Plastika je *najzeleniji*, a guma nezamjenjivi materijal 21. stoljeća

1. Uvod

Za običnog čovjeka vršni polimeri, poznati pod nazivom plastika, još uvijek su nedovoljno poznati materijali, za što postoje brojni razlozi. U svega nešto više od pola stoljeća ta je skupina tvoriva postala po obujmu najrašireniji materijal današnjice. Nametnula se istodobno kao *najzeleniji* materijal 21. stoljeća. Nešto manje je proširena druga skupina vršnih polimera, guma, koja je u nešto manje od dva stoljeća postala nenadomjestivim materijalom o kojemu ovisi cjelokupni suvremeni cestovni i zračni promet.

Tim dokazivim činjenicama suprotstavlja se trenutno najlošiji ugled ili imidž koji jedan materijal uživa u javnosti. Zašto plastika ima tako loš imidž, bit će objašnjeno u nastavku. Za bolje razumijevanje cijelog kompleksa pitanja koja su vezana osobito uz plastiku potrebno je najprije navesti podatke o proizvodnji tog materijala. Kako bismo precizno raščlanili probleme koji su vezani uz plastiku, potrebno je prikazati njihov položaj među svim materijalima. To će omogućiti usporedbu vjerojatno najspornijeg plastičnog proizvoda, a to su polietilenske vrećice, sa sličnim proizvodima napravljenim od drugih materijala.

2. Svjetska proizvodnja plastike i gume

Rekordna godina za plastiku bila je 2007., kada je proizvedeno 260 milijuna tona plastike. Slijedile su dvije recesijske godine. Stoga je 2009. godine u svijetu proizvedeno tek nešto više od 230 milijuna tona plastike te 21,7 milijuna tona prirodnoga i sintetskoga kaučuka.[01]

Niz godina čelik je bio osnovni materijal na svijetu čija se važnost može usporediti s onom plastike. Budući da je plastika bitno lakša od čelika, nemoguća je težinska usporedba te ćemo ih zato usporediti po obujmu, pri čemu je omjer 1:8. To znači da se vrijednost proizvedene plastike množi s osam i tada uspoređuje s čelikom. Prema toj računici, 2009. godine je proizvedeno plastike u ekvivalentu od najmanje 1,84 milijardi tona čelika. Maksimalna proizvodnja čelika nikada nije premašila 1,4 milijarde tona godišnje. A to je postignu-

Igor Čatić

Plastic the Greenest of Green, Rubber an Irreplaceable Material for the 21st Century

1. Introduction

For most of the population the peak polymers known as plastic are still an insufficiently familiar material. There are numerous reasons for this. In no more than half a century, this set of materials has become, in terms of volume, the most widely distributed material of the present day. They have also made their presence felt as the greenest material of the 21st century. A little less widely diffused is a second group of peak polymers, rubber. In less than two centuries, it has become an irreplaceable material, on which the whole of contemporary road and air transport depends.

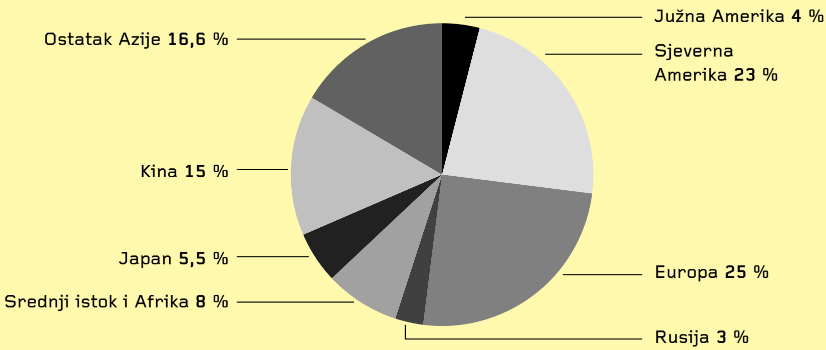
Opposed to these verifiable facts is the currently extreme bad reputation or image that the material enjoys in the public mind. Why plastic has such a bad image will be explained in the sequel. For a better understanding of the whole complex of materials related primarily to plastic, it is first necessary to give a few details about the production of these materials. For a precise analysis of the problems related to plastic, it is necessary to present their position among all the other materials. This will enable a comparison of probably the most contentious plastic product, the polyethylene shopping bag, with those made of other materials.

2. World production of plastic and rubber

The record year for plastic was 2007, in which 260 million tons of it were produced. Then came two years of recession. And worldwide in 2009 only a bit more than 230 million tons of plastic was made, and 21.7 million tons of natural and synthetic rubber.

For many years, the basic comparable material in the world was steel. Since plastic is essentially lighter than steel, it is impossible to use weight as a yardstick. And so a volumetric comparison has to be carried out, the ratio being 1:8. This means that the value of the plastic produced can be multiplied to u svega šezdesetak godina, budući da je proizvodnja sintetske plastike 1950. iznosila svega 1,5 milijuna tona.[01]

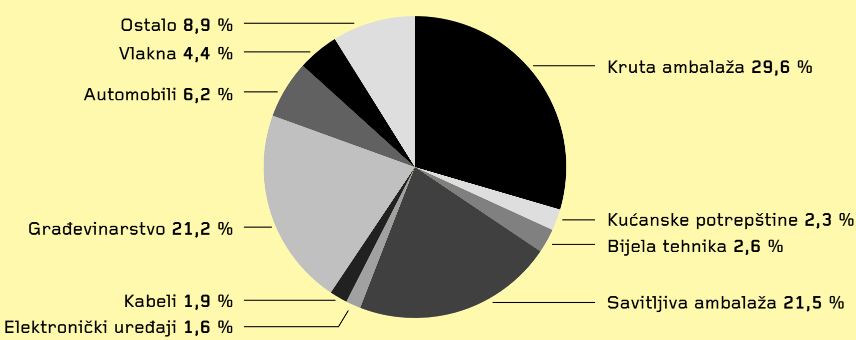
S obzirom na ukupna svjetska kretanja, predviđa se kako bi 2015. potrošnja plastike u svijetu mogla doseći 296 milijuna tona.[01] Najviše stope rasta u istom razdoblju očekuju se idućih godina u azijskim zemljama, gdje je današnja potrošnja tek oko 20 kg po stanovniku, a predviđa se kako bi porast potrošnje plastike do 2015. na tom području mogao iznositi čak 90 % te bi potrošnja mogla doseći i 36 kg po stanovniku.[01] Slika 1 prikazuje strukturu potrošnje u svijetu.[01]



