CODEN STJSAO ISSN 0562-1887
ZX470/1544 UDK 628.4.037:628.4.043:658.512

Material Flows Within an End-of-Life Vehicle Recycling System – A Periodical Analysis of Generated Quantities

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Keywords
Material
Method
Periodical analysis
Recycling ELV

Ključne riječi
Metoda za analizu
Pravovremeni monitoring
Sustav za reciklažu ELV
Tokovi materijala

Received (primljeno): 2009-04-30
Accepted (prihvaćeno): 2011-06-16

Preliminary note

The European Union Directive for End of Life Vehicles (ELV) defined the limits in the range of which the generated quantities of inapplicable material and the material for energy recovery can be tolerated, and those limits are standardized by ELV and year. One calendar year is expected for the report period. The great number and heterogeneity of the participants in the ELV recycling system make the recycling system complex. There are many centers within the subsystems for ELV processing that perform various manufacturing tasks. As a rule, problems with exceeding the limits do not appear the moment they are noted, but some time before. Besides, in case of a great number of different centers for ELV processing it is logical to expect the possibility of violations of standardized limits occuring with many revisers in a territory for a short period of time. For these reasons, this work focuses on analyzing material flows in an ELV recycling system, a problem analysis of the amount of generated material in the system and, primarily, on research of methods for timely precedures for introducing necessary corrections. The authors have noticed that it is necessary to introduce periodical material analyses in the flow of ELV recycling systems (a quarterly analysis is suggested). A short-term analysis would enable quicker detection of problems according to the elaborated and shown methodology and to prioritized response. This way, a great number of problem causes would be removed by external monitoring, and a greater reliability of the system and safer control would be provided through processes of technological and time optimization.

Tokovi materijala u sustavu recikliranja vozila na kraju životnog ciklusa – periodična analiza generiranih količina

Prethodno priopćenje

Direktiva Europske unije za vozila na kraju životnog ciklusa (ELV) odredila je granice u rasponu kojih se mogu tolerirati proizvedene količine neiskoristivih materijala i materijala za energetsku oporabu i te su granice standardizirane po ELV-u i godini. Predviđa se jedna kalendarska godina kao period za izvješćivanje. Veliki broj učesnika i njihova heterogenost u sustavu recikliranja ELV čine sustav za reciklažu složenim. Postoje mnogi centru unutar podsustava ELV obrade koji izvode razne proizvodne zadatke. U pravilu se problemi s prekoračenjima granice ne pojavljuju u istom trenutku kada su zamijećeni, već neko vrijeme ranije. Pored toga, u slučaju velikog broja različitih centara ELV obrade logično je očekivati da bi se prekoračenja standardiziranih granica mogla pojaviti kod mnogih revizora na području u kratkom vremenskom roku. Iz tih razloga je ovaj rad usredotočen na analize tokova materijala unutar sustava za reciklažu vozila na kraju životnog ciklusa, analizu problema količine generiranog materijala u sustavu, i naročito na istraživanje metoda za pravovremeno postupanje radi uvođenja neophodnih korekcija. Autori su zapazili da je neophodno uvesti periodičke analize tokova materijala (uz sugestiju da to budu kvartalne analize). Kratkoročne analize bi omogućile brže otkrivanje problema po opisanoj prikazanoj metodologiji i odazivu po prioritetima. Na taj način bi veliki broj uzroka nastalih problema bio otklonjen vanjskim nadzorom, a osiguralo bi se veću pouzdanost sustava i sigurnije upravljanje kroz procese tehnološke i vremenske optimizacije.

1. Introduction

Today it can be said with certainty that the enactment of European Union Directive for ELV 2000/53/EC [1], resulted not only in desired effects for environmental protection and tenable development in general, but also in the development of many technologies and many companies. Nearly five years later – April 1st, 2005, European Commission made a Decision that laying down detailed rules on the monitoring of the reuse/recovery and reuse/recycling targets set out in Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles [2].

