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MANAGEMENT OF MATERIALS FLOW FROM ELV VEHICLES

UPRAVLJANJE TOKOVIMA MATERIJALA IZ ELV VOZILA

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Abstract: *Waste must be managed and his amount has to be minimized. Significant amount of world waste is generated from used vehicles. Analysis of status of solving problem of treatment of used cars shows big disparity between other countries and in our country. Using positive experience of other countries dealing with this problem, and ruling by characteristics of this area, authors of this paper present results of researches which involve dealing with management of material flow from ELV vehicles.*

Key words: *waste, ELV, management, development.*

Apstrakt: *Otpadom se mora upravljati i njegova količinu je neophodno minimizovati. Značajna količina svetskog otpada potiče od korišćenih vozila. Analizom stanja u rešavanju problema tretmana korišćenih vozila uočava se značajan nesklad između stanja koje vlada u svetu i stanja kod nas. Koristeći pozitivna iskustva drugih zemalja koje se bave ovom problematikom, a rukovodeći se specifičnostima ovog područja, autori rada prilažu rezultate istraživanja koje obuhvata upravljanje tokovima materijala iz ELV vozila.*

Ključne reči: *otpad, ELV, upravljanje, razvoj.*

1 INTRODUCTION

Public thinks that vehicles have huge part in ecological charge of environment. At the moment, there are over half a billion active vehicles in the world. Some forecasts show that the number will reach over billion in next decade [19], if the market expands at current trend. The fact is that the vehicles must be made, used, renewed in order with legal regulations, which in good part deal with environment. Expectations are that everything made must be ecologically acceptably requires for looking of using new materials in beginning phase.

1 UVOD

U javnosti je zastupljena predstava o velikom udelu vozila u ekološkom opterećenju životne sredine. Trenutno u svetu „kruži“ preko pola milijarde automobila. Prognoze pokazuju da će se cifra popeti na preko milijardu u narednoj deceniji [19], ukoliko se tržište bude širilo postojećim tempom. Činjenica je da se vozila moraju praviti, koristiti, obnavljati i to u skladu sa zakonskom regulativom, koja se dobrim delom dotiče i okruženja. Očekivanja da sve što se napravi bude i ekološki prihvatljivo, zahteva da se u početnoj fazi istraživanja razmotri korišćenje novih materijala.

During product's construction, one must take care that every part is clearly signed so that it can be easily identified. After usage he is removed from other parts, so that it can be used in process of reusing. Accepting global aims in cycle process of material flow, known as ***R + 3E*** (**R**aw materials + **E**nergy + **E**conomy + **E**nvironment) [22] represents the main demand in developing of new technologies. Among them significant place takes treatment of used vehicles.

During solving of problem of used vehicles treatment (ELV – **E**nd of **L**ife **V**ehicle), we must consider number of those vehicles. About 9 million vehicles per year are being charged off in Europe at the moment. From that number, about 25% ends on the dump [19]. Respecting experiences in the world and a bit domestic, there is common estimation that when vehicles become unusable, recycling is stepping up (as one type of treatment of used vehicles). It is considered as one of the most dynamic industries in developed world and is in constant expansion [10]. It is interesting to point out the data that degree of recycling of vehicles in the world is around 75% of its entire weight. For electric machines in houses that percent is much lower - 52% [9]. Analysis of literature shows that trend of above mentioned growth will continue in the future.

Analysis of status of solving problem of treatment of used vehicles show disparity between status in world and in Serbia, especially in area connected with control of material flow. Dealing with this observation, aim of this paper is to help to decrease mentioned differences. Overview of most important researches from this is shown at the beginning of this paper. Some of results of researches referred to management of material flow are shown in further text, where the special comment is given on recommendations that can be used in this country.

2 LITERATURE REVIEW

Solving problem of ELV treatment is very complex and asks for wide range of knowledge - the most used are from area of technology and economy. By following material flows from ELV we can see that the aim is to maximize number of used parts that are returned to be reprocessed and/or some other kind of processing, so that they could be reused. The desired aim is that as

Prilikom izrade proizvoda, mora se voditi računa o tome da svaki deo bude vidno označen tako da može lako da se identifikuje. Nakon upotrebe on se odvaja od ostalih delova, kako bi se uveo u postupak ponovne upotrebe. Uvažavanje globalnih ciljeva u procesu kruženja materije, poznatih pod nazivom ***S + 3E*** (**S**irovine + **E**nergija + **E**konomija + **O**kruženje) [22] predstavlja imperativ u razvoju novih tehnologija. Među njima značajno mesto zauzima i tretman korišćenih vozila.

Tokom rešavanja problema tretmana korišćenih vozila *(ELV - **E**nd of **L**ife **V**ehicle)* važno je imati uvid i u broj tih vozila u okruženju. Trenutno se na teritoriji Evrope otpisuje oko 9 miliona vozila godišnje. Od toga 25% završi na otpadu [19]. Respektujući svetska i donekle domaća iskustva, opšta je ocena da kada vozila dospeju u fazu kada se više ne mogu koristiti, na scenu stupa reciklaža (kao jedan vid prerade dotrajalih vozila). Ona se smatra jednom od najdinamičnijih delatnosti u razvijenom svetu i u neprekidnoj je ekspanziji [10]. Interesantno je istaći podatak da stepen reciklabilnosti vozila u svetu iznosi oko 75% od njegove ukupne mase. Za električne uređaje u domaćinstvu taj procenat znatno niži – 52% [9]. Analizom literature može se zaključiti da će trend gore pomenutog porasta biti nastavljen u narednom periodu.

Analizom stanja u rešavanju problema tretmana korišćenih vozila uočava se značajan nesklad između stanja koje vlada u svetu i stanja u Srbiji, posebno u oblasti vezanoj za upravljanja tokovima materijala. Rukovodeći se ovakvim zapažanjem, cilj ovog rada je da doprinese smanjenju uočenih razlika. Na početku ovog rada je predstavljen pregled najznačajnijih istraživanja iz ove oblasti. U nastavku su priloženi neki od rezultata istraživanja koje se odnosilo upravljanje tokovima materijala iz ELV-a, pri čemu je posebni osvrt dat na preporuke koje se mogu primeniti na ovim prostorima.

2 ANALIZA LITERATURE

Rešavanje problema tretmana ELV-a je kompleksno i kao takvo zahteva širok spektar znanja. Među njma su najuočljivija znanja iz oblasti tehnike i ekonomije. Praćenjem tokova materijala iz ELV-a uočava se težnja za maksimizacijom broja korišćenih delova koji se vraćaju na ponovnu obradu, doradu, preradu i/ili neki drugi vid intervencije, kako bi se mogli

less material possible to be left at the dump. Such conclusion justifies some of the authors who classify this problem in group of problem of return logistics. [17].

