbes (data not showed).

In general, O_3 combined with UV proved to be the most successful in AOP-treatment of municipal wastewater for both colour and COD reduction. With this combination, significant colour reduction was achieved, whereas the decolouration of wastewater intended for re-use was especially important for further sheet former trials. The experiments with H_2O_2 were not as successful as ozonation as regards colour removal, and in this case, a combined treatment with UV did not give better results. With all AOP treatments, only limited COD reduction was obtained. H_2O_2 proved to be better for COD removal than the use of O_3 alone and the addition of UV only improved degradation. Nevertheless, the differences in COD reduction between AOP combinations were not so significant as for colour removal. The results show that by combining different AOPs, better treatment efficiency of municipal wastewater can be achieved in comparison with the use of single AOPs.

3.3. Paper properties

Table 2 shows the mean values of paper properties measured in the hand sheets. The a^*b^* -plane of the CIE $L^*a^*b^*$ colour system shows the influence of water use on the colour of hand sheets. Negative a^* -values represent the colour green, positive values the colour red, negative b^* -values represent the colour blue, positive values the colour yellow. The a^* - and b^* -values of absolutely white paper sheets would be zero. The L^* -value +100 is defined as white, 0 as black.

The use of AOP-treated municipal wastewater gives the same colour coordinates a^* and b^* of hand sheets as the use of white water 1 at a share of both 50% and even 100% wastewater use. The L^* -values are even somewhat higher when substituting white water by treated wastewater. It can be concluded that the reuse of AOP-treated municipal wastewater does not impair the whiteness of paper.

According to Table 2, the use of AOP-treated municipal wastewater did not impair the strength properties of hand sheets compared to the use of white

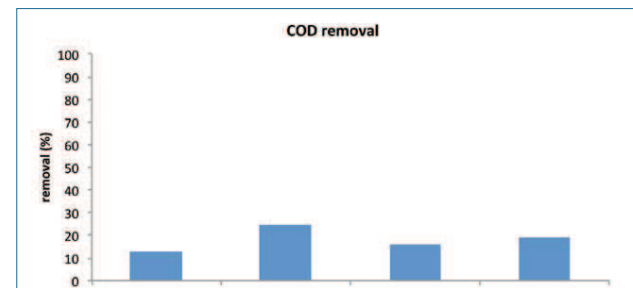


Figure 2: Colour removal in municipal wastewater with a combination of different advanced oxidation processes. Slika 2: Odstranjevanje barve iz komunalne odpadne vode s kombinacijo različnih naprednih oksidacijskih postopkov.

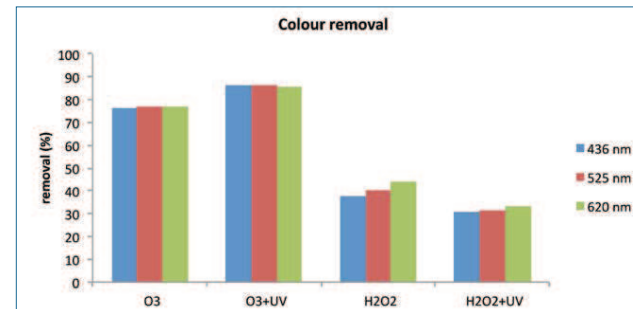


Figure 3: Chemical oxygen demand (COD) removal in municipal wastewater with a combination of different advanced oxidation processes. Slika 3: Odstranjevanje kemijske potrebe po kisiku (COD) iz komunalne odpadne vode s kombinacijo različnih naprednih oksidacijskih postopkov.

Table 2: Colour coordinates and mechanical properties of hand sheets produced with white water 1 and AOP treated municipal wastewater. AOP-advanced oxidation processes. Preglednica 2: Barvnometrične in mehanske lastnosti laboratorijskih vzorcev papirja, proizvedenih s sitovo vodo 1 (WW1) in AOP očiščeno komunalno odpadno vodo. AOP-napredni oksidacijski postopki.

Scenario	Colour			Strength properties			
	L^*	a^*	b^*	Bending stiffness N/m	Breaking elongation %	Tensile strength kN/m	Modulus of elasticity N/mm ²
100 % WW1	94.9	0.1	3.3	0.18	2.86	2.73	2.707
50% WW1 + 50% AOP treated municipal wastewater	96.0	-0.4	3.8	0.19	2.87	2.81	2.703
100% AOP treated municipal wastewater	96.2	-0.4	3.7	0.20	3.39	3.50	3.065

water, either. Even an increase in strength properties with an increased share of AOP-treated wastewater was noticed. This might be due to a lower load of treated wastewater in comparison with white water. It can therefore be concluded that the reuse of AOP-treated municipal wastewater in paper production process does not impair the mechanical product properties.

4 Conclusions

Considerable effects have been achieved by advanced oxidation processes (AOP) treatment and improved water qualities have been produced. The choice of the optimum process(es) and settings depends on the wastewater origin and on the water quality to be achieved

(requirements of the location for reuse). The main treatment aim depends on the origin, too. For example, for the treatment of municipal wastewater, the organic load is not an issue whilst disinfection is a major issue. The results of AOP experiments performed at raw municipal wastewater showed that the most effective option for colour removal was the combination of ozone (O_3) + ultraviolet irradiation (UV). The least effective one was the combination of hydrogen peroxide (H_2O_2) + UV. The most effective option for COD removal was the combination of O_3 + UV, and the least effective one was the H_2O_2 alone. Significant disinfection of municipal wastewater was achieved with all four tested AOP combinations. The use of AOP-treated municipal wastewater in

paper production process to substitute fresh water did not impair the colour and strength properties of paper in laboratory trials and is expected to be possible in paper mills. The required water qualities very much depend on the paper grade produced, the raw materials used and other specific mill conditions like production processes and technologies used. The national legislation and internal aspects of companies such as the economic situation and willingness to substitute fresh water by treated wastewater have to be considered as well. The results show that the use of municipal wastewater as an alternative water source is possible in paper production. This ensures that production can be maintained in regions and situations lacking fresh water.

