TYPES OF WASTE STREAMS CREATED IN STEELWORKS
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Abstract
Each manufacturing company, along with producing goods, creates waste. Depending on the technologies used and the complexity of the production processes, there can be a variety of waste sources, as well as different kinds of waste. Current legal regulations require companies to manage and to neutralize their waste. Waste management involves the creation of a complex system of collection, segregation, and neutralization of waste directly from the source. The steel mill presented in this article uses divergent and multiphase production processes, and consequently their waste management system is highly complex and comprises of multiple interconnected subsystems. Taking into consideration a full production cycle steel mill (as in our example), where the production technologies are shaping the streams of generated waste, we can distinguish among dozens types of residues. The priority of an ecological approach is, first and foremost, prevention which includes reduction and elimination of generated waste mass.

Keywords: industrial waste management, sustainable development, production processes

1. OBLIGATIONS OF ENTREPRENEURS IN RELATION TO WASTE MANAGEMENT
Current legal regulations require entrepreneurs to utilize and neutralize generated waste. The choice of actions leading to the prevention, reduction and elimination of generated waste is directly determined by economic profit and loss accounts [1]. A global approach to neutralizing the destructive impact of generated waste in all organizational units is the most beneficial from an ecological point of view. This requires preparing a complex system of receiving, classification, segregation and neutralization of waste, preferably starting at its source. To minimize the costs of waste management processes it is crucial to collect the residues in a systematic way. Segregated industrial waste collection is directly connected to a particular manufacturing sector and the technology used. Systematic accumulation facilitates further stages of waste utilization enabling the omission of the process of segregation and therefore leading to time and energy savings. The actions undertaken for the complete utilization of generated residues in a global waste management system influence the management structure of individual organizations. Waste management systems which take into account the systematic collection of residues starting at the source implemented within the company lead to a division of individual series of waste flow from the whole production process. This kind of approach considerably facilitates obtaining a generically uniform waste and therefore brings tangible benefits in further production stages.

Systematic collection of generated residues at the source can be easily conducted for post-production waste directly connected to the production of goods (so called, company’s mission, main goal of the organization). Among generated waste streams in production units we can identify communal waste, produced in so called processes supporting the realization of the main goal. According to the Waste Management Act each organization producing communal waste can direct it to the local waste management system. The analyzed steel mill is using the aforementioned solution and is directing the mass of waste generated as a result of human presence to the Regional Communal Waste Management System.
2. STEEL MILL IDENTIFICATION

A complex waste management system is a complicated composite comprising of a vast number of elements which interact with each other in an elaborate way [2]. To establish the optimal working conditions for the superior system, the main structure should be deconstructed into a number of interconnected subsystems. The object of interest in this article is an actual element (composite) – a steel mill – one of the manufacturing sector’s systems of waste management. In the examined steel mill, the technological process commences with the smelting of iron ore. The processes of goods production have a divergent character, which means that independent process lines are created for the realization of individual production tasks. In companies where the flows are realized in so called “branches”, the modeling of the technological system of waste flow streams is strongly codependent with flow streams of materials used in production. The variety of steel goods produced globally is vast, and therefore it is very difficult to find steel mills with identical technological and organizational structures, and the quantity and type of generated waste is very diverse. Another obstacle in modeling the generated waste flow streams is the fact that every phase of steel processing requires different times to complete. To create an optimal, complex system of waste management for the iron and steel industry it is crucial to analyze waste streams for each process line individually as they strongly shape the streams of generated waste within the company.

2.1 The classification of waste flow streams

For the purpose of detailed analyses of the flow streams of materials and generated residues, the structure of the full production cycle steel mill has been divided into three interconnected subsystems:
- pig iron production subsystem,
- steel production subsystem,
- rolling subsystem.

Each of the subsystems mentioned above carries the features of a complex system [2], which is why they will be treated as individual but interconnected systems in this article:
- System of Pig Iron Production (SPP),
- System of Steel Production (SSP),
- System of Rolling (SR).

Each isolated system of the production structure in the steel mill in question generates specified quantities and types of waste that is directly proportional to the amount of steel produced. In an analyzed year the aggregate mass of all transported residues equals: 2,725,678 [Mg/year]. Slag constitutes the largest mass of transported waste streams: 1,861,529 [Mg/year], which equals more than 68% of the mass of all residue streams. The remaining 32% of waste flow streams constitutes transports between different structures of the steel mill, namely: production, warehouse, storage or grading areas.