Generally we can say that there are **two groups of problems** directly connected to treatment of used vehicles and their parts. ***First group*** of problems deals with all activities realized on vehicles that end their exploitation and can't be used anymore (and/or at least some of their parts). This group also contains problems dealing with impact that used vehicles have on environment, also those that deal with industry of disassembling of used vehicles, to those dealing with technically-technological treatment of almost every part of disassembled vehicle. ***Second group*** are those that can be grouped under location-routing problems. There is huge number of authors that deal with treatment of this numerous and economically very valuable group of used products, but there are only few of them that are concerned on solving problem of location objects (and routing vehicles for collecting of this kind vehicles' parts). Even if they do deal with it, their researches are mostly dealing with treatment of ELV, less focused of where to locate objects for their treatment. One of examples of researches in this area is solving problem of collecting used vehicles on territory of Mexico. [14].

One of numerous authors that joined researches of both group of problems is *Schultmann* [16, 17]. He is considered as one of few those that joins analysis of flows of reverse logistics in general, analyzing flows in car industry and solving location problem of object for treatment of thermoplastic parts from ELV on German territory.

Henderson [8] mostly deals with models of car cycle, pointing on accent on material recycling and make special attention to management of material flows from ELV. He is analyzing where are parts and materials from vehicles going after their disassembling, over dealers to factories, for technologically and physically closed entity dealing with their following remanufacturing, and also suggests using proper models for that analysis. *Memczyk* [12] mostly deals with key reasons for treatment and recycling of vehicles in general, but within activities that are within reverse logistics. At the same time, he analyze economical aspects of these activities. This author mostly deals with economical analysis of

ponovo upotrebiti. Težnja je da što manji procenat proizvoda završi na deponiji. Takav zaključak opravdava neke od autora da ovaj problem svrstava u grupu problema povratne logistike [17].

Generalno se može izvesti zaključak da postoje ***dve grupe problema*** koje su direktno vezane za tretman korišćenih vozila i njihovih delova. ***Prva grupa*** problema odnosi se na sve one aktivnosti koje se primenjuju nad vozilima koja završe svoj radni vek i ne mogu se dalje koristiti (i/ili bar neki njihovi delovi). U ovu grupu se uključuju i problemi koji se odnose na uticaj koji korišćena vozila imaju na okruženje, zatim oni koji se bave industrijom rastavljanja korišćenih vozila, pa do onih koji se odnose na tehničko-tehnološki tretman skoro svakog dela rastavljenog vozila. ***Druga grupa*** su oni koji se mogu podvesti pod lokacijsko-ruting problematiku. Postoji veliki broj autora koji se bavi tretmanom ove brojne i ekonomski veoma vredne grupe korišćenih proizvoda, ali je mali broj onih koji su se opredelili za rešavanje problema lociranja objekata (i rutiranja vozila za sakupljanje ove vrste delova vozila). Čak i ako se njime bave, onda su opet njihova istraživanja dobrim delom usmerena na tretman ELV-a, sa nešto manjim osvrtom na to gde će se locirati objekti za njihov tretman. Jedan od primera istraživanja u ovoj oblasti je rešavanje problema sakupljanja korišćenih vozila na teritoriji Meksika [14].

Jedan od brojnih autora koji je objedinio istraživanja obe grupe problema je *Schultmann* [16, 17]. Svrstava se u grupu malobrojnih koji su se opredelili za objedinjavanje analize tokova povratne logistike uopšteno, analiziranje tokova u auto industriji i rešavanje problema lociranja objekata za tretman termoplastičnih masa iz ELV-a na teritoriji Nemačke.

Henderson [8] se bavi uglavnom modelima automobilskog ciklusa, stavljajući akcenat na reciklažu materijala i posebnu pažnju posvećuje upravljanju tokovima materijala iz ELV-a. Naime, on analizira puteve kretanja delova i materijala iz vozila nakon njihovog rastavljanja, preko dilera, pa do pogona, odnosno tehnološki i fizički zaokruženih celina koje se bave njihovom daljom preradom, a za tu analizu predlaže i primenu odgovarajućih modela. *Memczyk* [12] se uglavnom usmerio na ključne razloge za tretman i reciklažu vozila uopšte, ali u sklopu aktivnosti koje spadaju u domen povratne logistike. Istovremeno razmatra i ekonomske aspekte ovih aktivnosti. Ovaj autor se uglavnom bavi ekonomskom analizom postupaka

procedures of recycling parts and materials of ELV. The accent is on that part that provides energy saving (materials that can't be reused or renewed go to process of burning, providing huge amount of energy that is used in industrial processes).

In paper [15] authors are mostly oriented to define number of dumps (in certain geographically closed area) for ELV disposal. Analysis is based on real indexes related to analyzed area (country). As result of analysis, they give suggestion of procedures and ways to reduce number of dumps and amount of materials left at them.

Kim [9] mostly deals with basic problems of car cycle, but apart from od *Hendersona* [8], he defines hierarchy of aims in control of waste that comes from used vehicles. According to him, in that hierarchy, preventive is on the first place, recycling on fourth, and on the bottom is storing of waste. Like most authors, he also touches problems related to analysis of material flow from ELV (but there is small amount of papers in general that give special attention to this problem), as well as legal acts and regulations for storing waste from this kind of waste material. He partly deals with location problem of objects for their further treatment.

Solving problem of treatment of used vehicles by analyzing vehicle's parts material content is accomplished in paper [11]. Special significance of this paper is given by practical analysis accomplished on example model of *Volkswagen Golf III*. Achieved results are mostly based on researches done in Swedish company *Folksam Auto*, which is, for now, one of leading when speaking about degree of development of technology used in treatment of ELV. They are also dealing with experiences from *Ford's* plants for treatment of parts from used vehicles. In that approach, we can mention solving problem of recovering engines from *Mercedes* vehicles from aspect of growing user's satisfaction, economical efficiency and ecological factor. [7].

Camp [3] deals with benchmarking in treatment of used product, with special retrospective to so called *six sigma* concept and its role in logistics of used vehicles. He makes special attention to place and role of comparing management of own company that deals with treatment of used vehicles with companies that do it better, by comparing performances of their management.

recikliranja delova i materijala ELV-a. Akcenat stavlja na onaj deo koji se odnosi na uštedu energije (materijali koji se ni na jedan drugi način ne mogu iskoristiti, odnosno preraditi, idu u proces spaljivanja, pa se na taj način oslobađa velika količina energije koja se koristi u industrijskim procesima).

