The International Journal of
TRANSPORT &*LOGISTICS*
Medzinárodný časopis
DOPRAVA A LOGISTIKA

ISSN 1451-107X

LOGISTICS COSTS IN THE WASTE DISPOSAL SYSTEM ON THE EXAMPLE OF STELL MILL

Bożena Zwolińska [1]
[1] *AGH University of Science and Technology,*
al. Mickiewicza 30, 30-059 Cracow, Poland,
tel: (+48) 600-393-943, e-mail: zwolinska@op.pl

Abstract: *An industrial waste management system is a set of processes enabling space-time transformations along with quantity and quality changes aiming at the reduction of negative influence of the industry on the ecosystem. One of the ways of controlling the destructive impact of waste on the environment is recycling. There is no type of residue that cannot be reutilized having suitable technologies and financial resources. An important part of a company's development strategy is the profit and expenditure account. This article presents the overall costs generated within the waste management system of a full production cycle steel mill. The costs have been grouped by objects according to the criteria of main logistics processes realized within the waste management system.*

Key words: *Industrial waste management, Ecosystem, Logistics system*

1 INTRODUCTION

Logistics is an area of business which aims at the optimization of processing of goods, information and capital flows in the logistics chain (from raw materials to the final product and its use). The whole logistics chain can be broken into separate, elementary links, which are codependent with close environment [1] and stay in "peculiar" relations with the superior system [1,2]. What we call a logistics chain is a structured set of supply chains, in which we can identify the following processes: raw materials extraction, supply, production and/or services, distribution and waste management. [4] Recently, a lot of business decisions and industrial processes have been influenced by sustainable development principles. [5] This is partly related to an enhancement in environmental protection, which includes a more cautious approach towards non-renewable raw materials. Humankind has been shaping the environment to maximize its own profits for a long time. Actions undertaken by humans have often had destructive, irreversible consequences on the ecosystem. Fortunately, people have become more aware of the fact that the environment cannot exercise a limitless stabilizing function to their actions and therefore they have created a series of ecological norms and strategies. Nowadays, the principle behind business decisions is to achieve harmonious economical development without having a destructive influence on the ecosystem. [3]

On every stage of processing the logistics product, a certain amount of materials (substances) classified as waste with no value for the customer is produced, influencing the final price of the product. Waste as post-consumption residues, meaning communal and post-production (industrial) waste, is an inherent part of the processes of extracting and processing raw materials and semi-finished goods. Post-consumption and post-production residues have undesirable and burdensome properties which can harm the natural environment. Modern technological processes aim at minimizing the amount of waste produced at every stage of the logistics chain and utilizing fully all residues created in the process as well as those collected in previous years. "It has been proven that there is a possibility of a maximum return to business circulation and reuse of practically every ingredient of waste, however it implicates significant expenditures and access to certain technologies." [6]

2 LOGISTICS IN WASTE MANAGEMENT SYSTEMS

One of the main aims of a company's logistics in the area of waste management is a reduction of the mass of residues stream directed to disposal sites by using so called feedbacks or closed circuits. [7] Closed circuits can be realized within the company's system **(S)** or other (**S_1, S_2, S_3, ... S_n, S_{n+1}**) organizationally independent units, realizing the ecological aim (or aims) of a superior system. Figure 1 shows an example of closed circuits within waste management systems for a number of independent companies, which can represent different industrial branches.