Slika 1. Udjeli pojedinih dijelova svijeta u ukupnoj svjetskoj proizvodnji plastike u 2008. (proizvedeno 245 milijuna tona)[01]

Od 245 milijuna tona plastike proizvedene 2008. godine gotovo 175 milijuna tona (ili 72 %) čine širokoprimjenjivi plastomeri, od kojih su najrašireniji polietileni. Godine 2008. proizvedeno je oko 36,5 milijuna tona ili 21 % polietilena niske gustoće i linearnog polietilena niske gustoće (PE-LD i PE-LLD) te približno 30 milijuna tona ili 17 % polietilena visoke gustoće (PE-HD). Polipropilena (PP) je proizvedeno 43,5 milijuna tona ili 25 %. Vrlo je visoka i proizvodnja PVC-a [poli(vinil-klorida)], naime gotovo 35 milijuna tona (20 %), a sve je rašireniji i PET [poli(etilen-tereftalat)], kojega je proizvedeno 14 milijuna tona (8 %). Naposljetku, polistirena (PS) i pjenećeg polistirena (PS-E) proizvedeno je ukupno oko 16 milijuna tona (9 %).[01]

Za ova razmatranja zanimljiva je i struktura primjene plastike u Europi 2009. godine, a slična je situacija i u drugim zemljama. Više od 50 % potrošnje otpada na ambalažu.



Slika 2. Područja primjene plastičnih materijala u Europi u 2009.[01]

by eight, and then compared with steel. In 2009, then, plastic equivalent to at least 1.84 billion tons of steel was produced. The maximum production of steel has never exceeded 1.4 billion tons per annum. And this was accomplished in no more than sixty years, for the production of synthetic plastic in 1950 came to only 1.5 million tons.

Considering overall world trends, it is forecast that the consumption of plastic in the world in 2015 might come to 296 million tons.[01] The biggest rates of growth in the same period of the coming years are expected in Asian countries, where current consumption is a mere 20 kg per capita, and it is anticipated that the growth in the consumption of plastic by 2015 might be 90%, consumption rising to 36 kg per capita[01]. Figure 1 shows the structure of consumption in the world.[01]

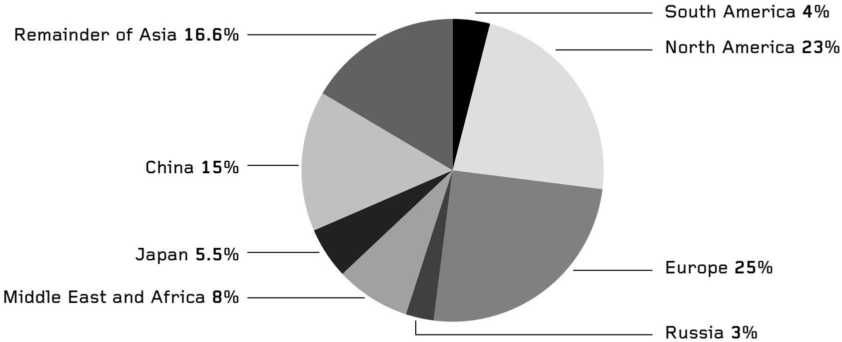


Figure 1. Shares of parts of the world in total world plastic production in 2008 (245 million tons were produced)[01]

Of the 245 million tons of plastic produced in 2008, almost 175 million tons (72%) consist of wide-application thermoplastics. Most widespread of all are polyethylenes. In 2008, about 36.5 million tons of low density polyethylene and low density linear polyethylene (LDPE and LDLPE) were produced or 21% of total plastics; approximately 30 million tons of high density polyethylene (HDPE) were made, or 17%. Forty three and a half million tons of polypropylene (PP) was made, or 25% of total production. There was a high production of PVC (polyvinyl chloride), of about 35 million tons, or 20%, while PET [poly(ethylene terephthalate)] of which 14 million tons were produced, or 8%, is becoming increasingly widespread. Finally there are polystyrene (PS) and expandable polystyrene (EPS), produced in about 16 million tons (9%).[01]

For these considerations, the structure of applications of plastic in Europe in 2009 is also interesting. The situation is similar in other areas. More than 50% is accounted for by packaging.

O važnosti plastike i gume u suvremenom svijetu govori i podatak da informacijska globalizacija, naime bankarstvo, prijenosi sportskih i kulturnih događaja i slično, izravno ovise o globalnoj mreži optičkih kabela koje čine anorganski polimeri na osnovi silicija te organska plastika i guma.

3. Plastika i guma, vršni polimeri

Pridjev "vršni" znači da se ovi materijali nalaze na vrhu ili prvi među polimerima, kao i da proizlaze iz onih tvari i materijala koji su na nižoj razini. Međutim, stvarna rasprostranjenost polimera dovela je do temeljite promjene paradigme o podjeli materijala.[02, 03] Do sada su se materijali dijelili na metale i nemetale, ali na temelju sintezologijskih istraživanja[A] načinjena je nova podjela na polimere i nepolimere. Ta podjela temelji se na samoj definiciji riječi "polimeri".[03] Pojednostavljeno, "polimeri" su skupno ime za prirodne i sintetske polimerne tvari (kemijski spoj sastavljen od makromolekula) i polimerne materijale, kojih je osnovni sastojak sustav makromolekula, makromolekularni spoj, s *opetovanim* jedinicama.[03] Pri tome je ključna sintagma "opetovane jedinice". Prema toj definiciji, moguće je razlikovati anorganske i organske polimere (slika 3).[03]

Pogled na sliku 3 opravdat će novu podjelu. Među anorganske polimere ubrajaju se, primjerice, zeoliti, mica i glina, a posebno su važni anorganski polimeri na osnovi silicija, od kojih se prave najraznovrsniji čipovi, ali i plastika (npr. polisilazani) te silikonski gumeni proizvodi.