Autori su se u radu [15] prevashodno orijentisali na broj deponija (u određenom geografski zaokruženom području) za odlaganje ELV-a. Analizu baziraju na realnim brojnim pokazateljima vezanim za analizirano područje (državu). Kao rezultat analize daju predlog postupaka i načina za smanjivanje broja deponija kao i ukupne količine materijala koja se na njima odlaže.

Kim [9] se uglavnom bavi osnovnim problemima automobilskog ciklusa, s tim što, za razliku od *Hendersona* [8], on definiše i hijerarhiju ciljeva u upravljanju otpadom, koji potiče od korišćenih vozila. Po njemu, u toj hijerarhiji, preventiva je na prvom mestu, reciklaža tek na četvrtom, a na dnu piramide je skladištenje otpada. Kao i većina drugih autora, takođe se dotiče problematike vezane za analizu tokova materijala iz ELV-a (ali je generalno mali broj radova koji su baš ovoj problematici posvetili posebnu pažnju), kao i zakonskim odredbama i propisima vezanim za odlaganje otpada iz ove vrste otpadnih materijala. Delimično se bavi i rešavanjem problema lokacije objekata za njihov dalji tretman.

Rešavanje problema tretmana korišćenih vozila analizom primenjenih materijala delova je ostvareno u radu [11]. Posebno težinu ovom radu daje praktična analiza koja je ostvarena na primeru *Volkswagen*-ovog modela *Golf III*. Rezultati do kojih su došli, uglavnom su bazirani na istraživanjima koje su sproveli u Švedskoj kompaniji *Folksam Auto*, koja je, za sada, jedna od vodećih kada je reč o stepenu razvijenosti tehnologije koja se primenjuje u tretmanu ELV vozila. Pored ove kompanije, dosta se bave iskustvima *Ford*-ovih postrojenja za tretman delova iz korišćenih vozila. U tom smislu se može pomenuti i rešavanje problema obnavljanja motora *Mercedes*-ovih vozila sa aspekta povećanja zadovoljstva korisnika, ekonomske isplativosti i ekološkog faktora [7].

Camp [3] se bavi benčmarkingom u tretmanu korišćenih proizvoda, sa posebnim osvrtom na takozvani koncept *six sigma* i njegovom ulogom u logistici korišćenih vozila. Posebnu pažnju posvećuje mestu i ulozi upoređivanja poslovanja sopstvene kompanije koja se bavi tretmanom korišćenih vozila, sa kompanijama koje to rade bolje, upoređivanjem performansi njihovog poslovanja.

By analyzing literature, it could be seen existence of models of different complexity and quality. They are mostly based on real problems that occur in developed countries. Status in our area is very different from their. Is the solution to do like them? Their experience is very valuable, but specifics of this area make us to modify other recommendations to our conditions. Having that aim in mind, in the following text there is further research made, with focus on control of material flow from ELV vehicles.

3 MANAGEMENT OF MATERIAL FLOW FROM ELV

To achieve efficient management of material flow from ELV, it is necessary to take some common steps dealing with process of management of flow of any kind and characteristics itself. First is needed to determine who are the generators of that kind of materials and in which types are present. In this phase we explain how to get those materials. In other words, it is discussed about which procedures are used to disassemble ELV to parts and materials. Then we must deal with of flow's characteristics (routes of material, elements of flow, eventual problems). Important and inevitable role in control of material flow usually have technically closed workshops dealing with their recycling. It's common conclusion that system like a entity must be managed from one point. So, database with all information on activities over ELV, and all generated material flows on that way, is necessary. At the end, we must investigate the specifics of these flows analyzed for certain geographical area.

3.1 Generators of material flow – characteristics of materials

The most suitable part for recycling (as one of the most used way of treatment of ELV vehicles) are one containing following materials: steal, aluminum, plastic, antifreeze, batteries, and whole parts of vehicles: tires, seats, engines and alternators. These results are obtained by association USCAR-a (*United States Council on Automotive Research*), according to whose data almost 27 million of passenger vehicles are getting old and ready for recycling. There is also conclusion that from recycled material some 80%

Analizom literature se može uočiti postojanje modela različite složenosti i kvaliteta. Oni su većinom bazirani na realnim problemima koji se javljaju u razvijenim zemljama. Stanje na našim prostorima se značajno razlikuje u odnosu na njihovo stanje. Da li je rešenje ići njihovim koracima? Njihova iskustva su dragocena, pa ipak, razne specifičnosti ovog prostora nas upućuju na potrebu prilagođavanja tuđih preporuka našim uslovima. U tom cilju je u nastavku rada i sprovedeno dalje istraživanje, sa težištem na upravljanje tokovima materijala iz ELV vozila.

3 UPRAVLJANJE TOKOVIMA MATERIJALA IZ ELV VOZILA

Da bi se postiglo efikasno upravljanje tokovima materijala iz ELV-a, neophodno je sprovesti nekoliko uobičajenih koraka koji se odnose na sam postupak upravljanja tokovima bilo koje vrste i prirode. Najpre je neophodno utvrditi ko su generatori te vrste materijala i u kojim pojavnim oblicima se isti pojavljuju. U ovoj fazi se objašnjava kako se do takvih materijala dolazi. Drugim rečima, govori se o tome koji se postupci primenjuju, kako bi se ELV-i rastavili na delove i materijale. Zatim je potrebno analizirati karakteristike tih tokova (putevi materijala, elementi tokova, eventualni problemi). Važnu i neizbežnu ulogu u upravljanju tokovima materijala uglavnom imaju one tehnološki zaokružene celine koje se bave njihovom reciklažom. Opšti je zaključak je da se sistemom kao celinom mora upravljati sa jednog mesta. Za to je neophodna baza podataka koja sadrži sve informacije vezane za aktivnosti sprovedene nad ELV-ima, kao i tokove materijala koji su na taj način dobijeni. Na kraju bi se trebalo posvetiti specifičnostima ovih tokova koji se analiziraju za određeno geografsko područje.