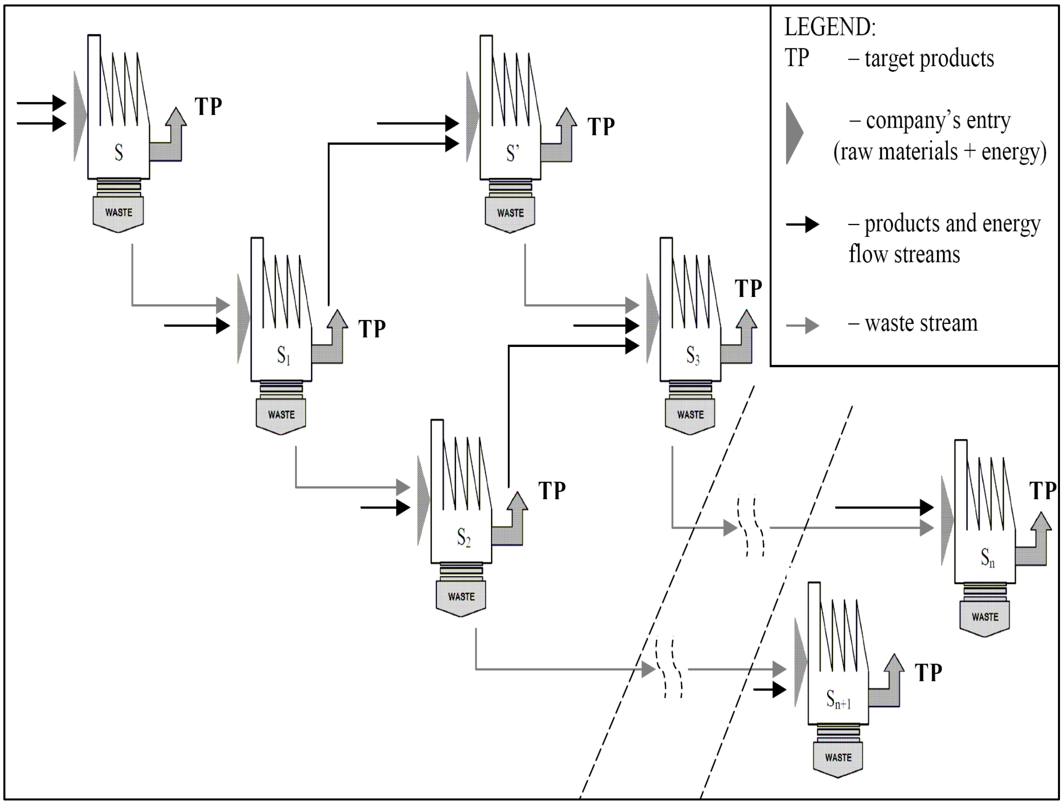

Fig.1 *Example of a waste flow between companies*

3 LOGISTICS IN WASTE MANAGEMENT SYSTEMS

Legal regulations constitute frameworks for all business operations. Companies, on all levels of their development, have to obey the rules of the local market in which they are established. An ecological policy program should be embedded in a company's strategy. Constant development that takes into consideration ecological aims is not a burden to economical growth on a micro or macro scale. Recognizing the importance of the problem of industrial and consumer waste's destructive impact, a number of countries created a series of legal acts which are designed to lead to a reduction of the negative influence of human actions on the ecosystem. The ordinances and acts on environmental protection and waste management are considered to be one of the most voluminous and complicated legal segments of international, European and internal laws of many countries.
The most important European Union legal regulations on environmental protections are [11]:

GENERAL REGULATIONS ON WASTE

- Council Directive of 15 July 1975 on waste (75/442/EEC) which defines waste as any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of the national law in force. This act excludes some kinds of waste such as: radioactive waste, waste waters or agricultural waste. Some of the regulations of the 75/442/EEC Directive have been changed by the following acts: 91/156/EEC of 18 March 1991; 91/692/EEC of 23 December 1991; 96/350/EC of 24 May 1996 and 96/59/EC of 16 September 1996,
- Council Directive of 12 December 1991 (91/689/EEC) on hazardous waste.

DIRECTIVES ON UTILIZATION, DISPOSAL AND TRANSPORTATION OF WASTE

- Directive 2000/76/EC of 4 December 2000 on the incineration of waste,
- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste,
- Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control,
- Council Directive 75/439/EEC on the disposal of waste oils,
- Council Directive 78/176/EEC on waste from the titanium dioxide industry,
- Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture,
- Council Directive 91/157/EEC on batteries and accumulators containing certain dangerous substances,
- Council Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT),
- Directive 2000/53/EC on end-of life vehicles,
- Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues,
- Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment,
- European Parliament and Council Directive 94/62/EC on packaging and packaging waste,
- Council Regulation (EEC) No 259/93 on the supervision and control of shipments of waste within, into and out of the European Community.

4 LOGISTICS TASKS IN THE AREA OF WASTE MANAGEMENT

Waste management which takes into consideration the experience and practice of logistics in the area of planning, managing and organizing product flow streams will result in reducing the overall company costs. Figure 2 presents the general direction of waste and costs flow for a chosen manufacturing company.