Mnogo učestalije su plastika i guma koje se temelje na organskim polimerima. Pritom se pretežni dio suvremene plastike dobivene sintetskim putem temelji na sirovinama, proizvodima prirode ili prirodninama poput nafte i prirodnog plina. Tek se u novije vrijeme u proizvodnji organske plastike upotrebljavaju proizvodi iz uzgoja, odnosno uzgojine poput kukuruza, krumpira itd. Takva se plastika naziva bioplastikom i trenutno je njezin udio u ukupnoj plastici manji od 1 %. Nasuprot tome, u proizvodnji gumenih tvorevina je udio osnovnog sastojka, kaučuka, podjednak.

U 2009. je u svijetu od oko 21,7 milijuna tona potrošenog kaučuka na prirodni i uzgojeni (plantažni) kaučuk otpadalo 44 %, dok je ostatak od 56 % sačinjavao sintetski kaučuk.[01] Pritom je kaučuk osnovni sastojak kaučukove smjese od koje poslije njezina praoblikovanja (stvaranja početnog oblika tvorevine) kemijskom reakcijom umrežavanja nastaje gumeni proizvod.

4. Zašto je plastika *najzeleniji* materijal 21. stoljeća?[04]

Slika 4 prikazuje zbog čega se tvrdi da je plastika *najzeleniji* materijal. Kada bi se plastika zamijenila drugim materijalima, uključivši nezamjenjivu plastiku, odnosno onu koja omogućuje jedinstveno rješenje, ukupna bi težina istih funkcionalnih jedinica porasla za 3,7 puta. Potrošnja energije tijekom proizvodnje i uporabe (od kolijevke pa do groba) porasla bi za 57 %, a emisija stakleničkih plinova za 61 %.

A Za definiciju termina "sintezologija" vidi: www.sintezologija.hr.

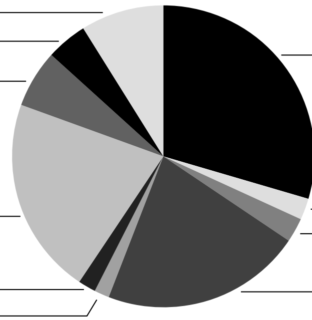


Figure 2. Areas of application of plastic materials in Europe in 2009[01].

How important plastic and rubber are in the contemporary world is shown by the fact that computerised globalisation, in banking, the transmission of sporting and cultural events, and the rest, depends directly on the global network of optical cables consisting of inorganic polymers based on silicon and organic plastics and rubber.

3. Plastic and rubber, the peak polymers

Peak means that they are at the peak among polymers. And also that they derive from substances and materials at a lower level. However, the real wide distribution of polymers has led to a thoroughgoing change in the paradigm about the division of materials.[02, 03] Until recently, materials were divided into metals and non-metals. Synthesiological research[A] has produced a new division into polymers and nonpolymers.[03] This is based on the definition of the word polymer. Put simply, polymers are a collective name for natural and synthetic polymer substances (a chemical compound composed of macromolecules) and polymeric materials the basic component of which is a system of macromolecules, a macromolecular compound, with *repeat units*. Here the key phrase is repeat unit. It is possible according to this division to differentiate inorganic and organic polymers (Figure 3).[03]

A look at Figure 3 will justify this new division. Among inorganic polymers are, for example, zeolite, mica and clay, while inorganic polymers based on silicon are particularly important for from them the most diverse chips are made, as well as plastics such as polysilazane and silicon rubber products.

Much more common are plastics and rubbers that are based on organic polymers. Here the major part of contemporary plastic obtained synthetically is based on raw materials, natural products, and natural raw materials like oil and natural gas. Only in recent times have cultivated products such as corn and potato been used for the production of organic plastics. Such plastic is called bioplastic, although at the present time it accounts for less than 1% of total plastics. By contrast, in the production of rubber materials, the share of the basic component, rubber, is the same.

In 2009, worldwide, of the 21.7 million tons of rubber used, 44% was accounted for by natural and planted rubber, and the remaining 56% came from synthetic rubber. Rubber is the basic component of the rubber compound from which, after its primary shaping (the creation of the initial form of the material), the rubber product arises by the chemical reaction cross-linking.

A What synthesiology is can be found at www.sintezologija.hr.

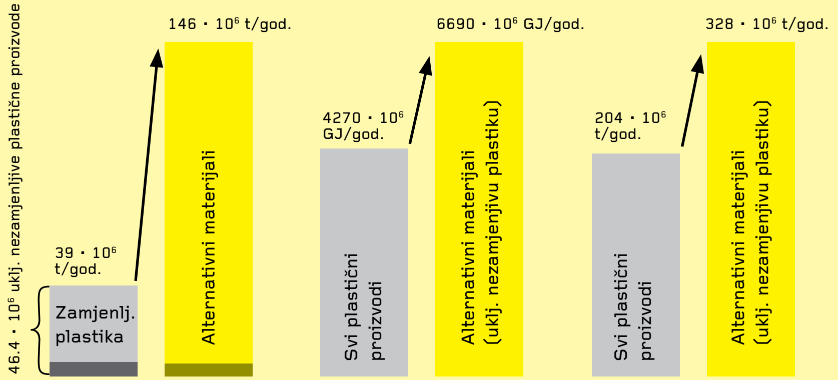
Slika 3. Od makromolekularnih spojeva do složenaca[03]