Obviously introducing and regulating the recycling system ELV is a complex and time-consuming task. It requires a scientific and a professional solution for many problems. ELV issues are multidisciplinary and such approach requires searching the answers to many questions. The necessity for optimization of adopted solutions is also permanent. Such a conclusion comes

Symbols / Oznake

ASR	- automotive shredder residue - automobilski šrederski ostatak	*MPA*	- center for mechanical processing of ASR - centar za mehaničko procesuiranje ASR
CI	- chemical industry - kemijska industrija	*OI*	- other industies - ostale industrije
CR	- centers for repairing - centar za reparaciju	O_{PT}	- optimization - optimizacija
DC	- dismantling center - centar za demontažu	*P*	- producer - proizvođač
ELV	- end of life vehicle - vozilo čiji je životni vijek završen	P_{RD}	- activity of removing defects - aktivnost otklanjanja nedostataka
ELV-P	- subsystem for ELV processing - podsustav za procesuiranje ELV	*R*	- rank of priority - rang prioriteta
EP	- energy producers - proizvođači energije	*RC*	- reczcling - reciklaža
ER	- energy recovery - povrat energije	*RU*	- reuse - ponovno korišćenje
F	- relationship between mass - odnos između masa	*S*	- shredder center - šrederski centar
F_{WT}	- temporary suspension of work - privremena zabrana rada	*SI*	- relevant state institutions - nadležna državna institucija
k	- coefficient of participation - koeficijent učešća	*TPA*	- center for thermal processing of ASR - centar za termičko procesuiranje ASR
LUM	- landfill of unusable materials - odlagalište nekorisnog materijala	*U*	- using - korišćenje
m	- mass - masa		**Indices / Indeksi**
$\overline{m}$	- average mass - prosječna masa	*ELV1*	- depollution of ELV - dekontaminacija ELV
MI	- metallurgical industry - metalurška industrija	R_i	- received materials - primljeni materijali
MP	- center for material processing - centar za procesuiranje materijala	*t*	- temporary control value - privremena kontrolna vrednost

from permanent technology development as well as from the necessity for effective environmental protection, for preserving natural, raw and energy resources.

The idea that led the authors of this work, refers to the research of forehand professional influence on some participants in the recycling system ELV, in order to reach the limits regulated by European Union Directive for ELV. Term 'professional influence' means process optimization and managing of some actualising modification ELV.

2. Literature Review

Up-to-date researches of flows in recycling system ELV have given results in many useful explanations and numerous applicative models. However, it seems as if there are not enough researches that refer to optimization of material flows in order to reach the determined limits, i.e. the necessity for the advancement of methodolgy in this field is significant.

Anup P. Bandivadekar and others in [3] have described the development of a simulation model for the material flows and economic exchanges within the automotive recycling infrastructure. They concluded that the Japanese/European recycling target of 95% by 2015 seems unattainable without dramatic and fundamental changes.

In defined recycling system ELV the emphasis is on material flows and efficiency of every operational unit, which can be optimized by specific models that are developed for that purpose. This generally shown, but very important conclusion which was reached by Van Schaik and M.A. Reuter in [4] and M.A. Reuter and others in [5], implies the necessity for monitoring material flows from the perspective of determined limits.

In study [6], authors concluded that there are many currently available technologies that will allow Danish shredder companies to meet the 2015 EU targets for recycling and recovery. The environmental impact of the researched thermal and mechanical treatments is favorable in comparison to landfilling. Currently, the most economically feasible option is to keep landfilling the shredder residue in Denmark. However, after the landfill taxes are implemented in 2012 and 2015, it will become more economically feasible to process SR rather than landfill it. The authors of this work believe that there has to be an intervention in ELV treatment within each participant in order to optimize the process, even at the cost of lack of economy.

The driving force, criteria, and concept for ELV recycling result from different factors that have changed with time – concluded autors in [7]. Authors establish that recycling of ELV today is introduced not only for economic and technological factors, but for the environmental and social concern. In other words, car industry is turning towards sustainable waste material managment. This finding supports the necessity for continual measures of process optimization among all participants in technological modification of ELV.

In order to assess the recovery performances per calendar year, Franz P. Neubacher considered two calculation methods: first version, in order to assess the achievement of objectives within one calendar year, the reused and recovered mass has to be compared with the mass of the end-of-life vehicles that have been taken back in the same calendar year; second version, the number of end-of-life vehicles whose recovery is completed by transfer to the shredding process in one calendar year serves as assessment basis. In doing so, all components and materials that originate from these end-of-life vehicles are used for the calculation of the recovery quota, regardless of whether the recovery took place in this calendar year or in the previous calendar year [8]. Suggested method in two versions provides continual insight in integrated indexes. Further researches should enable forehand corrections in processes and recycling system ELV as well, in order to provide reaching the regulated limits.