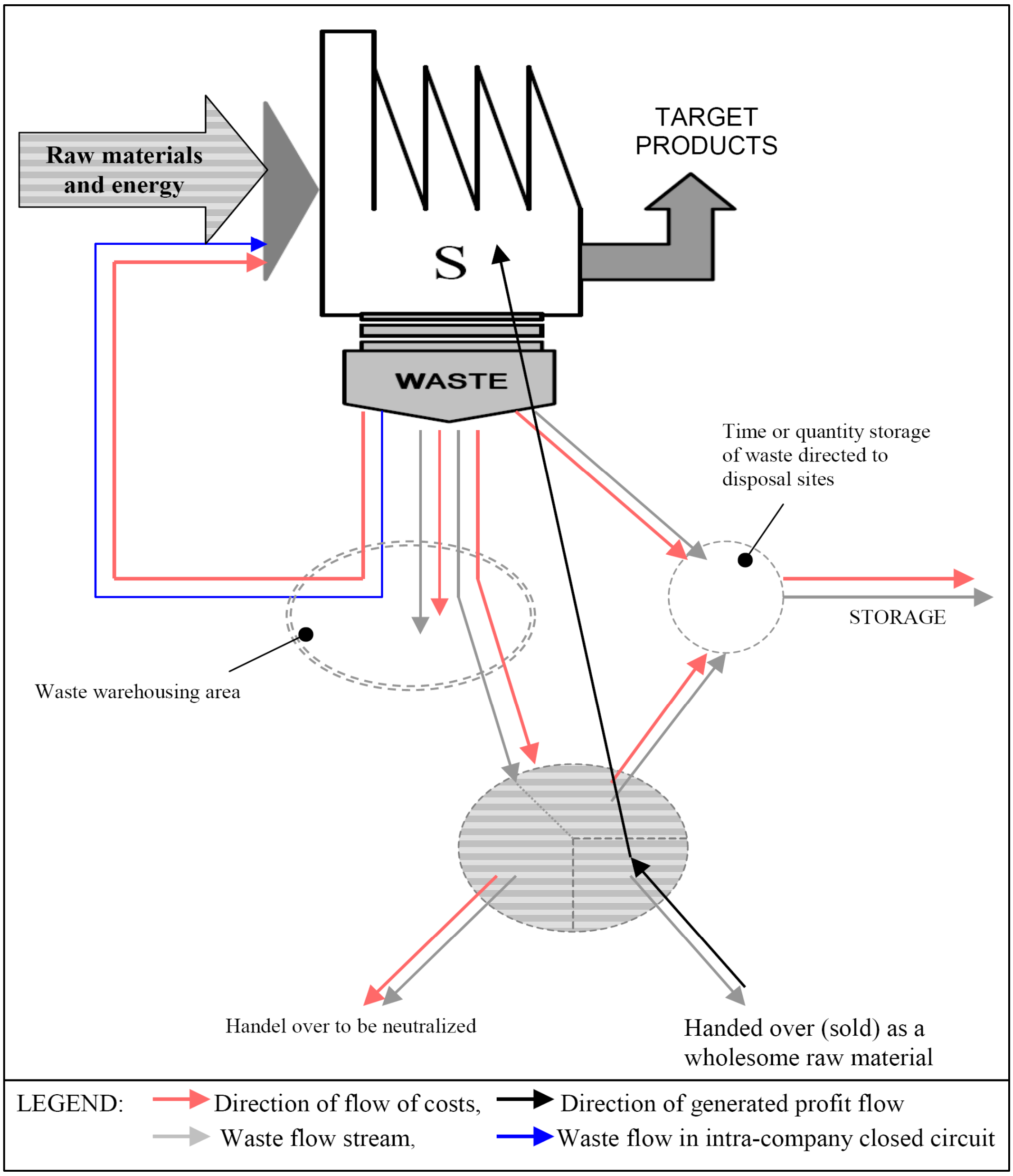

Fig.2 Waste flow stream within a company

Within the waste management system of a manufacturing unit four characteristic flow streams of generated residues can be identified:

- waste stream recycled within the company,
- waste stream directed to the warehousing area,

- waste stream transferred to external recipients for further utilization or processing according to physical and chemical properties of a substance,
- waste stream directed to disposal sites.

Waste recovery is understood as a series of transformations (industrial or non-industrial) where a certain residue which is useless in a particular place and/or time may become a wholesome entry product for further processing in some other place and/or time. Looking at waste recovery from an ecological point of view, we can identify: intra-company and extra-company waste recovery (fig.1). Recovery from a company's point of view takes into account all kinds of waste processing which leads to further utilization of a substance within a company. Waste streams undergoing intra-company recovery are shown in blue in figure 2.