3.1 Generatori tokova materijala - pojavni oblik

Za reciklažu (kao jedan od najčešćih vidova tretmana ELV-a) najpogodniji su delovi koji u sebi sadrže sledeće materijale: čelik, aluminijum, plastiku, antifriz, baterije, kao i celi delovi vozila: gume, sedišta, motori i alternatori. Do ovih rezultata došla je asocijacija USCAR-a (*United States Council on Automotive Research*), prema čijim podacima u svetu skoro 27 miliona putničkih automobila godišnje biva dotrajalo i spremno za reciklažu. Došlo se takođe i do zaključka da se iz prerađenog i recikliranog

of total weight of (recycled) car can be recovered, while 20% of them [8], are not suitable for this process and are grouped as shredded pieces of car (***ASR*** – *auto shredder residue*). As ASR we consider some types of plastic, rubber, paper, textile, glass, sand, iron and aluminum parts. They (according to present conditions, legal acts and legal regulations) must be stored to landfills (about 5 million tons per year).

ASR represents the weakest part of treatment process, which is problem worldwide. Generally, there are two alternatives to which ASR is subjected: recycling and storing to dump. More than 25 million tons of materials from used vehicles are included into recycling every year, which give about 90% of aluminum used in production of one vehicle by its refining (Figure 1). Beside the fact that aluminum represents less than 10% of weight of vehicle, it is very valuable on world market. That is why it is interesting as object of research, from aspect of his generators and aspects of material flows as well [18].

materijala može povratiti oko 80% ukupne težine (recikliranog) vozila, dok oko 20% njih [8], na koji se ne bi mogao primeniti ovaj postupak i spada u sečene ostatke automobila (***ASR*** – *auto shredder residue*). U ASR se ubrajaju neke vrste plastike, guma, drvo, papir, tkanine, staklo, pesak, gvozdeni i aluminijumski delovi. Oni (prema sadašnjim uslovima, propisima i zakonskom regulativom) moraju biti odloženi na deponije (to je oko 5 miliona tona godišnje).

ASR predstavlja najslabiju tačku procesa tretmana, što predstavlja problem na svetskom nivou. Generalno postoje dve opcije kojima podleže ASR: reciklaža i odlaganje na otpad. Reciklažom je u svetu svake godine obuhvaćeno više od 25 miliona tona materijala iz dotrajalih vozila, iz kojih se daljom preradom dobija približno 90% aluminijuma koji se koristi u proizvodnji jednog vozila (slika 1). Pored toga što aluminijum predstavlja manje od 10% mase motornog vozila, on ima izuzetno veliku cenu na svetskoj tržištu. Zbog toga i jeste interesantan kao predmet istraživanja, kako sa aspekta njegovih generatora, tako i sa aspekta tokova materijala [18].

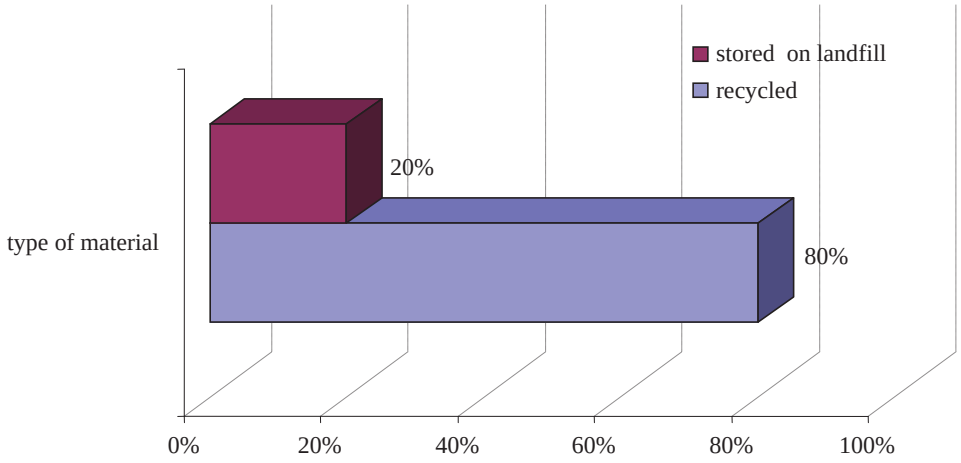

*Figure 1 Percentage display of relation of weight of material from used vehicles (**ASR**) recycled compared to those stored to dump [8]*
*slika 1 Procentualni prikaz odnosa mase materijala iz dotrajalih vozila (**ASR**-a) koji se recikliraju u poređenju sa onim koji idu na otpad [8]*

The fact is that nowadays vehicle is high complexity product, for whose production few hundred technologies is used and has about 15000 parts built in. Parts are made from different materials. With aspect of possible reusing, materials can be divided into following groups:

Naime, činjenica je da je sadašnje vozilo proizvod visoke složenosti, za čiju proizvodnju se koristi više stotina različitih tehnologija i u koji se ugrađuje oko 15000 delova. Delovi se proizvode od različitih materijala. U pogledu mogućnosti ponovnog korišćenja, materijali mogu podeliti u sledeće grupe:

- recyclable (can be used by putting back in production process);
- non-recyclable (can't be input of process of reusage and they are mostly used for energy gain – by burning and/or are ecologically safely stored);
- dangerous – hazard materials (dangerous for man and his environment);
- no - dangerous materials (not dangerous for man and his surrounding) .

- reciklabilni (mogu se iskoristiti ponovnim vraćanjem u proces proizvodnje);
- nereciklabilni (ne mogu se vratiti u proces ponovnog korišćenja i uglavnom se koriste za dobijanje energije – spaljivanjem i/ili se na ekološki bezbedan način skladište);
- opasni – hazardni materijali (štetni i opasni za čoveka i njegovo okruženje);
- bezopasni materijali (koji nisu štetni za čoveka i njegovo okruženje).

The process of recycling a vehicle and/or part itself is chronologically done in four key steps (Figure 2):

Sam postupak reciklaže vozila i/ili delova se hronološki obavlja u četiri ključna koraka (slika 2):

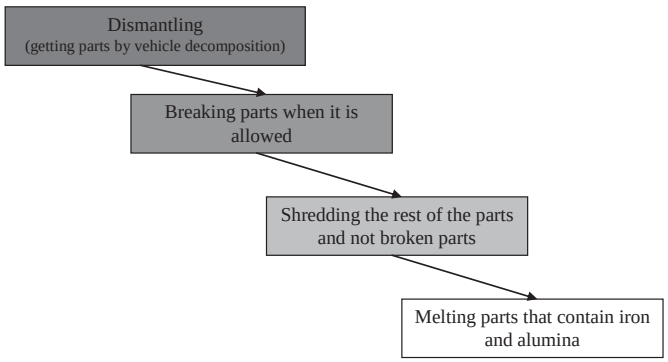

Figure 2 Chronological schedule of vehicle recycling
slika 2 Grafički prikaz hronološkog postupka reciklaže vozila

First step in recycle, dismantling, represents process of disassembling vehicle to components and parts like: batteries, wheels, tires, bumpers, radios, engines, electrical stators, gears, alternators, plastic parts and components, glass, foam. This also goes for all other parts need on market on used parts. In *second phase of recycling* vehicles are broken by breaking machines, followed by *third step* in which shredder first crumbles parts of processed vehicle to parts size of a fist. Then *shredder* separates parts containing iron, aluminum and ASR. *Fourth step* in recycling is melting. In this phase, metals containing iron and aluminum are melted, and ASR is put to dump.