P	**Kompozitni materijali:** — **organski proizvod sinteze** (npr. polietilenska vlakna i plastomerna matrica) **Kompozitni proizvodi:** — **organski proizvod sinteze i uzgojeni proizvod** (npr. duromerna matrica i juta) — **organski proizvod sinteze and anorganski polimer** (npr. duromerna matrica i staklena vlakna) — **organski proizvod sinteze i anorganskog nepolimera (metal)** (npr. plastična matrica i metalno ojačavalo)		**Hibridni materijali:** — **organskoanorganski hibridi** (npr. plastično zeolitni hibrid) — **anorganskoorganski hibrid** [npr. poly(organosiloksan) i plastika] — **organsko *xxx* + osnovni organski polimer** (*xxx* i protein) — **organski polimerno/organsko nepolimerni hibrid** [npr. pol(laktik-ko-glikolna kiselina) i lipid] **Hibridni proizvod:** — **injekcijski prešani višeslojni hibridi**			
P	**Kompozitni materijali* i kompozitne tvorevine****		**Hibridni materijali i hibridne tvorevine**			
P	**Složenci (materijali i proizvodi)**					*n* + 7
P	**Metali** čelici, Al-slitine, itd.	**Plastomeri**: npr. polisilazani **Elastomeri**:npr. polisiloksani	**Duromeri /** PF, UP, PUR, itd.	**Plastomeri** PE, PVC, PS, PA, itd. **Elastomeri** guma, elastoplastomeri		
P	**Anorganske nepolimerne tvari i materijali**	**Anorganski sintetski polimeri**	**Organski sintetski polimeri (neživo)**	**Kemijski modificirani biopolimeri od prirodnih i uzgojenih proizvoda (živo)**	**Npr. ulja**	
P	**Anorganske tvari i materijali**		**Organske tvari i materijali**			*n* + 6
T	KONTROLIRANE ANORGANSKE REAKCIJE		KONTROLIRANA ORGANSKA SINTEZA	KONTROLIRANA BIOSINTEZA		
T	UMJETNA TEHNIKA					
P			**NEŽIVI ORGANSKI PRIRODNI PROIZVODI** (npr. prirodni plin)	**ŽIVI ORGANSKI PRIRODNI PROIZVODI**		*n* + 5
P			**fiTOPOLIMERI** (npr. drvo)	**ŽIVOTINJSKI POLIMERI** (npr. kosti)		*n* + 4
P			**Biopolimerni organizmi** (mikroorganizmi i makroorganizimi)			*n* + 3
P	PRIRODNO: - samorodni metali: zlato, živa - metalne rudače	PRIRODNO: - glina - mica (tinjac) - zeoliti	PRIRODNO: - bjelančevine (proteini) - nukleinske kiseline - polisaharidi		PRIRODNO	
P	**Prirodni nepolimerni anorganski makromolekulni spojevi**	**Prirodni geopolimeri** (prirodni anorganski polimeri)	**Biopolimeri** (prirodni organski polimeri)		**Prirodni nepolimerni organski makromolekulni spojevi** (npr. lipidi)	*n* + 2
P	**PRIRODNI ANORGANSKI MAKROMOLEKULNI SPOJEVI** (nežive prirodnine – minerali)		**PRIRODNI ORGANSKI MAKROMOLEKULNI SPOJEVI** (žive prirodnine – živi organizmi)			*n* + 1
	A	B	C		D	
T	GEOLOŠKI PROCESI NEŽIVOGA		BIOSINTEZA (SINTEZA ŽIVOGA)			
P	**MAKROMOLEKULNI SPOJEVI** (tvar)					*n*
	MATERIJA					
T	PRIRODNA TEHNIKA					
T	OPĆA TEHNIKA					Razine

Figure 3. From macromolecular compounds to composed materials

	A	B	C	C	D	Levels
P	— **organic product of synthesis** (e.g. polyethylene fibres and thermoplastics matrix) — **organic product of synthesis and cultivated products** (e.g. thermoset matrix and jute) — **organic product of synthesis and inorganic polymers** (e.g. thermoset matrix and glass fibres) — **organic product of synthesis and metals** (e.g. metallic reinforcement agent and plastics matrix)		— **inorganic-organic polymers** (e.g. polymer-zeolite hybrid) — **organic-inorganic polymers** [e.g. poly(organosiloxanes)] — **organic *xxx* + organic basic polymer** (*xxx* and proteins) — **organic polymer – organic non-polymer** [e. g. poly(lactic-co-glycolic acid) and lipids — **hybrid product** (e.g. made by injection moulding)			
P	**Composite materials and composite products**		**Hybrids materials and products**			
P	**Composed materials and composed products**					*n* + 7
P	Metals steels, Al-alloys, etc.	**Thermoplastics:** e.g. polysilazanes **Elastomers:** e.g. polysiloxanes	**Thermosets** PF, UP, PUR, etc.	**Thermoplastics** PE, PVC, PS, PA, etc. **Elastomers** vulcanized rubber thermoplastics rubber		
P	**Inorganic non polymeric substances and materials**	**Inorganic synthetic polymers (non-living)**	**Organic synthetic polymers (from non-living)**	**Chemically modified biopolymers from natural and cultivated products (from living)**	**E. g. oils**	
P	**Inorganic substances and materials**		**Organic substances and materials**			*n* + 6
T	CONTROLLED REACTIONS INORGANIC		CONTROLLED ORGANIC SYNTHESIS	CONTROLLED BIOSYNTHESIS		
T	ARTIFICIAL TECHNOLOGY					
P			**NON-LIVING ORGANIC NATURAL PRODUCT** (e.g. natural gas)	**LIVING ORGANIC NATURAL PRODUCTS**		*n* + 5
P			**PHYTOPOLYMERS** (e.g. wood)	**ANIMAL POLYMERS** (e.g. bones, skins)		*n* + 4
P			**Biopolymeric organisms** (microorganisms and macroorganisms)			*n* + 3
P	**NATURAL:** - native metals: gold, mercury - metal ores	**NATURAL:** - clay - mica (glimmer) - zeolites	**NATURAL:** - proteins - nucleic acids - polysaccharides		**NATURAL**	
P	**Other natural inorganic macromolecular compounds** (non-polymers)	**Natural geopolymers** (Natural inorganic polymers)	**Biopolymers** (Natural organic polymers)		**Other natural organic macromolecular compounds** (e.g. lipids)	*n* + 2
P	**NATURAL INORGANIC MACROMOLECULAR COMPOUNDS** (Non-living natural products - minerals)		**NATURAL ORGANIC MACROMOLECULAR COMPOUNDS** (Living natural products – living organisms)			*n* + 1
	A	B	C		D	
T	**GEOLOGICAL PROCESSES OF NON-LIVING**		**BIOSYNTHESIS (SYNTHESIS OF LIVING)**			
P	**MACROMOLECULAR COMPOUNDS** (substance)					*n*
	MATTER					
T	**NATURAL TECHNOLOGY**					
T	**GENERAL TECHNOLOGY**					**Levels**