Based on the analysis of technological flow of all the materials within the production system of the steel mill [3], it is possible to distinguish among open and closed waste streams in each of the three systems mentioned above. The open streams include all of those streams which commence or finish their flow phase in one of the previously defined production systems of the steel mill, that is: SPP, SSP and SR. One of the examples of an open flow stream is slag generated in SPP, which is then transferred to external recipients. This kind of residue is a solid material that can be used for example in road surface construction. In the analyzed year the sum of slag produced in the System of Pig Iron Production (SPP) and System of Steel Production (SSP) equals:
- slag from SPP = 1,355,590 [Mg/year]
- slag from SSP = 505,939 [Mg/year]
However, only slag generated by the System of Pig Iron Production (SPP) has been transferred to external recipients, whereas all of the converter slag was transported to the storage area – Slag Storage Area that is a part of SSP-SS.

The open streams also include waste that is transferred to a disposal site due to lack of technology for its industrial use or due to economical inefficiency of its management. In the steel mill in question, based on analyses of the technological flow of products within the production structure, there are no residues transferred directly to the disposal site. Waste described as “Other waste + garbage” is not classified according to the Waste Catalogue [4] and it is non-selectively accumulated in the source spheres of production and then transferred to the SSP system within its Grading Area (SSP-GA), where it is divided by fraction. The open streams also include waste that is transferred to a disposal site due to lack of technology for its industrial use or due to economical inefficiency of its management. In the steel mill in question, based on analyses of the technological flow of products within the production structure, there are no residues transferred directly to the disposal site. Waste described as “Other waste + garbage” is not classified according to the Waste Catalogue [4] and it is non-selectively accumulated in the source spheres of production and then transferred to the SSP system within its Grading Area (SSP-GA), where it is divided by fraction.

The largest group of generated waste flows is represented by the closed streams. Closed streams refer to waste which is produced in one of the workshops of the steel mill and then its flow is carried out within the SPP, SSP and SR systems or between these systems (fig.1).

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**Legend:**

**Fig. 1** Sankey’s graph of waste streams flow
The number of closed streams constitutes 49% of all waste flow mass in the steel mill production structure. Logistics systems aim to reduce the flow streams, as transport of waste requires energy, which generates additional costs [5]. In the analyzed steel mill such a large amount of closed streams results from the processes of storing waste in specially prepared places. By the process of storing in logistics streams we understand the phase of intentional suspension of the waste flow before further utilization. The duration of storage cannot be longer than 3 years, starting from the date of production, if such storage is necessary on account of the technological and organizational processes.

Storing processes in the analyzed steel mill effect from [6]:
- temporary retention in order to accrue a suitable amount of waste which would be then economically efficient to process or transport,
- waiting for a particular waste to acquire demanded properties, e.g. cooling down,
- temporary suspension of the flow in order to apply suitable processes suited to the type of residue, that is separation, segregation, waste treatment or mixing.

Waste storage in the analyzed steel mill is held in specially designated areas. After analyses of the flow streams of generated residues it is possible to discern six units (areas), which are used for storing processes: 1. SPP – S 0-1 (System of Pig Iron Production – Storage Space ), 2. SSP – SA (System of Steel Production– Scrap Aisle), 3. SSP – SS (System of Steel Production – Slag Storage Bay), 4. SSP – SCT (System of Steel Production – Scrap Cars Transfer Area), 5. SSP – IS (System of Steel Production – Ingots Storage) and 6. SSP – SY (System of Steel Production – Storage Yard). Waste stored in each of these areas can be later used in production processes. Sinter and coke screenings, dust from the blast-furnace dust catcher as well as iron-bearing sludge from the IBST (Iron-bearing Sludge Tank) are directed to the SPP-S 0-1. The aforementioned waste is completely utilized in production processes within the steel mill after being prepared by bonding processes, e.g. briquetting. Iron scrap and skulls (waste containing iron Fe) are directed to other storage areas: SSP – SA, SSP – SS and SSP – SCT.