3. Problem statement

Using the European Union Directive (EU) for used vehicles 2000/53/EC the limits have been defined that they have to be reached by January 1st, 2015. Those limits, calculated per vehicle and per year are [1]:

$RU + RC + ER \geq 95\%$
$RU + RC \geq 85\%$

where: RU – Reuse; RC – Recycling; ER - Energy recovery.

The mentioned Decision EU [2] determined a uniformed, comparable way of showing data that refers to limits defined by Directive. It is about the periodical description. The rule is that problems do not really appear the moment they are noticed but they appear before. Therefore, it is absolutely logical that not reaching the regulated limits happens as a result of deviation of at least one, and by rule of more modifiers on a territory during a calendar year. The problem is how to react on time on deviations so that they could be eliminated by necessary optimizations and the masses could be brought within allowed limits. In this research the assumption at the beginning was that the problem appeared when 'popping out' of limits appeared, no matter to which center of ELV processing those limits belonged. Problem is more complex when exceeding of limits is present in few centers, where they can perform different activities, i.e. belong to different technological groups. It can happen in few recycling centers on a territory in short period of time.

Hipothesis of this research is: relevant analises that would indicate deviations of limited values and determine priority ranges for optimization of specific recycling centers' work can be periodically performed through managing recycling system ELV and material flows.

4. Material flows

Figure 1 shows a scheme of usual material flows in recycling system ELV. Subsystem for ELV processing (ELV-P) consists of different activity centers: Dismantling centers (DC), Shredder centers (S), Centers for repairing (CR), Centers for materials processing (MP), Centers for thermal processing of ASR - automotive shredder residue (TPA) and Centers for meshanical processing of ASR (MPA).

A term “relevant period” has been used in this work, which stands for time interval which gathers quantitative parameters. According to Directive 2000/53/EC it is a one calendar year period. However, we think that on a territory of a country, state competent state institutions have to continually monitor the data, have to make trimestral reports, so that the system could be optimized on time.

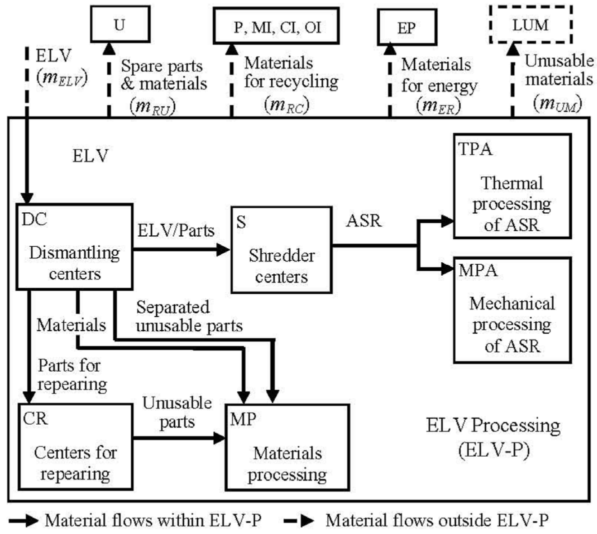

Figure 1. Scheme of material flows

Slika 1. Shema tokova meterijala

In relevant period ELV total masses m_{ELV} come to subsystem ELV-P. These vehicles are admitted in DC depollution and dismantling is performed. The dismantling degree depends on vehicles condition. Usable built parts are returned to a process of using vehicles (U), and unusable ones are sent to S or MP – depending on the type of material. Also, materials are sent to MP for the treatment. The parts that can be repaired then reused are sent to CR. The output from S branches into metal materials for recycling and ASR which refines into TPA and MPA. Therefore, output from E LV-P consists of: spare parts and materials, which return to the stage of using the vehicles (U) in total mass m_{RU}; materials for recycling of total mass m_{RC}, which are delivered to parts' manufaturers (P), to Metallurgy Industry (MI), Chemical Industry (CI) and other industries (OI); materials for energy recovery of total mass m_{ER} are delivered to manufacturers and energy users (EP); in each center within ELV-P there is an unusable material which must be directed to proper landfill (LUM) for the amount of m_{UM}.