Warehousing in the material management system constitute a separate process of managing and directing waste flow streams, which aim at temporary suspending the flow. Residue warehousing may be one of the stages of recovery or transfer to external recipients. Temporary retention of waste in order to accrue a suitable amount of waste which would be then economically or technologically efficient to process is used in intra-company recovery. Warehousing may also indicate one of the stages of waste collection in suitable containers in a process of handing over the waste to external businesses. In waste management system we talk about time-phased and quantity warehousing.

- Time-phased warehousing refers to a situation in which a recipient collects a certain, indeterminate amount of waste periodically, according to a previously created schedule or in which a company stores waste due to its lack of usage at the time, knowing, however, that the costs of that process will be reimbursed with profit,
- Quantity warehousing means that the recipient collects the waste not periodically but after a certain amount of waste is stored,
- Time-phased and quantity warehousing refers to a situation in which the recipient collects a certain amount of waste periodically, according to the schedule regardless of the total amount of waste produced by a company.

Handling of the waste is carried out between two organizationally, legally and financially independent companies. Part of the waste stream is handed over to be neutralized. Remaining waste streams undergo processes similar to those which are characteristic for a distribution of exit (target) products. External recipients who purchase waste products from another company treat them as entry substitute for services or production processes. Companies which produce waste and sell it as an entry product to another organization receive payments as for raw materials or semi-finished products. Aforementioned profit generates an additional income for the company (fig. 2 – the direction of capital flow stream opposite to the direction of waste flow stream).

Waste storage is a process that has a negative impact on the ecosystem. Stored waste is transferred to a disposal site due to lack of technology for its industrial use or due to economical inefficiency of its management. For companies the superior criterion for almost all actions is the profit and loss account. It is easier and more profitable for a lot of organizations to transfer waste to disposal sites and pay for its storage than to impose new procedures and organize distribution processes for waste that is treated as recycling material.

5 THE COSTS OF THE WASTE FLOW STREAM IN A RAW STEEL MILL

The manufacture of final steel products can take place in two different types of steel mills. Namely, in integrated steel mills, where steel is being produced from a raw material like iron ore and in steel mills where the manufacturing of steel products starts with scrap and/or semi-finished steel products penetration. Raw steel mill can be used alternatively with integrated steel mill. In this kind of mill the technological process commences with the production of pig iron and slag constitutes the greatest portion of generated waste. In the whole production process the amount of generated slag fluctuates from 0.5 to 0.8 for each tonne of final product. These numbers depend on the quality of steel produced, in the sense that the higher the quality of steel produced, the more slag is obtained. In integrated steel mills the part of iron slag with the highest content of Fe is reused in blast furnace processes. In the full production cycle steel mill that we use as an example in this article, the amount of slag reused within the company makes up 383,306,000 Mg/year. Table 1 presents the amount of generated waste, specifying waste streams recycled within the company, waste temporary stored and waste handed over to external recipients in order to be utilized, neutralized or stored. The waste which has the greatest impact on costs and profits value has been included in detail. The data presented below covers one year of manufacture in the analyzed steel mill, where the mean annual production of steel goods approximates 200,000,000 Mg/year.

Tab. 1*Waste flow streams on the example of steel mill*

Type of waste	Amount generated	Amount recycled	Amount warehoused	Amount handed over as a product	Amount handed over to be neutralized	Amount stored on-site	Amount stored at collective landfills
	[Mg/year]	[Mg/year]	[Mg/year]	[Mg/year]	[Mg/year]	[Mg/year]	[Mg/year]
General amount of waste processed in one year	**1,672,456.224**	**915,727.382**	**220,602.520**	**206,229.642**	**536,235.639**	**106,351.010**	**31,478.477**
Slag as by-product of smelting (blast furnace slag, iron slag)	746,136.770	383,306.000	219,443.000	119,030.000		24,357.770	
Sludge and precipitate as by-products of gas treatment	44,946.120	15,986.920				28,959.200	
Melting loss		15,098.454		26,708.700			
Mill scale		14,543.500				6.000	
Sulphur from gas treatment			1, 159.520				
Carbon flue dust				23,500.000			
Furnace lining and heat -resistant materials from metallurgical processes				767.000			
Solid waste from waste gas treatment				8,995.710			
Particles and dust of iron and its alloys						14.640	
Waste classified as group 20 (solid communal waste)	1,752.290						1,752.290

Four main processes can be discerned within the logistics system of waste management in the analyzed steel mill:

- recovery,
- warehousing,
- handing over to external recipients,
- storing.