The steel mill as an element of a “greater” waste management system has an opportunity to use steel scraps from sources outside of the company. An exceptional example of waste is pit scrap, which is considered as open stream in the analyzed company; however, in terms of the superior system, that is, e.g., the national level of industrial waste management system, it is considered as closed cycle. This is derived from the fact that waste produced in the consumer sector is utilized by the steel mill and is not transferred to a disposal site, which minimizes the destructive influence of human production on the ecosystem.

The category of pit scrap includes all kinds of used steel products, such as: pipes, metal bars, rails and other steel products, that are directed to the steel mill from the consumer sector.

Table 1 The classification of waste

<table>
<thead>
<tr>
<th>Waste category</th>
<th>Attribute waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Segregated and treated waste</td>
</tr>
<tr>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Segregated and not treated waste</td>
</tr>
<tr>
<td>B</td>
<td>Not segregated and treated waste</td>
</tr>
<tr>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>Not segregated and not treated waste</td>
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</tbody>
</table>

In the logistics system of iron-bearing waste management, the steel scrap stream falls into the A2 category (table 1), which means it undergoes grading but is not treated. This kind of stream is directed to SSP – SY, where it is prepared for further utilization in production processes. An example of such preparation processes would be the removal of the anticorrosive coatings or enamel coatings which were applied to protect the surface of the steel product during its original intended use. Only waste containing iron (Fe) is fully utilized within the analyzed steel mill. Iron – bearing waste which is temporarily stored in SSP – SA, SSP – SS and SSP – SCT falls into the A1 category and bears features of segregated and treated waste (table 1). This kind of waste can be directly transferred to steel production processes (to converters) omitting the preparation phases like material treatment, grading, grinding or bonding.
3. CONCLUSION

Depending on the division criteria, the waste flow streams in the analyzed steel mill can be classified into three categories:

- secondary raw materials,
- waste which can be transformed into secondary raw materials,
- waste which cannot be utilized apart from storing.

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.

Only waste containing iron (Fe) is fully utilized within the analyzed steel mill. Slag scrap containing low levels of iron is transferred to the external organizational units where it is used as a complete product. The other waste streams such as “Used refractory materials” (→ stream nr 23 fig. 1), “Debris” (→ stream nr 24 fig. 1) and “Other waste + garbage” (→ stream nr 25 fig. 1) are directed to SSP – GA (System of Steel Production – Grading Area), where they are segregated by fraction. The mass of unutilized waste directed to the grading area equals: 38,252 [Mg/year]. The proportion of the waste directed to the SSP - GA in relation to the mass of all waste flow streams within the subsystems in the analyzed steel mill equals 1.4%.

Smelting technologies along with the high complexity of steel goods production processes influence the expansion of the technical and organizational structure of the waste management system within the steel mill [7]. A large amount of waste in the analyzed company is utilized. It should be emphasized though, that only the materials containing iron (Fe) are fully utilized e.g. skulls and scrap screenings. The remaining waste, described as “Other waste + garbage” is excluded from the process of classification and segregation at the source. This also includes residues which value parameters (features) classify them to be fully utilized, such as paper, plastics, and glass. The steel mill is using the non-selective method of waste collection, which influences the chain of residue management by augmenting the expenditures as well as the amount of manufacturing processes and stages. The aforementioned inefficiency can be easily eliminated by introducing additional containers to facilitate segregated waste collection and increasing the ecological consciousness of the employees.

In recent years, the discussion on economic development has been dominated by aspects of environmental protection and sustainable development principles [8]. The majority of waste which goes into the environment comes from the industrial sector: the so called post-production waste group. An important feature of industrial waste, apart from its being produced in vast quantities as compared to communal waste, is the relative ease with which it can be segregated and stored.

In the new integrated approach the ecosystem is considered as a superior system within which the destructive influence of other components should be reduced to minimum. Actions undertaken on the basis of a sustainable development approach have to take into consideration the integration of economic, social and political growth as well as sustaining the ecological balance [9]. Recently, we have observed a major reduction in the destructive influence of the industrial sector on the natural environment. This is a result of the implementation of modern, low-waste technical and technological solutions, as well as the use of recycled materials in production. However, the current state of waste management systems is still far from ideal and requires constant improvement. The priority of an ecological approach is, first and foremost, prevention which includes reduction and elimination of generated waste mass.
LITERATURE