Slika 4. Porast težine, potrošnje energije i stvaranja stakleničkih plinova ako se plastika zamijeni drugim materijalima[04]



5. Polietilenska vrećica je ekološki najprihvatljivija

Već je naglašeno da je polietilenska, općenitijim rječnikom plastična vrećica, simbol negativnog imidža plastike u javnosti. Nemoguće je citirati svu dostupnu literaturu o tome, pa čak niti samo onu koja je u posljednjih petnaestak godina objavljena, primjerice, na hrvatskom jeziku. Dio novijih radova dostupan je na internetu.[05]

Na temelju brojnih istraživanja koje je sažela austrijska konzultantska tvrtka Denkstatt,[04] a provjerili su ih nezavisni recenzenti, opravdanost uporabe polietilenskih vrećica najpreglednije prikazuje slika 5.[06] Iz slike 3 proizlazi da su sve tri vrećice načinjene od organskih polimera: papirnate od drva (razina n+4), platnene vrećice su biljnog podrijetla iz uzgoja, a polietilenske od prirodnina: nafte ili prirodnog plina. Pritom su papirnate i pamučne načinjene od materijala kojima je osnovni sastojak polimer celuloza. Uspoređuju se ustvari polimeri celuloznog i fosilnog podrijetla.

Zato kriterij usporedbe nije ulaz u proces, dakle celuloza ili fosilna goriva (nafta i prirodni plin), nego tragovi.[B] Kako se po pokazateljima pamučne vrećice nalaze između polietilenskih i papirnatih, usporedit će se samo ova dva materijala.

Za papirnate vrećice treba ukupno 22 puta više materijala, utjecaj na stvaranje stakleničkih plinova je 10 puta veći, a faktori za iscrpljivanje prirodnih resursa nešto su viši od 4 puta. Međutim, u proizvodnji papirnatih vrećica nastaju zagađivači (eurotrifikacija) nitrati i sulfati, čega nema kod polietilenskih vrećica.

Neshvatljivo je da se promiču pamučne vrećice. Pamuk se trenutno uzgaja na oko 3 % svjetskih obradivih površina, za njegov uzgoj troši se 25 % pesticida, a u proizvodnji pamuka i pamučnih proizvoda troše se ogromne količine vode. Istodobno trajno raste cijena pamuka: u posljednjih godinu dana gotovo za 80 %.

B Engleske riječi *footprint* i *fingerprint* treba prevoditi na hrvatski kao trag, a ne otisak. Primjer: Tijekom istrage pronađen je trag koji je vodio do otiska gumene čizme. Svaki otisak je trag, ali nije svaki trag otisak.

4. Why plastic is the greenest material of the 21st century?[04]

Figure 4 shows why plastics are the greenest of the greens. If plastic were replaced with other materials – all plastic, even the kind of plastic that has unique uses and is irreplaceable – the total mass for the same functional units would rise 3.7 times. The consumption of energy in production and use (from cradle to grave) would rise by 57% and the emission of greenhouses gases by 61%.

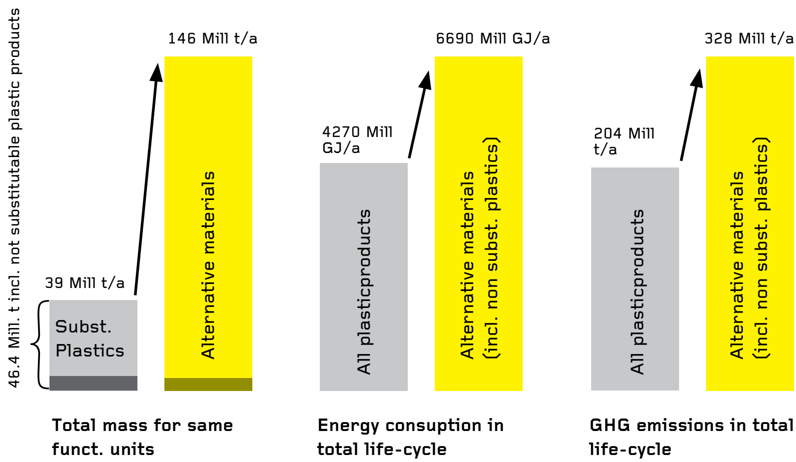


Figure 4. Rise in weight, energy consumption and generation of greenhouse gases if plastic were replaced by other materials.

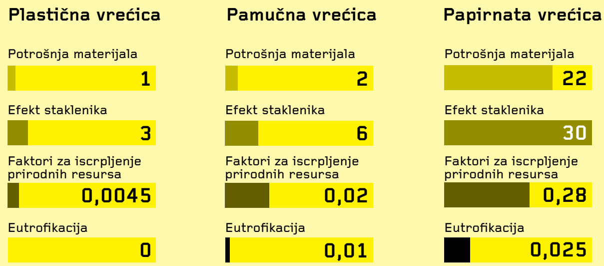
5. Polyethylene bag ecologically the most acceptable

It has already been remarked that the polyethylene or plastic bag is the symbol for the negative image of plastic present in the public mind. It is impossible to quote the available references, even those published in the last fifteen years for example in Croatian. Some of the more recent works are available on the portal.[05]

On the basis of the many research works synopsised by the Austrian consulting firm Denkstatt[04] and checked out by independent reviewers, the justification of the use of polyethylene bags is most cogently shown in Figure 5.[06] Figure 3 has already shown that all three bags are made of organic polymer: paper of wood (level *n*+4), while cotton bags are of cultivated plant origin, and polyethylene bags come from natural sources, from oil or natural gas. Paper and cotton bags are made from materials the basic component of which is the polymer cellulose. It is in fact polymers of cellulose and fossil origin that are being compared.