Prvi korak u reciklaži, *demontiranje*, predstavlja proces rastavljanja vozila na komponente i delove kao što su: baterije, točkovi, gume, upravljači, branici, radio-aparati, motori, elektro pokretači, reduktori, alternatori, plastični delovi i komponente, staklo, pena. Ovo važi i za sve druge delove za kojima postoji potražnja na tržištu polovnih delova. U *drugoj fazi reciklaže*, vozila se lome pomoću mašina za lomljenje, posle čega dolazi *treći korak*, u okviru koga sekač (*shredder*) vozila najpre mrvi delove obrađenog vozila na delove veličine pesnice. Potom *shredder* odvaja metale koji u sebi sadrže gvožđe, aluminijum i ASR. *Četvrti korak* u procesu reciklaže je pretapanje. U ovoj fazi, metali koji sadrže gvožđe i aluminijum pretapaju, a ASR se odlaže na deponije.

These and similar activities are supported by *US Department of Energy* which also finances project "*Vehicle Recycling Partnership*" which includes big car manufacturer like Ford, General Motors, Chrysler etc. With cooperation with ***APC*** (*American Plastics Council*), pilot project of ASR refine is developed, in order to get plastic concentrate

Takve i slične aktivnosti podržava Odeljenje za energetiku SAD-a (*US Department of Energy*), koje je ujedno i finansijer projekta "*Vehicle Recycling Partnership*" (u prevodu "Partnerstvo za recikliranje vozila"), u koji su uključeni veliki proizvođači automobila, kao što su Ford, General Motors, Chrysler i dr. U saradnji sa ***APC***-om (*American Plastics Council*), osmišljen je pilot projekat prerade

(representing about 45% of ASR weight), fraction of polyurethane foam (about 10%)and oxide fraction (about 45%) [18]. The second project has been carried out in Virginia area and through which official government collected old vehicles and recycled them for free. Huge savings by recycling are related not only on raw materials saving, but also related to user who save up to 50% when buying second-hand cars and repaired parts, in comparison to buying new vehicles.

Discussing about this processes, the possibility of huge energy save should not be forgotten. Comparing energy saved with primary production (figure 3), we get following results: recycled steal 74%, recycled aluminum 95%, recycled copper 85%, recycled wires 65%, recycled paper 64%, recycled plastic 80% [21]. Data bring the solution that secondary production has significantly less pollution than primary. That is from great significance from ecological aspect. When speaking about iron and aluminum, recycling of parts containing these materials has huge importance in saving of raw materials of valuable metals like steal, stainless steel, copper, aluminum, wires, strontium, zinc but also the most valuable substance: gold and platinum, which are extracted by specialized refining of electronic equipment, including computer equipment in cars and silver extracted from used photos and pictures for x-ray machines. Thanks to recycling, the dependence from world market of real meal reserved lessens. On the other hand, there is no increase in price of already expensive and rare metals, what would be the result of law of offer and demand for them if refining of used products and their parts is not being done.

ASR-a, kojim bi se dobili plastični koncentrati (koji predstavljaju oko 45% mase ASR-a), frakcija poliuretanske pene (oko 10%) i frakcija oksida (oko 45%) [18]. Drugi projekat sproveden je u oblasti Virdžinije i u okviru njega zvanične vlasti su prikupljale dotrajala vozila i besplatno ih reciklirale. Velike uštede koje se postižu reciklažom, odnose se ne samo na uštedu sirovina, već su jednim delom vezane i za korisnike koji kupovinom polovnih automobila i repariranih delova štede čak do 50%, u poređenju sa kupovinom novih vozila.

U svemu ovome, ne bi trebalo zanemariti ni mogućnost značajne uštede u energiji. Ukoliko se vrši poređenje sačuvane energije u odnosu na primarnu proizvodnju (slika 3.) dobijaju se sledeći rezultati: reciklirani čelik 74%, reciklirani aluminijum 95%, reciklirani bakar 85%, reciklirani provodnici 65%, reciklirani papir 64%, reciklirana plastika 80% [21]. Podaci dovode do zaključka da sekundarna proizvodnja emituje signifikantno manje zagađenja nego primarna. To je od izuzetnog značaja posmatrano sa ekološkog aspekta. Kada se radi o gvožđu i aluminijumu, reciklaža delova od ovih materijala ima ogromnu važnost u uštedi sirovina vrednijih metala u koje se ubrajaju čelik, nerđajući čelik, bakar, aluminijum, provodnici, stroncijum, cink, ali i najskuplje supstance: zlato i platina, koje se inače izdvajaju specijalizovanom preradom elektronske opreme, uključujući kompjutersku opremu u automobilima i srebro koje se izdvaja iz iskorišćenih filmova i snimaka za rendgen aparate. Zahvaljujući postupku reciklaže, smanjuje se zavisnost svetskog tržišta od stvarnih rezervi metala. Sa druge strane, ne dolazi ni do povećanja cene već ionako skupih i retkih metala, što bi svakako bio rezultat zakona ponude i potražnje za istim, da se u ovom slučaju ne primenjuje prerada dotrajalih proizvoda i njihovih delova.