The mass of waste recovered within the company equals 915,727,382 Mg/year and 42% of that mass consists of slag.

Warehousing in the analyzed steel mill is a separate process of temporary retention of flow streams which effect from:

- waiting to accrue a suitable amount of waste which would be then economically and technologically efficient to recover within the company,
- waiting for further flow stages in logistics chain.

The next stages of warehoused waste flow are recovery and handing over to an external recipient in order for it to be neutralized or utilized. According to the Waste Management Act, the duration of warehousing cannot be longer than 3 years and cannot precede the processes of storing. [8] Handing waste over to external recipients is preceded by time-phased and/or quantity warehousing. The waste for which there is a seasonal demand is directed for time-phased warehousing. Slag is a good example of this kind of seasonal product as it is mostly used for construction works during spring, summer and autumn months. In the analyzed steel mill the warehousing processes generate costs as a result of waste management system aims. Costs generated by warehousing processes consist of: waste collection costs, handling operations costs, costs of premises, space and equipment in which waste is being stored, costs of securing the waste from undesirable impact of external factors and additional costs. Additional costs cover all expenses, not mentioned above, that a company would have to bear in order to realize the processes of warehousing.

Handing over the waste to external recipients means transferring waste management responsibilities and obligations onto another organizational unit. It is important to fulfill all the organizational and legal formalities as well as obtain all the necessary permissions in the process of transferring the waste. In the analyzed company, the processes of transferring the waste can be divided into two categories: those that bring profits and those that generate expenses. The first group consists of waste generating a certain profit, like metallurgical residues originating from production as well as ancillary processes, [7,9] that are used as entry raw material in another company. This kind of waste as a result of business transaction is treated as a wholesome product, for which there is a certain demand on the market. Companies (e.g. S_1 , S_2 lub S_3 – fig.1) purchasing materials that are classified as waste in another company (e.g. S – rys.1) generate an added value for that company (for S). The second group of waste generates costs as a result of expenses that a steel mill bears for transport and transformation processes. [10] This group consists of waste undergoing the processes of neutralization (waste containing hazardous substances) and a part of the waste flow stream that is directed to be stored at collective landfills. Logistics costs of managing waste that is handed over to external recipients will sometimes be treated in a company's account as an added value for a group of waste that is sold as a wholesome product to another organizational unit and sometimes as a loss for neutralized waste and partly for waste directed to storage facilities.

Waste storage is an undesirable process that has a destructive impact on the environment. In the analyzed waste management system there are waste streams that are directed to disposal sites. The first stream consists of waste which could be used as a valuable raw material for the iron and steel industry. Currently, the steel mill does not have a suitable technology for its transformation, thus it is stored for further usage in the future. The storing period exceeds 36 months, therefore the waste undergoes all the storing procedures according to legal regulations. All the residues with high Fe content, like sludge from blast-furnace and iron gas scrubbing, fall into this category. The second group of waste directed to disposal sites consists of residues that cannot be utilized within the steel mill, like plastic, paper or cardboard waste. Both of the streams mentioned above generate expenses for the company. The first group of waste, which has a potential of being used in the future is directed to disposal sites owned and managed by the steel mill. The process of storing this type of waste is more expensive as it takes place on the legal and organizational premises owned by the company. From a logistics point of view that takes into consideration local legal regulations, this kind of storage constitutes another form of warehousing. The waste from the second group is directed to disposal sites outside of the company. The storage costs for the steel mill in the first case consist of: environmental fee and the costs of building, exploiting, monitoring and managing the disposal site. In the second case, all of the aforementioned expenses are included in one storage fee that is divided proportionally among all the users according to the mass of waste directed to a disposal site. The type of waste stored is also included in the fee.

Relative total value of costs generated within the analyzed full production cycle steel mill will be described by a following equation:

$$K_C = K_O + K_M + K_P + K_S + K_D \tag{1}$$

where:

$$K_P = \sum_{i=1}^{m} k_{Pz} + \sum_{i=1}^{m} k_{Ps} \tag{2}$$

$$K_S = \sum_{i=1}^{m} k_{Sz} + \sum_{i=1}^{m} k_{Sw} \tag{3}$$

K_C– relative total costs of waste management system,
K_O– intra-company recovery costs,
K_M– warehousing costs,
K_P– joint costs of waste transfer,
K_S– joint costs of waste storage,

$\sum_{i=1}^{m} k_{Pz}$ – the sum of costs generated in the processes of transferring the waste treated as a wholesome product,

$\sum_{i=1}^{m} k_{Ps}$ – the sum of costs generated in processes of transferring the waste directed for utilization or neutralization,

$\sum_{i=1}^{m} k_{Sz}$ – the sum of storage costs at external disposal sites,

$\sum_{i=1}^{m} k_{Sw}$ – the sum of costs generated in processes of storing within the company.