And so the criteria for comparison are not inputs into the process: cellulose or fossil fuel, oil and natural gas, rather *footprints*. Since according to the indicators cotton bags come between polyethylene and paper, only these two materials will be considered.

Paper bags need all told 22 times as much material; the effect on the creation of greenhouses gases is 10 times greater; the depletion-of-natural-resources factor is a bit more than four times as great. And in the process of making paper bags, pollutants are produced (eutrophication): nitrates and sulphates, which do not come with polyethylene bags.



Slika 5. Faktori kojima se određuje utjecaj materijala na onečišćenje okoliša[06]

6. Dvojbenost razgradivih vrećica

Posljednjih godina promiču se bioplastika i biorazgradive vrećice. I to potpuno pogrešno. Bioplastika se suprotstavlja običnoj plastici (npr.[07])[C], iako je to isključivo plastika posebne namjene, načinjena na temelju uzgojenoga, bilo primarnog proizvoda uzgoja, npr. kukuruza ili krumpira, ili od otpadne biomase, pri čemu se biomasa najčešće definira kao tvari iz polja koje rastu za potrebe proizvodnje biogoriva, ali uključuje i biljne ili životinjske tvari za proizvodnju vlakana, kemikalija ili topline.[08, 09] U biomasu se ubraja i biorazgradivi otpad koji može poslužiti kao gorivo.[08] Bioplastika danas čini udio manji od 1 % ukupne proizvodnje plastike i tek će postati važnijim faktorom za 20 do 30 godina (R. Lang).[09] Očekivanje porasta važnosti bioplastike temelji se na njezinoj primjenjivosti u medicinske svrhe, za filmove za malčiranje u poljoprivredi i slične proizvode.

Postoji pet vrsta razgradive plastike. "Biorazgradiva" plastika je ona kod koje je razgradnja rezultat djelovanja enzimske aktivnosti prirodnih mikroorganizama (bakterije, gljivice, alge). Materijal se pretvara u vodu, CO_2 i/ili metan i biomasu. Kod "kompostabilne" plastike razgradnja nastaje uslijed bioloških procesa tijekom kompostiranja (proces koji kontrolira biološku razgradnju biorazgradivog materijala u tvar nalik humusu – kompost). Materijal se pretvara u CO_2, metan, vodu, anorganski dio i biomasu. Materijal je kompostabilan kada je kompatibilan s uvjetima na odlagalištu (temperatura, vlažnost, vrijeme). Pod nazivom "oksidacijski biorazgradiva plastika" podrazumijeva se ona kod koje je razgradnja rezultat dodavanja dodataka koji potiču ("trigeriraju") i ubrzavaju razgradnju. Razgradnja se inicira prirodnom svjetlošću, toplinom i/ili mehaničkim naprezanjem. Slijedi "fotorazgradiva" plastika, koja se razgrađuje uslijed djelovanja UV svjetlosti, koja razbija kemijsku vezu ili kemijsku strukturu materijala. U suštini su i ostale vrste plastike fotorazgradive pa im se dodaju UV-stabilizatori kako bi im se produljio vijek uporabe. Kada se polietilenskim vrećicama ne bi dodavali UV-stabilizatori, raspale bi se vrlo brzo. Naposljetku, postoji i "vodotopiva" plastika, koja se otapa u vodi u određenom temperaturnom rasponu, nakon čega se biorazgrađuje u dodiru s mikroorganizmima.

Postavlja se pitanje korištenja biomase za izradu plastičnih proizvoda. Primjenom bioplastike smanjuje se korištenje fosilnih goriva. Međutim, trenutno

C Tekst[07] je nastao kao rezultat reakcije na jednu štetnu reklamu na izložbi plastike i gume u Düsseldorfu u listopadu 2010. Članak je prenesen na portale u Poljskoj i Mađarskoj pa postoje inačice na poljskom, mađarskom, češkom čak i srpskom. Trenutno je u tisku njemačka inačica u jednom njemačkom časopisu, kao i do sada najsveobuhvatniji tekst o bioplastici u njemačkom časopisu na engleskom jeziku. Središnja točka u tom članku je opis slike 3 zbog kasnije usporedbe triju vrsta vrećica koji je i ovdje korišten.

It is incomprehensible that cotton bags should be promoted. Cotton is currently grown on about 3% of the world's cultivable land, 25% of pesticides are used during cultivation, and for the production of cotton and cotton products vast quantities of water are used. At the same time the price of cotton is constantly rising, almost 80% in the last year.

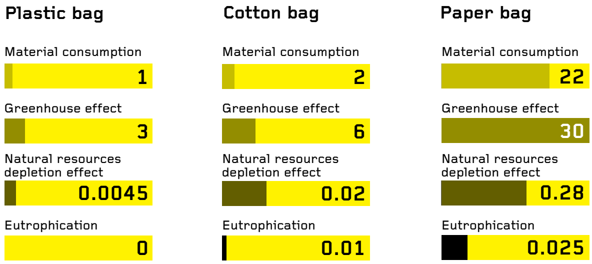


Figure 5. Factors determining the impact of materials on environmental pollution.[06]

6. Doubts about degradable bags

In the last few years bioplastics and biodegradable bags have been busily promoted, absolutely wrongly. This material is contrasted to ordinary plastic (e.g.[07])[C], and bioplastic is only special purpose plastic made from cultivated products, either primary products such as corn and potato or of waste biomass, the definition of biomass most often being substances from the land that are grown for the production of biofuel but can also include plant and animal substances for the production of fibres, chemicals or heat.[08, 09] Biomass also includes bio-degradable waste, which can be used as fuel. Bioplastic today makes up less than 1% of total plastic production and will become a major factor in 20 or 30 years (R. Lang).[09] The expectations in the rise in the importance of bioplastic are based on its applicability in medical purposes, mulching films in agriculture and similar products.