While managing recycling system ELV it is necessary to provide managing of material flows the way that provides reaching the determined limits. Authors suggest that information flows are established between ELV-P and state competent institution (SI), as shown on Figure 1.

Figure 2. shows scheme suggestion of managing material flows in recycling system ELV. ELV recycling system must be globally managed from one place [9]. The data of material masses, specified by their kinds, are delivered to competent state institution (state institution SI – arecycling agency, for example) from the centers that make ELV Processing (ELV-P). ELV manager and a team of independet experts perform data analysis. If the results are within the limits determined by the Directive, competent state institution is notified. If the permitted limits are exceeded, monitoring of centers occurs where exceeding is found and necessary instructions are given , as it is explained further on, and then the optimization of their (centers') work is performed.

Beside the total mass of received ELV and their number, DC also keeps record of ELV mass, where

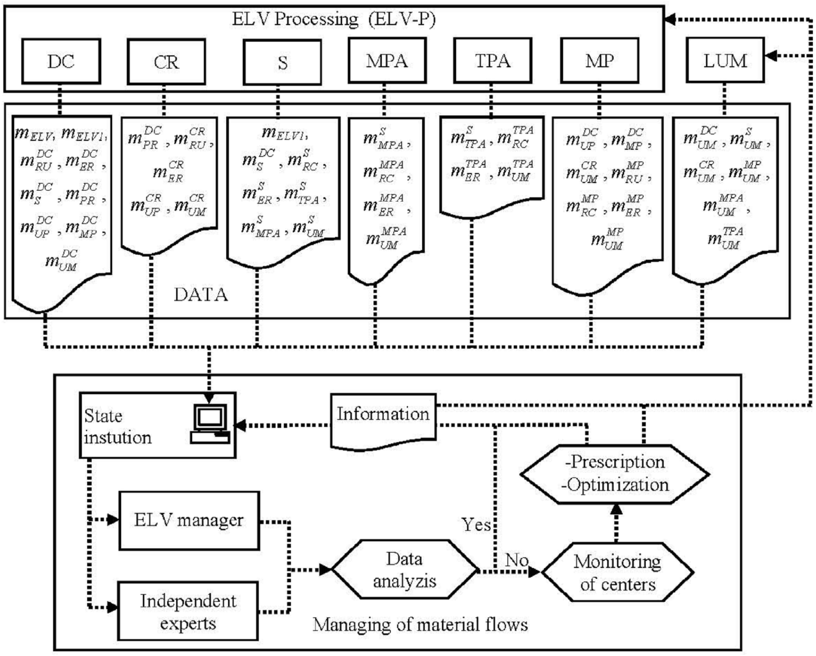

Figure 2. Shema of managing of material flows into ELV recycling system

Slika 2. Shema upravljanja tokovima materijala u sustavu za reciklažu ELV depollution has been performed after which they have been delivered to S (m_{ELV1}). These are the vehicles for which it is determined that they should not be disassembled. Parts for a reuse of total mass m_{RU}^{DC} come from DC, also materials for energy recovery of mass m_{ER}^{DC}, parts and assemblies which are delivered to S (m_{S}^{DC}), parts for mass repairing m_{PR}^{DC}, unusable parts for material processing center m_{UP}^{DC}, materials for processing before recycling m_{MP}^{DC} and unusable materials which are sent to landfill (m_{UM}^{DC}). CR input has parts for repairing, output has repairing mass parts m_{RU}^{CR}, materials for energy recovery m_{ER}^{CR}, unusable parts for further refining m_{UP}^{CR} and unusable materials for landfill masses m_{UM}^{CR}. ELVs come to Shredder centers where depollution has been performed and also come the parts and assemblies which are sent from DC. The result for input is the material for RC of total mass m_{RC}^{S}, material for energy recovery m_{ER}^{S}, ASR for thermal processing - m_{TPA}^{S}, ASR for mechanical processing (m_{MPA}^{S}) and unusable materials for landfill m_{UM}^{S}. Input to MPA is ASR, and at the output there are recycling material m_{RC}^{MPA}, material for energy recovery m_{ER}^{MPA} and unusable material m_{UM}^{MPA}. Analogically shown for MPASR, masses are determined at the input and output to TPASR, where is imput from shredder centers (m_{MPA}^{S}), and masses at the output are mentioned with upper subcript TPASR. Unusable parts from DC and CR come to centers for material processing and also unusable material from DC, but materials for mass recycling m_{RC}^{MP}, mass of materials for energy recovery m_{ER}^{MP}, materials for reuse m_{RU}^{MP}, and mass of unusable materials m_{UM}^{MP} leave the centers. As shown, LUM receive all quantities of unusable materials from all centers. Upper subscript denotes the center from which unusable materials come.