The equation (1) presents a simplified method of analyzing the costs that the steel mill needs to bear for the realization of generated waste management processes. Total costs of waste management system has been divided into five groups for main logistics processes, according to the significance criterion, creating homogenous cost objects, namely: recovery costs, warehousing costs, transfer costs, storage costs and additional costs. By using the aforementioned classification into cost objects, the individual costs of task completion within the total balance sheet of a company can be easily allocated to the waste management costs account in *ex post* terms. *Ex post* costs object statement constitutes the grounds for planning the *ex ante* account, taking into consideration the fixed costs and other variables depending on the quantity of production.

6 CONCLUSIONS

Manufacturing of steel products requires the usage of a considerable amount of charging materials and energy. The process of production generates large quantities of waste of use value. During the last few years the metallurgy industry has achieved a lot in the area of generated waste management. In some steel mills 90% of the generated waste is being managed. The waste management system in the analyzed steel mill focuses on minimizing the mass of generated waste. All of the residues containing Fe are utilized in the intra-company closed circuits. A considerable part of waste undergoes the processes of systematic collection (storing, warehousing). The analysis of metallurgical waste flow streams showed that an intensification of ecological actions should take place for waste directed to collective landfills. In full-scale terms, the steel mill does not have technologies for efficient utilization of e.g. plastic waste. The market economy forces steel mills to optimize all of the costs generated from production and ancillary processes. Creating procedures and taking actions aimed at managing a small part of waste (in relation to the total mass of generated residues) would increase the waste management costs and therefore decrease the competitiveness of the company. Enhancing the ecological efficiency of individual companies without the legal and financial help from the government (or the commonwealth of states) decreases the financial efficiency of a company. The profit and loss account plays a pivotal role in the functioning of companies and taking environmentally friendly actions usually means obeying environmental protection regulations as stated by the statutory law.

References

[1] Michlowicz E., Zwolińska B.: Reverse Logistics Systems in a Steel Mill a Full Production Cycle. (2011) Brno, Conference proceedings

[2] Michlowicz E.: Logistyka a teoria systemów. (2009) Kraków, Automatyka, Vol.13, No. 2. 453 p. ISSN 1429-3447

[3] Gajdzik B., Wyciślik A.: Jakość, środowisko i bezpieczeństwo pracy w zarządzaniu przedsiębiorstwem. (2011) Gliwice, Wydawnictwo Politechniki Śląskiej, 286 p. ISBN 978-83-7335-762-4

[4] Michlowicz E.: Zarys logistyki przedsiębiorstwa. (2012) Kraków, Wydawnictwo AGH, 210 p. ISBN 978-83-7464-406-8

[5] Gajdzik B.: Efektywność ekologiczna jako wynik realizacji strategii Czystszej Produkcji w przedsiębiorstwie hutniczym. (2011) Warszawa, Hutnik – Wiadomości Hutnicze, 6/2011 512 p. ISSN 1230-3534

[6] Strzałko J., Mossor – Pietraszewska T.: Kompendium wiedzy o ekologii. (2006) Warszawa Wydawnictwo Naukowe ISBN 83-01-13589-8

[7] Kisiel P., Michlowicz E.: Logistyczny system gospodarki odpadami hutniczymi. (2001) Kraków, Automatyka, Vol.5, No. 1/2. 421 p. ISSN 1429-3447

[8] Council Directive of 15 July 1975 on waste – 75/442/EEC

[9] Kisiel P.: Ocena możliwości wdrożenia zintegrowanych systemów sterowania produkcją w małych i średnich przedsiębiorstwach. (2009) Kraków, Automatyka, Vol.13, No. 2. 353 p. ISSN 1429-3447

[10] Michlowicz E.: Modelowanie zintegrowanych systemów transportowo-produkcyjnych w walcowni zimnej blach. (1998) Kraków, Wydawnictwo AGH 95 p. ISSN 0867-6631

[11] http://ec.europa.eu