There are five kinds of degradable plastic. Biodegradable plastic is the one in which degrading is the result of enzymal activity of natural microorganisms such as bacteria, fungi and algae. The material turns into water, CO_2 and/or methane and biomass. In the case of compostable plastic, degradation results from the biological processes during composting (a process that controls the biological breakdown of biodegradable materials in a material similar to humus). The material is turned into CO_2, methane, water, an inorganic part and biomass. Material is compostable when it is compatible with conditions in the pile (temperature, humidity, time). The name oxidational biodegradable plastic means that in which degradation is the result of additives that trigger and accelerate the breakdown process. Degradation is initiated by natural light, heat and/or mechanical tension. Then comes photodegradable plastic, which is degraded because of the effect of UV light, which breaks down the chemical bond or chemical structure of the materials. In essence, other kinds of plastic are photodegradable, but they have UV stabilisers added to them, which extends their useful life. If polyethylene bags did not have added UV stabilisers, they would fall to pieces very rapidly. Finally there are water soluble plastics that dissolve in water in a certain tem-

B The text[07] was created as a result of a reaction to a harmful advert at a plastic and rubber trade fair in Dusseldorf in October 2010. It was covered on portals in Poland and Hungary, and there are versions in Polish, Hungarian, Czech and Serbian. Now a German version is in print in a German journal. Also in print is the most comprehensive text to date about bioplastics in a German journal, in English. The central point in the article is a description of Fig. 3, here, because of the later comparison of the three bags, also used here.

se samo 4 % fosilnih goriva rabi za proizvodnju plastike. Kako bioplastika danas na tržištu plastičnih materijala ima udio < 1 %, ukupni efekt zamjene fosilnih izvora biomasom bit će vrlo malen zbog malenog udjela fosilnih goriva u proizvodnji plastike. Znatno veće uštede mogu se postići boljom izolacijom zgrada s pomoću plastičnih izolacija. Tu je potencijal od oko 10 % uštede energije. Kako se na zagrijavanje troši gotovo 50 % energije, uporabom plastičnih izolacija, prozora, vrata i sličnim rješenjima može se uštedjeti cjelokupna potrošnja fosilnih goriva potrebnih za proizvodnju plastike.

Primjenom bioplastike smanjuje se emisija stakleničkih plinova, što doprinosi zaštiti klime.

CO_2-neutralnost bioplastike vezana je uz korištenje biljaka. Međutim, faza proizvodnje, od sijanja preko žetve pa sve do proizvodnje materijala, zahtijeva konvencionalne izvore energije, koji doprinose CO_2 emisijama. Poljoprivredni uzgoj zahtijeva zemlju, vodu, gnojiva i proizvode za zaštitu usjeva, on troši energiju i uzrokuje emisije. Ukupni ugljikov trag plastike je samo 1,3 %. Najveći je za grijanje, naime 15 %, ali iznenađuje podatak da je trag sporta i dokolice punih 14 %. Treba li se zbog toga odreći sporta i dokolice, ili bi trebalo potražiti mjere kako ga smanjiti?

Promocija poljoprivrednih proizvoda za industrijske svrhe nije ograničena WTO propisima. Namjena obradivih površina dijeli se s obzirom na potrebu za hranom, biogorivima i sirovinama za plastiku, iz čega slijedi sukob interesa. Kako je dostupnost obradivog zemljišta ograničena, slijedi da podupiranje jedne primjene (npr. biogoriva, bioplastike) dovodi do smanjene dostupnosti za druga područja (hranu), što rezultira povišenjem cijene hrane (npr. kukuruza zbog proizvodnje bioetanola). A to sve češće dovodi do političkih sukoba, osobito u siromašnijim zemljama.

Na kraju ovog odlomka možemo doći do određenog zaključka. Proizvodi od razgradivih materijala ne nude posebnu prednost, a nekontrolirani su u okolišu štetniji od fosilne plastike.

Odjeljci 4. do 6. pokazuju da je javnost izložena teškim manipulacijama od strane nezajažljivog kapitala, koji se skriva iza održivog razvoja i društvene odgovornosti. Tome bitno pridonose strogo kontrolirani mediji, koji su pod pritiskom vlasnika i oglašivača. Međutim, ne može se zanemariti ni uloga najrazličitijih "zelenih" udruga, koje se bave sporednim problemima poput plastičnih vrećica. Primjerice, godišnji trag stakleničkih plinova koji su rezultat plastičnih vrećica za jednu osobu jednak je ekvivalentu njezine vožnje osobnim vozilom od 13 km. Istodobno ljudsko biće konzumiranjem konvencionalno uzgojene hrane, koja uključuje i meso, potroši godišnje ekvivalent od 4758 km. Dakle, plastične vrećice su na razini udjela od nekih 0,3 % potrošnje hrane. A prosječno ljudsko biće proizvede godišnje otprilike 12,5 tona stakleničkih plinova. Plastične vrećice tome pridonose s 0,02 %.

7. Umjetnost i plastika

S obzirom na projekte Kontejnera, treba skrenuti pozornost i na ulogu plastike i gume u umjetnosti. Ta je uloga dvoslojna. Svi nosači informacija: sve vrste nosača zvuka, slike itd. praktički su uvijek bili i jesu neka vrsta plastike.

Ono što je možda neuobičajeno jest sljedeća činjenica. U pravilu, umjetnici perature range, after which they are biodegraded in contact with microorganisms.

The question arises as to the use of biomass for the making of plastic products. The use of bioplastic reduces the use of fossil fuels. But at the moment, only 4% of fossil fuels go to the making of plastic. Since bioplastic on the marketplace for plastic materials has a less than 1% share, the total effect of replacing fossil sources with biomass is very small, since such a small percentage of fossil sources anyway goes to making plastics. A much greater saving could be obtained with insulating buildings with plastic insulation. Here there is a potential for an about 10% saving of energy. Since about 50% of all energy is used for heating, the use of plastic insulation, windows, doors and similar solutions can make up for the whole of the use of fossil fuels needed for plastic.

The use of bioplastic reduces the emissions of greenhouse gases, which contributes to protection of the climate. That bioplastic is CO_2-neutral is related to the use of plants. But the production phase, from sowing to harvesting and production requires conventional sources of energy, which add to CO_2 emissions. Agricultural cultivation requires land, water, fertiliser, plant protection preparations; it uses energy and causes emissions. The total carbon footprint of plastic is only 1.3%. The biggest of all footprints is for heating, which is 15% of the total; a surprising fact is that the footprint of sports and leisure activities is a full 14%. Does this means that sports and leisure activities have to be given up, or should measures be found to reduce this percentage?