5. Periodical analyses of generated amounts

Specified masses on Figure 3. represent totals of all masses of adequate material kinds which originate in all subsystem cetners for ELV processing, on a specific territory. Therefore:

$$m_{ELV} = \sum_{i=1}^{N_{ELV}} m_{ELV_i}, \tag{1}$$

where N_{ELV} is a number of ELV received in ELV-P in relevant period. Average mass ELV can be hence calculated as:

$$\overline{m}_{ELV} = \frac{m_{ELV}}{N_{ELV}}. \tag{2}$$

The mass for parts and materials for reuse (RU) equals:

$$m_{RU} = \sum_{1}^{N_{DC}} m_{RU}^{DC} + \sum_{1}^{N_{CR}} m_{RU}^{CR} + \sum_{1}^{N_{MP}} m_{RU}^{MP}. \tag{3}$$

Recycling material mass (RC) is:

$$m_{RC} = \sum_{1}^{N_S} m_{RC1}^{S} + \sum_{1}^{N_{MPA}} m_{RC\ m}^{MPA} + \sum_{1}^{N_{TPA}} m_{RC\ n}^{TPA}. \tag{4}$$

In formulations (3) and (4) i has the value from $i = 1$ to $i = N$, where N has varying values depending on a center,and therefore is: N_{DC} (number of dismantling centers), N_S (number of shredder centers), N_{CR} (number of repearing centers), N_{MP} (number of material procesing centers), N_{MPA} (number of MPA centers), and N_{TPA} (number of TPA centers).

The material mass for energy recovery (ER):

$$m_{ER} = \sum_{1}^{N_{DC}} m_{ER}^{DC} + \sum_{1}^{N_{MPA}} m_{ER}^{MPA} + \sum_{1}^{N_{TPA}} m_{EP}^{TPA} + \sum_{1}^{N_{MA}} m_{ER}^{MP}. \tag{5}$$

Total amount of unusable material which developed in all centers during the relevant period is:

$$m_{ER} = \sum_{1}^{N_{DC}} m_{UM}^{DC} + \sum_{1}^{N_S} m_{UM}^{S} + \sum_{1}^{N_{CR}} m_{UM}^{CR} + \sum_{1}^{N_{MP}} m_{UM}^{MP} + \sum_{1}^{N_{MPA}} m_{ER}^{MPA} + \sum_{1}^{N_{TPA}} m_{EP}^{TPA}. \tag{6}$$

Average values of masses for further purpose of material and at the end of ELV processing:

$$\overline{m}_{RU} = \frac{m_{RU}}{N_{ELV}}; \overline{m}_{RC} = \frac{m_{RC}}{N_{ELV}}; \overline{m}_{ER} = \frac{m_{ER}}{N_{ELV}}; \overline{m}_{UM} = \frac{m_{UM}}{N_{ELV}}. \tag{7}$$

Now, reaching the limits, in accordance with Directive EU for ELV, can be checked (since January 1st, 2015):

$$\overline{m}_{RU} + \overline{m}_{RC} \geq 0{,}85 \cdot \overline{m}_{ELV}, \tag{8}$$

$$\overline{m}_{RU} + \overline{m}_{RC} + \overline{m}_{ER} \geq 0{,}95 \cdot \overline{m}_{ELV}, \tag{9}$$

i.e.:

$$\overline{m}_{UM} \leq 0{,}05 \cdot \overline{m}_{ELV}; \overline{m}_{ER} \leq 0{,}10 \cdot \overline{m}_{ELV}. \tag{10}$$

In case of deviation of limits at any time (formulations 8, 9 or 10), the activities' schedule should be followed as shown in Figure 2.