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MOŽNOSTI VKLJUČITVE PAPIRNE INDUSTRIJE V PROCES BIORAFINERIJ

POSSIBILITIES OF BIOREFINERY CONCEPT IMPLEMENTATION IN PAPER INDUSTRY

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IZVLEČEK

V članku je predstavljena možnost celovitejšje izrabe lesne biomase v papirni in lesnopredelovalni panogi oziroma vpeljava koncepta biorafinerije v proizvodnjo. V papirnicah z integrirano proizvodnjo lesovine in v lesnopredelovalnih obratih ostajajo večje količine drevesne biomase, na primer skorja, grče, žagovina itd. Tovrstni ostanki so bogat vir komponent in kemikalij, na primer polimernih sladkorjev, polifenolov, različnih olj, smole, škroba in proteinov. Lesne ostanke je možno učinkovito pretvoriti v sekundarno gorivo bioetanol oziroma bi bilo smotno iz njih izolirati spojine z dodano vrednostjo, ki bi našle svojo uporabnost v različnih industrijskih panogah. Lesna biomasa je v nasprotju z nafto in fosilnimi materiali obnovljiv surovinski vir, zato je njegova optimalna izraba bistvenega pomena za nadaljnji razvoj.

Ključne besede: biorafinerija, lesni odpadki, bioetanol, specialne kemikalije, alternativni viri.

ABSTRACT

The article describes the possibility for a more comprehensive exploitation of wood biomass in papermaking and wood converting industry by introducing a concept of biorefinery. In wood converting plants and paper mills with integrated production of mechanical pulp, substantial quantities of wood material such as bark, knots and sawdust are left behind. These residues represent a rich source of components and chemicals, for example polymeric sugars, polyphenols, oils and fats, starch, resin and proteins. Woody residues can be efficiently converted into secondary fuel bioethanol or else it is reasonable to extract added-value compounds for application in different industries. In contrast to oil and fossil fuels, wood biomass is a renewable raw material. Its optimal exploitation is therefore of key importance for further development.

Keywords: biorefinery, wood residues, bioethanol, specialty chemicals, alternative sources.

1 Uvod

Temelj energetske ekonomike v prihodnosti je iskanje alternativnih možnosti pridobivanja energije. Obnovljivi viri so ena izmed najbolj perečih tem današnjega časa. Zavedamo se, da so potrebe po energiji vedno večje, obenem pa se njene zaloge manjšajo.

Tako imenovane biorafinerije so v zadnjem času med najpomembnejšimi raziskovalnimi temami s področja obnovljivih virov. Njeni pozitivni učinki so razlog za relativno veliko finančno podporo s strani EU raziskovalnega programa (Petrič, 2011). Slovenija si že kar nekaj časa prizadeva za razvoj in vpeljavo procesa biorafinerije, vendar žal brez konkretne realizacije. Prednost omenjenega procesa je tudi zmanjšanje vplivov na okolje in omilitev problema globalnih klimatskih sprememb (Petrič, 2011).

Okolje igra v papirniški industriji še prav posebej veliko vlogo, saj so energetske porabe velike, istočasno pa je omenjena industrijska panoga znana po nastanku znatnih količin odpadkov. Po podatkih slovenske papirne industrije je bilo

ugotovljeno, da povprečne skupne količine lesnega odpadka v slovenskih papirnicah znašajo okoli 30.000 ton/leto. Glede na količine bi bilo smiselno poiskati rešitev ponovne uporabe oziroma izrabe slednjega. Poleg tega, da so količine dokaj velike, predstavlja odpadki za podjetje precejšen strošek, hkrati pa negativno vpliva na okolje. Izboljšanje okoljske uspešnosti, zlasti zmanjšanje energijske porabe, izboljšanje učinkovitosti rabe vode in zmanjšanje onesnaženosti zraka so dolgoročni cilji za papirno industrijo.

Integrirana industrija celuloze in papirja z drugimi industrijskimi panogami, predvsem s kemično industrijo. Ena izmed idej je bila, da bi se v proizvodnjo celuloze vključil proces uplinjevanja biomase materialov (les, sekanci, kmetijski odpadki ...), katerega produkt bi bil sintezni plin. Sintezni plin lahko

pretvorimo v različna zelena goriva in kemične substrate, kot so na primer octna kislina, metanol, metil acetat ... Poleg produktov se pri proizvodnji sinteznega plina sprošča tudi toplota, ki bi se lahko uporabila kot energija. V papirniški industriji bi tako zmanjšali nakup plina in električne energije (Luguel, 2008).

2 Koncept biorafinerije

»Biorafinerija« (slika 1) je nov izraz, ki se je razvil iz pojma »rafinerija nafte« V naftnih rafinerijah pridobivamo energente in kemikalije, prav isto pa počnemo tudi v biorafinerijah, le da je surovinski vir drugačen. Namesto neobnovljive nafte v biorafinerijah uporabljamo trajnostne, obnovljive lignocelulozne materiale, tudi les (Petrič, 2011).

Kamm in sodelavci (2004) ter Dye in sodelavci (1999) opisujejo tri vrste biorafinerij glede na vhodne surovine, in sicer: biorafinerije, katerih vhodni materiali so pridelki v celoti (pšenica, rž, koruza ...), le-te pa vključujejo mehansko predobdelavo. Naslednja vrsta so tako imenovane »zelene biorafinerije«.

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