The promotion of farm products for industrial purposes is not restricted by WTO regulations. The purpose of cultivable land is shared by needs for food, biofuels and raw materials for plastics, which means there is a conflict of interest. Since the accessibility to cultivable land is limited, it follows that support given to one application (such as biofuel or bioplastic) will result in a reduction of accessibility for other areas (food), which will result in food price hikes (of corn, for example, because of the production of bioethanol). And this increasingly leads to political conflicts, particularly in the poorer countries.

At the end of this section, a conclusion is possible. Products of degradable materials do not provide any particular benefits, and when uncontrolled in the environment are more harmful than fossil-derived plastic.

Sections 4 to 6 show that the public is exposed to serious manipulations from the insatiable capital concealed behind sustainable development and social accountability. This is essentially contributed to by the strictly controlled media, under pressure from owners and advertisers. But we also cannot neglect the role of the most diverse green organisations that deal with minor problems like plastic bags. For example, the annual greenhouse gas footprint of plastic bags for a single person is equivalent to that person's driving a car 13 km. At the same time, that same human being, by consuming conventionally raised food that includes meat consumes the annual equivalent of 4,758 km of driving. Plastic bags contribute about 0.3% the amount of greenhouse gases produced by the consumption of food. The average human being prosu uvijek prednjačili u uporabi novih materijala, ali to se ne može reći za plastiku i gumu. Točno je da postoje artefakti koji su izrađeni pretežno od plastike, ali oni nedovoljno odražavaju važnost tih materijala u suvremenom životu.

8. Zaključak

Plastika je opravdano proglašena *najzelenijim* materijalom, koji je postao nezaobilaznim čimbenikom suvremenog života.

Međutim, plastika ima možda najlošiji imidž u javnosti, i to potpuno neopravdano, uglavnom zbog manipulacije nedovoljno poučenom i obaviještenom javnošću.

Zahvala

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duces about 12.5 tons p.a. of greenhouse gases. Plastic bags contribute no more than 0.02% of this.

7. Art and plastic

Because of the projects of Kontejner, I ought to draw attention to the role of plastic and rubber in art. This role has two layers. All information media, all kinds of recording media, paintings, and so on, have practically always been some kind of plastic.

What perhaps is uncommon is the next fact. As a rule, artists have been in the lead in the use of new materials. But this cannot be said of plastic and rubber. It is true that there are some artworks made mainly of plastic, but they are far too few to reflect the importance of these materials in contemporary life.

8. Conclusion

Plastic is with good reason called the greenest of green materials, one that has become an essential factor in contemporary life.

However, totally without justice, plastic has an extremely bad image. Mainly because an insufficiently tutored and informed public has been improperly manipulated.

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Translated from Croatian by **Graham McMaster**

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Životopis

Dr. sc. **Igor Čatić** (1936.) umirovljeni je redoviti profesor Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu. Usporedo je završio gimnaziju i izučio alatničarski zanat. Diplomirao je i magistrirao na današnjem Fakultetu strojarstva i brodogradnje. Doktorirao je 1972. na Tehničkom sveučilištu u Aachenu. Radio je u alatničarskoj radionici *Štanca* (1955.-1960.), tvornicama MEGA (1960.-1963.) i TOZ (1963.-1965.) te na FSB-u (1965.-2006.). Predavao je predmete s područja proizvodnje plastičnih i gumenih tvorevina na dodiplomskim ili postdiplomskim studijima u zemlji i inozemstvu. Predavao je studentima arheologije, ekonomije, filozofije i sociologije. Pokrenuo je osnivanje prethodnica današnjeg Društva za plastiku i gumu. U časopisu *Polimeri* je urednik za inozemstvo (1982.-). Primio je Nagradu *Nikola Tesla* za znanost (1977.), promicanje tehničkih znanosti (2000.), Nagradu grada Zagreba za znanost (2002.) i Nagradu za životno djelo *Faust Vrančić* (2005). Posebno se ističe nagrada Society of Plastics Engineers (SAD) pod nazivom *International Education Award* (1998.). Član je više udruga, među ostalim doživotni je član sa statusom Fellow of Institute of Materials, Metallurgy and Mining.
Osim na užem području objavio je više izvornih znanstvenih i stručnih radova s područja jezika, filozofije i etike te više rječnika. Pisao je i jazz kritike te pripremao jazz emisije.

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Biography

Igor Čatić (b. 1936) is professor emeritus of the Faculty of Mechanical Engineering and Naval Architecture, Zagreb. While he was attending secondary school, he also learned the toolmaker's trade, after which he graduated and obtained his MA degree from today's Faculty of Mechanical Engineering and Naval Architecture (FSB). He wrote his PhD dissertation at the Technical University in Aachen, after which he worked at the toolmaker's workshop of *Štanca* (1955-1960) and the factories MEGA (1960-1963) and TOZ (1963-1965). While he was professor at the Faculty of Mechanical Engineering and Naval Architecture, he taught various courses related to the production of plastic and rubber substances for BA and MA students in Croatia and abroad (1965-2006). He also headed courses for students of archaeology, economy, physics, and sociology. He initiated the foundation of a precursor of today's Plastics and Rubber Association. Since 1982, he has worked as international editor for the periodical *Polimeri*. He has won the following awards: *Nikola Tesla* Award for Science (1977), Award for the Promotion of Technical Sciences (2000), Science Award of the City of Zagreb (2002) and *Faust Vrančić* Award for Lifetime Achievement (2005). A particularly prestigious award was that of the Society of Plastics Engineers (USA), entitled *International Education Award* (1998). Čatić is a member of various professional organizations and a permanent fellow of the Institute of Materials, Metallurgy, and Mining.
Apart from publishing in his field of expertise, he has written a number of scientific and professional papers from the field of linguistics, philosophy, and ethics, as well as several dictionaries. He has also written reviews on jazz music and produced radio programmes on jazz.