The Directive determines the obligation of tracking the accomlished limits for one calendar year period. Establishing the unpermitted deviation at the end of a calendar year doesn't leave the possibility to repair the determined condition. Due to that, it is necessary to perform the analysis periodically (auhors of this work suggest: quarterly), and then carry out the activities according to scheme in Figure 2.

It is assumed in this work that at the observed territory, system for ELV processing has a greater number of all kinds of centers. Therefore, there is a greater number of dismantling centers, centers for repearing and others. As scheme in Figure 2 shows, relevant information flows are provided from every center. In cases of exceeding the limits simultaneously within many centers, optimization of work for each of them will require a lot of time, which could threaten the annual findings. For these reasons, the authors suggest that monitoring and optimization of centers for ELV processing are organized according to priority list.

Criteria that should be taken in consideration are quantitative parameters about exceeding the limits. All centers need to be determined on how much they have generated unusable material during the relevant period, and how much material for energy recovery.

Values of generated unusable material in centers are:

$$m_{UM\,i}^{DC}, m_{UM\,i}^{S}, m_{UM\,i}^{CR}, m_{UM\,i}^{MP}, m_{UM\,i}^{MPA}, m_{UM\,i}^{TPA}. \tag{11}$$

Equivalent to that, average values of generated unusable material for each center can be reached, dividing upper mass amounts by ELV number, i.e. by N_{ELV}, and the result is:

$$\overline{m}_{UM\,i}^{DC}, \overline{m}_{UM\,i}^{S}, \overline{m}_{UM\,i}^{CR}, \overline{m}_{UM\,i}^{MP}, \overline{m}_{UM\,i}^{MPA}, \overline{m}_{UM\,i}^{TPA}. \tag{12}$$

Both generated material values for energy recovery through centers and average values for this material are obtained analogically by previously shown procedure for unusable material:

$$m_{ER\,i}^{DC}, m_{ER\,i}^{S}, m_{ER\,i}^{CR}, m_{ER\,i}^{MPA}, m_{ER\,i}^{TPA}, m_{ER\,i}^{MP}. \tag{13}$$

$$\overline{m}_{ER\,i}^{DC}, \overline{m}_{ER\,i}^{S}, \overline{m}_{ER\,i}^{CR}, \overline{m}_{ER\,i}^{MPA}, \overline{m}_{ER\,i}^{TPA}, \overline{m}_{ER\,i}^{MP}. \tag{14}$$

In formulations 11, 12, 13 and 14 the value »*i*« goes from *1* to *N*, where *N* is different and depending on the center it is: N_{DC}, N_{CR}, N_{MP}, N_{DC}, N_{CR}, N_{MP}.

As shown, it is possible to determine average masses for each relevant period, even quarterly. However, not all kinds of centers with the same intensity of generating the unusable materials and materials for energy recovery do participate, and that is a clear and a well-known matter. Of course, centers can have a discontinuity within work parameters, and the important thing would be to keep the generated amounts of unusable materials and materials for energy recovery within regulated limits in totality for the whole territory, at the end of one caledar year. Therefore, the total of all masses iz in formulation (12) should be $\leq 0{,}05 \cdot \overline{m}_{ELV}$, and total of all masses iz in formulation (14) should be $\leq 0{,}10 \cdot \overline{m}_{ELV}$.

Centers separately cannot be responsible for the results of overall recycling system ELV, which also, speaks for the necessity of periodical analysis and overtaking the right steps. For further mentioned reasons, the suggestion is that each center takes average masses generated in the same center as temporary referent values during the previous calendar year.

For example, the average mass of unusable material in dismatling center No. 12 was 6,1341 kg per ELV and per year. It could be written as:

$$\left(\overline{m}_{ER\,12}^{DC}\right)_t = 6{,}1341 \text{kg/ELV,yr}, \tag{15}$$

where subscript »*t*« stands for temporary reference value.

Analogically to this, temporary reference values are introduced for material masses for energy recovery.