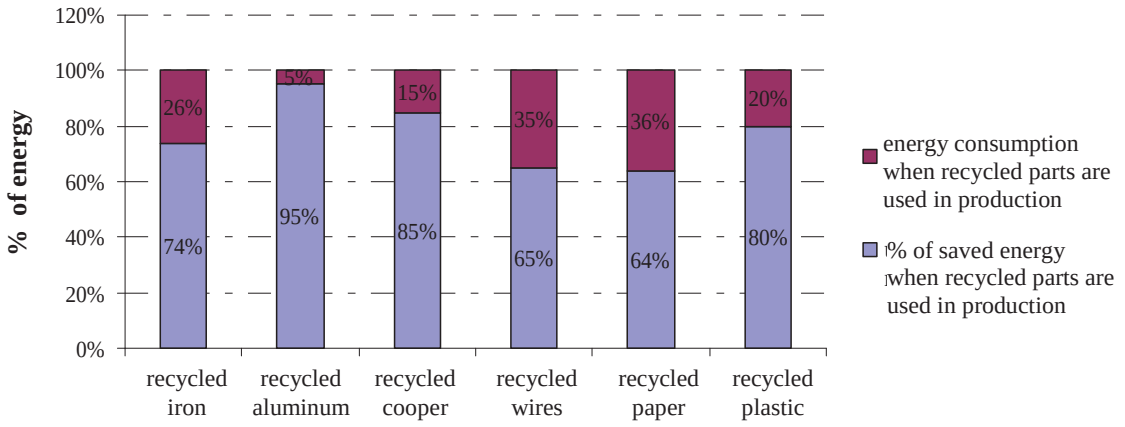

Figure 3 Comparison of used and saved energy introducing recycled parts in production
slika 3 Poređenje potrošene i sačuvane energije korišćenjem recikliranih delova pri proizvodnji

Segment of industry that deals with recycling of old vehicles and by that supply huge part of industrial production in USA that deals with refining of waste became significant in business domain; about 600 million tons of waste is being processed per year. We must also consider that secondary material is not available everywhere and on every place in the world, so we must include transport. One third from above mentioned 600 million tons of materials refined by recycling industry is being sold internationally, which brings huge profits to recycling companies that goes over few hundreds of million euros re year [12].

During analysis of given task, it's necessary to mention 3**R** principle (***R**educe – **R**euse – **R**ecycle*), which defines modern aproach to recycling in simple way. *Reduce* refers to type of designing vehicles that will have longer working life while using less resources. This concept proved very popular and very usable. Toyota extended 3R to 5R concept, adding process of refining material to present activity to allow his easier recycling and process of returning energy back from waste and everything in order to decrease rest of 25% parts that is being dumped.

After determining generator of material whose flows are being analyzed, we can concentrate on analysis itself. Here we deal with materials from ELV, so we are considering specifics related with characteristics of flows of these materials.

3.2 Analysis of material flow from ELV

In order to establish efficient system for treatment of used vehicles and material flows within it, it is necessary to define basic entities of that system (Figure 4). It is clear that industrial manufacturing provides that is consumed, and that one part of consumption generates waste that is (most of it) returned in production. All this tree related activities have direct impact on human environment, which is every day more and more in danger, as consequence of rapid technical-technological development of all aspects of people activities. By analyzing Figure 4, we can see that it is necessary to take certain initiatives so that space and environment in which we live remains preserved and less in danger. In order to that, there are different directives, legal acts,

Segment industrije koja se prevashodno bavi reciklažom dotrajalih vozila i samim tim snabdeva veliki deo industrijske proizvodnje u SAD-u koja se bavi preradom otpada, postala je značajan u domenu biznisa; na godišnjem nivou prerađuje oko 600 miliona tona otpada. Treba imati u vidu činjenicu da sekundarni materijal nije dostupan svuda i na svakom mestu u svetu, usled čega je neophodno uključiti i transport. Jedna trećina od gore pomenutih 600 miliona tona materijala koji preradi industrija za reciklažu, prodaje se internacionalno, što kompanijama koje se bave reciklažom donosi značajne profite koji prelaze godišnje nekoliko stotina miliona evra [12].

Tokom analize postavljenog problema neophodno je pomenuti i princip 3**R** (***R**educe – **R**euse – **R**ecycle*), koji na veoma jednostavan način definiše savremeni pristup recikliranju. *Reduce* se odnosi na takav pristup projektovanju (idejnom rešenju) vozila, koji će imati duži životni vek, a uz sve to koristiti manje resursa. Ovaj koncept se pokazao kao izuzetno popularan i veoma često primenljiv. Concept 3R Toyota je unapredila u 5R, dodajući već postojećim aktivnostima proces prečišćavanja materijala radi njegovog lakšeg recikliranja i proces povraćaja energije natrag iz otpada, a sve i dalje u cilju smanjenja ostatka od 25% koji se deponuje.

Nakon utvrđivanja generatora materijala čiji se tokovi analiziraju, može se pristupiti samoj analizi. Ovde se radi o materijalima iz ELV-a, pa su stoga u obzir uzete specifičnosti vezane za karakteristike tokova ovih materijala.

3.2. Analiza tokova materijala iz ELV-a

U cilju postavljanja efikasnog sistema za tretman korišćenih vozila kao i tokove materijala u okviru njega, neophodno je definisati osnovne celine tog sistema (slika 4). Jasno se može uočiti da se industrijskom proizvodnjom dobija ono što se i troši, a da potrošnja jednim delom stvara otpad, koji se (većim delom) vraća u proizvodnju. Sve ove tri uzajamno povezane aktivnosti imaju direktan uticaj na životnu sredinu, koje je iz dana u dan, kao posledica rapidnog tehničko-tehnološkog razvoja svih oblika ljudske delatnosti, sve ugroženija. Analizirajući sliku 4., može se zaključiti da je neophodno preduzeti određene inicijative, kako bi se prostor i sredina u kojoj živimo očuvala i bila što manje ugrožena. U tom smislu, postoje razne direktive, propisi, zakonska regulativa, i sl.

legal regulations... Main aim is that everything produced is used, consumed. What finishes its life should be (as much possible) returned to production, to preserve living environment, but also to decrease usage of natural resources and to save energy.

Osnovni cilj je da sve ono što se proizvede, bude iskorišćeno, odnosno potrošeno. Ono što završi svoj životni vek, ponovo bi trebalo (u što većoj meri i količini) da bude vraćeno u proizvodnju, kako bi se zaštitila životna sredina, ali i smanjila upotreba prirodnih resursa i uštedela energija.

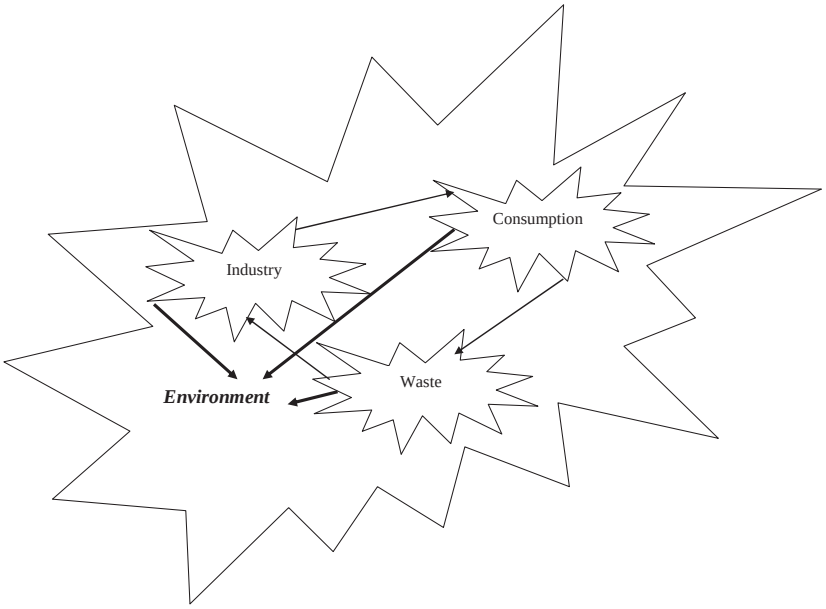

Figure 4 Correlation between manufacturing, consumption and waste, and their effect to living environment (surrounding)
slika 4 Uzajamna sprega između proizvodnje, potrošnje i otpada i njihov uticaj na životnu sredinu (okruženje)