As already said, during a periodical analysis of result it can be determined that a larger number of centers generate more unusable material and materials for energy recovery in a relation to the appropriate temporary reference values. In that case it is necessary to determine ranks of priority shown here. First, determining »coefficients of participation« for each center, with an established exceeding. This coefficient can be taken as the difference ratio of the actually determined average value of mass $\overline{m}_{UM\,i}$ and temporary control value $\left(\overline{m}_{UM\,i}\right)_t$ according to:

$$k_{UM_i} = \frac{\overline{m}_{UM\,i} - \left(\overline{m}_{UM\,i}\right)_t}{\overline{m}_{UM\,i}}. \tag{16}$$

Analogically, coefficient of participation can be determined for material for energy recovery:

$$k_{ER_i} = \frac{\overline{m}_{ERi} - \left(\overline{m}_{ERi}\right)_t}{\overline{m}_{ERi}} \tag{17}$$

Coefficient is bigger if the exceeding of average mass of generated material is bigger in a relation to temporary reference value.

Generating greater amount of unusable waste i.e. waste for energy retransfer by a center can signify the center with a great fulfilled range of processing. Therefore, it is necessary to calculatethe relation between the mass of developed unusable waste $m_{UM\,i}$ and a mass of received materials m_{Ri}, i.e.generated mass fo obtainingthe energy m_{ERi} and received materials, for each center with determined limit exceeding:

$$F_{UM_i} = \frac{m_{UM\,i}}{m_{R_i}}, \tag{18}$$

$$F_{ER_i} = \frac{m_{ERi}}{m_{R_i}}. \tag{19}$$

Now ranks of priority can be determined for all kinds of centers where limit exceeding has been identified:

$$R_{UM\,i} = k_{UM_i} \cdot F_{UM_i}, \tag{20}$$

$$R_{ERi} = k_{ER_i} \cdot F_{ER_i}. \tag{21}$$

Ranks of priority should be aligned with decreasing values from the highest to the smallest, i.e.:

$$R_{UM_1} = \left(R_{UM_i}\right)_{\max}, \ldots, R_{UM_{\max}} = \left(R_{UM_i}\right)_{\min}, \tag{22}$$

$$R_{ER_1} = \left(R_{ER_i}\right)_{\max}, \ldots, R_{ER_{\max}} = \left(R_{ER_i}\right)_{\min}. \tag{23}$$

The rank of first (the highest) priority is R_1, then R_2, etc. A team of experts will perform a work analysis of chosen centers according to determined priorities and starting from the first rank and further on. In accordance with findings during the inspection they will propose, i.e. adopt appropriate measures, as shown in Table1.

Table 1. Results of the inspection of centers - example

Tablica 1. Rezultati inspekcije centara – primer

Finding / Nalaz	Evaluation and proposed measures / Centri (Evaluacija predložene mjere)						
The center has the necessary and proper equipment / Centar raspolaže svom potrebnom opremom koja je ispravna	+	-	+	+	-	+	-
Employees are trained for jobs that do / Zaposleni su obučeni za poslove koje rade	+	+	-	+	-	-	+
Act in accordance with regulations and proceduranma / Postupanje s materijalima je u skladu sa propisima i procedurama	+	+	+	-	-	-	-
Act / Mjera	O_{PT}	P_{RD}	P_{RD}	F_{WT}	F_{WT}	F_{WT}	F_{WT}

As shown, the optimization of technological concept (O_{PT}) makes sense only if the center has a positive rate in all kinds of verification. In all other cases, before joining the optimization a behest for defects removal should be given (P_{RD}) or the work of center should be temporarily forbidden (F_{WT}),until all the causes of such decision are removed.

6. Further researches

Further researches in this field should be focused on simplifying and improving the shown method, so that they could be implemented in the process of continual monitoring of the material flows in ELV recycling system and of the amounts of generated materials, allowing the optimal way to improve segments of the system.

7. Conclusion

There are numerous different material components in material flows of ELV recycling system and they are the ones that can be used and the ones that do not allow such a possibility. When their relationship is determined at the end of the binding time (one calendar year), then there is no opportunity for optimization. Based on data received through managingthe recycling system ELV and material flows, relevant analyses can be performed periodically (quarterly) which would indicate to deviations of limited values.

In case of exceeding the determined limits by several centers at the same time, as the methodology shows, ranks of priority can be determined to take appropriate actions in order to remove defects and the optimization of work of some recycling centers can be accessed.

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