Technologically closed entities dealing with recycling have important and inevitable role in control of material flow present there. If this system is based only on market conditions, there would inevitable be interest conflict of system subjects with common interests of business politics. The conclusion is that system as an entity must be managed from one place.

Važnu i neizbežnu ulogu u upravljanju tokovima materijala uglavnom imaju one tehnološki zaokružene celine koje se bave njihovom reciklažom. Naime, ukoliko bi se ovakav sistem zasnivao samo na tržišnim uslovima, neizbežan bi bio konflikt interesa subjekata sistema sa opštim interesima poslovne politike. Zaključak je da se sistemom kao celinom mora upravljati sa jednog mesta.

To provide management process of material flow, technology closed entities dealing with material recycling must also form special database for ELV. Basic jobs that those entities should realize belong to following areas: [8, 9, 10, 17]:

Da bi se obezbedio proces upravljanja tokovima materijala, tehnološki zaokružene celine koje se bave reciklažom materijala moraju da formiraju i posebnu bazu podataka za ELV-a. Osnovni poslovi koje te celine treba da realizuju, pripadaju sledećim oblastima [8, 9, 10, 17]:

- installing infrastructure for recycling of used vehicles;
- financial management;
- giving certificates (licenses) to proper subjects for jobs dealing with recycling of ELV;
- permanent inspection over legal acts respecting;

- instalisanje infrastrukture za recikliranje iskorišćenih vozila;
- finansijski menadžment;
- izdavanje sertifikata (licenci) odgovarajućim subjektima za obavljanje delatnosti koje se odnose na reciklažu ELV-a;
- permanentni nadzor nad poštovanjem usvojenih propisa;

- analysis of effects and finding solution for optimization of all processes and activities dealing with treatment (recycling) of ELV;
- advertising - promotion activities in order to expedite recycling of ELV.

Technologically closed entities dealing with recycling, should rely on independent experts[1], meaning competent experts. Management of material flow in centers of technological treatment of ELV is realized by proper models. To subsystems dealing with recycling are sent data of materials and parts, and realization of material flow is controlled by comparing input and output, meaning material given and taken. This is very important parameter, because it provides quick tracking of respecting legal acts in waste control.

During recycling, technologically closed entities analyze material flow based on available data (from special database developed), and especially check total amounts of useless waste, as well as amount of materials used for energy gain (they are being burnt). Legal regulative should determine maximum allowed weight of material that can be stored (for example Directive of EU for ELV).

Generally observing, the process of management of material flow from ELV consist on following: team f experts analyze material flow, and then suggests activities for their optimization so that quantities of material for storing and energy recover are provided within prescribed limits [6, 8, 9]. One of activities is recycling of vehicles.

Serbia is currently at the beginning of procedure to be carried over ELV. So it is very important to use positive experience of other countries that already made some measures in order to solve problems of this kind. The following part of paper shows situation for our country and eventual expectations in using already existing solutions by countries that are, regarding these problems, are similar to our.

- analiza efekata i iznalaženje rešenja za optimizaciju svih procesa i aktivnosti vezanih za tretman (reciklažu) ELV-a;
- propagandno – promotivne aktivnosti u cilju pospešivanja reciklaže ELV-a.

Tehnološki zaokružene celine koje se bave reciklažom, trebalo bi, u delatnostima koje obavljaju, da se oslanjaju na nezavisne eksperte[2], odnosno pre svega kompetentne stručnjake. Upravljanje tokovima materijala u centrima za tehnološki tretman ELV-a se realizuje odgovarajućim modelima. Podsistemima koji se bave reciklažom se upućuju podaci o materijalima i delovima, a poređenjem ulaza i izlaza, odnosno predanih i preuzetih materijala se kontroliše realizacija tokova materijala. Ovo je veoma bitan pokazatelj, jer omogućava brzo praćenje poštovanja propisa u upravljanju otpadom.

Tokom obavljanja postupka reciklaže, tehnološki zaokružene celine na osnovu raspoloživih podataka (iz posebno oformljene baze podataka), vrše detaljne analize tokova materijala i posebno proveravaju ukupne količine uskladištenog nekorisnog otpada, kao i količine onih materijala koji se koriste za dobijanje energije (spaljuju se). Zakonskom regulativom bi trebalo da bude utvrđena maksimalna dozvoljena masa materijala koja se može trajno uskladištiti (na primer Direktiva EU za ELV).

Generalno posmatrano, postupak upravljanja tokovima materijala iz ELV-a je sledeći: tim eksperata najpre vrši analizu tokova materijala, a zatim predlaže aktivnosti kojima će se izvršiti njihova optimizacija, tako da se obezbede količine materijala za skladištenje i povraćaj energije u okvirima propisanih limita [6, 8, 9]. Jedna od aktivnosti je i reciklaža vozila.

Srbija je trenutno na početku postupaka koji bi se sproveli nad ELV-ima. Stoga je od značaja koristiti pozitivna iskustva drugih zemalja koji su već primenili neke mere u cilju rešavanja problema ove vrste. U nastavku rada predstavljena je situacija vezana za našu zemlju i eventualna očekivanja u primeni već postojećih rešenja zemalja koje su, vezano za ove probleme, bliske našoj.

[1] "independent expert", person that got license from proper Agency to deal with his industry, given base on his expert qualifications; expert is independent from technologically closed entity dealing with recycling, because it is not employee of entity nor any system subject;

[2] "nezavisni ekspert", osoba koja je po osnovu svojih stručnih kvalifikacija dobila licencu od odgovarajuće Agencije za obavljanje svoje delatnosti; ekspert je nezavisan od tehnološki zaokružene celine koja se bavi reciklažom, jer kod iste nije u radnom odnosu, niti kod bilo kog subjekta sistema;

3.3 Status in Serbia

There are multiple problems with ELV in Serbia. Every year, Serbia imports around 30.000 tons of (dangerous) car waste [20]. The amount or the number of imported used vehicles is also huge. Data that in 2005 over 70.000 of used vehicles was imported in Serbia confirm that fact, and that makes a weight of app. 80.000 tons of waste. Analysis of materials from waste shows more than 320 different types of materials that pollute air, ground, underground water and river flows.

Above mentioned data are specific for this area. As such, they require modification of actual approaches from other countries. Lack of concept in treatment of used vehicles can be named as one of the biggest problem in Serbia. Also, the big problem is low level of development of infrastructure, which is, due to lack of clear concept, developing partly in chaotic way. From that reason, authors think that is it necessary to start solving problems of existing (categories of) wastes, and then to use recommendations and models of developed countries in this area. Obvious examples are used pneumatics. Analysis of domestic literature and practice should allow conclusion that there are no clear rules. Obvious example is that for city of Belgrade model of collecting and treatment of used pneumatics gathered from vulcanizing workshops is not developed. There are no official data on collected and treated used pneumatics.

Waste minimizing and management is very important global aim. But, this realization is often not economically profitable. But, there is the state engaged whose task is to stimulate solving given task by economical influence. Bad economical situation in Serbia makes solving of given problem much harder. From that reason, authors of this paper think that it would be best to solve problem in phases. It means that first phase considers development of infrastructure which would treat only specified class of parts of used vehicles (for example pneumatics). The rest should be collected, classified and then send it to countries in surroundings that already have developed systems for treatment, which we don't have. Development of our economy, in second phase, should allow significant resources to be invested in development and upgrade of our system with aim to take over these activities on economically acceptable level.

3.3 Stanje u Srbiji

Problemi vezani za ELV-a u Srbiji su višestruki. U Srbiju se godišnje uveze oko 30.000 tona (opasnog) auto otpada [20]. Količina, odnosno broj uvezenih polovnih vozila je takođe veliki. U prilog tome govori i podatak da je u toku 2005-e godine u Srbiju uvezeno preko 70.000 polovnih vozila, što čini masu od preko 80.000 tona otpada. Analizom materijala koji čine ovaj otpad može se izdvojiti oko 320 različitih vrsta materija koje zagađuju vazduh, zemljište, podzemne vode i rečne tokove.

Napred navedeni podaci su specifični za ovo područje. Kao takvi zahtevaju modifikaciju aktuelnih svetskih pristupa. Kao jedan najvećih problema u našoj zemlji se može označiti nedostatak jasne koncepcije u tretmanu korišćenih vozila. Značajan problem je i nizak stepen razvijenosti infrastrukture koji se, usled nedostatka jasne koncepcije, u određenoj meri razvija haotično. Iz tog razloga, stav autora rada je da je neophodno početi sa rešavanjem problema već postojećeg (postojećih kategorija) otpada, da bi se tek zatim krenulo sa primenom preporuka i modela razvijenih zemalja u ovoj oblasti. Očigledan primer su stari pneumatici. Analizom domaće literature i prakse može se zaključiti da jasna pravila ne postoje. Za teritoriju Beograda još uvek nije razvijen model sakupljanja i tretmana iskorišćenih pneumatika koji bi trebali da se preuzimaju od vulkanizera. Ne postoje ni zvanični podaci o sakupljenim i tretiranim iskorišćenim pneumaticima.

Svetski cilj je da se otpad minimizuje i da se sa njim upravlja. Ovakva realizacija često nije ekonomski isplativa. Tu na scenu stupa država čiji je zadatak svojim ekonomskim uticajem stimuliše rešavanje postavljenog zadatka. Nepovoljna ekonomska situacija u Srbiji rešavanje postavljenog problema čini težim. Iz tog razloga, autori ovog rada smatraju da bi za naše uslove najefikasnije bilo etapno rešavati problem. To bi, u prvoj fazi, podrazumevalo razvoj infrastrukture koji bi se bavio samo određenom klasom delova korišćenih vozila (npr. pneumaticima). Ostatak bi trebalo sakupljati, klasifikovati (razdvajati) i kao takvog ga usmeravati u zemlje u okruženju koje već imaju razvijene sisteme za preradu koje mi nemamo. Razvojem naše ekonomije bi se, u drugoj fazi, značajna sredstva bi trebala biti uložena u razvoj i nadogradnju našeg sistema u cilju preuzimanja ovih aktivnosti na ekonomski prihvatljivom nivou.

4 CONCLUSION

The development of science and technology has allowed man to create huge number of materials with complex chemical constitution for his needs. Such materials can hardly or can't be disjoint at all the natural way due to their complexity, or the time of their disjoint can be considered as indefinite. Storing those materials on dumps represents potential danger of polluting of environment. During recycling of these materials, with economical gain, protection of environment is resulting. The consequence is more qualitative and healthier life of man himself.

Critical analysis of development of world experiences in area of material flows from ELV management shows constant progress. Specific problems have been spotted, and science and industry have influence on them with different level of success. But, the most important thing is constant developing of existing systems of management of material flows from ELV. Level of development of these systems in Serbia in this area is low. From that reason, it is necessary to develop and upgrade our current system using good results on world level on proper way.

4 ZAKLJUČAK

Razvojem nauke i tehnologije, čovek je za svoje potrebe stvorio veliki broj materijala složenih hemijskih sastava. Takvi materijali se zbog svoje složenosti teško ili čak uopšte ne mogu razgraditi prirodnim putem ili se vreme njihove razgradnje može smatrati beskonačnim. Upućivanje na deponije takvih materijala, bez obzira da li su one uređene ili divlje, predstavlja potencijalnu opasnost zagađenja životne sredine. Reciklažom ovakvih materijala, pored ekonomske dobiti čovek štiti životnu sredinu. To za posledicu ima kvalitetniji i zdraviji život samog čoveka.

Kritičkom analizom razvoja svetskih iskustava u oblasti upravljanja tokovima materijala iz ELV-a može se uočiti stalan napredak. Uočeni su specifični problemi i na njih nauka i privreda deluje sa različitim stepenom uspeha. Ipak, najznačajnije je konstanto usavršavanje postojećih sistema upravljanja tokovima materijala iz ELV-a. Nivo razvijenosti sistema iz ove oblasti u Srbiji je nizak. Iz tog razloga je neophodno na odgovarajući način, koristeći dobre rezultate na svetskom nivou, etapno razvijati i nadograđivati naš postojeći sistem.

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