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THE ORIGIN OF MINERAL WASTE FROM CONSTANTA PORT AND THE NECESSITY TO INTRODUCE IT INTO THE CIRCULAR ECONOMY

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Abstract: *Constanta Port is the largest port on the Black Sea. Only here are operated the largest ships that have access through the Bosporus and Dardanelles straits. Of these, the largest tonnage is operated in berths 80 – 84 belonging to COMVEX SA. In the port there are also terminals for operating bulk cargo belonging to SOCEP and Minmetal.*

During the operation of ships, transport and storage of bulk cargo, basic activities of the terminal, losses of bulk materials occur, which periodically collected are waste because they no longer meet the original characteristics of the goods.

According to GD 111/2002, these quantities of materials are called technological losses and are a mixture of iron ore, bauxite, coke and coal. The mineral components of this waste, defined as mineral waste, are from the handled materials, and which are of the highest quality.

This quantity cannot be shipped to customers and therefore the respective quantities of goods represent operating and storage losses. Periodically, this mixture must be removed so that the land surfaces on which the stacks of materials are formed remain clean.

The production of mineral waste is closely linked to the activity of the Ore Terminal. The mineral mixture from cleaning operations is stored in temporary storage dumps. In addition to the fact that these quantities of goods represent losses, they also represent an impact on the environment.

The storage of this waste involves occupying important, available, adjacent areas and sometimes production areas. This also has implications for the operator's handling capacity as it requires additional operations involving energy consumption, labour consumption, vehicle use, etc. In conclusion, this scenario negatively affects the economic and social development of the company operating with bulk materials.

Due to the specificity of the bulk cargo handling terminal, between 1991 and until now, significant quantities of mineral waste valued at approx. 650.000 t.

Similar wastes are a characteristic of large ports, which transit such bulk goods, such as: Rotterdam – EMO operator – Netherlands, Dunkirk and Sollac sur Mer – France, Tianjin – China.
Keywords: *Constanța, minerals, mineral waste, consumption*

1. Introduction

Constanta Port – the most important port on the Black Sea and the fourth largest in Europe, has a total area of 3,926 ha, of which 1,312 ha - land and 2,614 ha - water and is located on the western coast of the Black Sea, 179 nM from the Bosporus Strait and 85 nM from Sulina through which the Danube flows into the sea. [1]

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Located at the crossroads of trade routes linking the developed countries of Western Europe and the developing markets of Central Europe with suppliers of raw materials from ICS, Central Asia and Transcaucasia, Constanta Port offers several advantages, of which the most important are:

- A multifunctional port with modern facilities and water depths in the port basin sufficient to berth ships with a capacity of 220,000 dwt.
- Direct access to Pan-European Corridor VII - Danube, via the Danube-Black Sea Canal, providing a shorter and cheaper transport alternative to Central Europe than routes using ports in the northern part of Europe.
- Good connections with all modes of transport: rail, road, river, air and pipeline; a new container terminal on Mol II S, through which container operating capacities in Constanta Port have increased considerably.
- Ro-Ro terminals and Ferry Boat suitable for the development of cabotage navigation serving the countries bordering the Black Sea and the Danube.
- The status of 'port with customs facilities'.
- Integrated environmental management.
- Planned programmes for future development of the port.
- With a total length of quays of 29.83 km, Constanta Port has 145 berths of which 119 are operational and have depths between 8 and 19 m, which allows access for tanks and bulk cargo ships of 220,000 dwt.

Constanta Port has the potential to become the main gateway for Europe-Asia corridor. River traffic in Constanta Port is approximately 10 million tons/year and represents 24% of the total annual traffic.

Every day, more than 200 barges are operated or moored waiting for loading or unloading goods. As far as port economic activity is concerned, Constanta Port operating companies provide all types of services for handling general cargo. Thus, food, beverages and tobacco, pulp and paper, laminates, spare parts, cement in bags and other goods can be transited through Constanta Port.

Several port operators operate in Constanta port, and one of the most important is COMVEX SA Constanta. It owns an Ore Terminal located in the North-West area of Constanta South port.

One of the activities foreseen in the object of activity and the most important of them is the handling of bulk goods, namely ores, coke, coal, etc.

The terminal consists of 3 (three) major "sectors", namely the receiving sector, the storage sector and the forwarding sector.

COMVEX has for unloading operations a quay consisting of 5 berths, with a total length of 1,400 m and a water depth between 10.8 and 18.5 m.

The unloading equipment consists of 3 unloading bridges with 50t grapple lifting capacity each, with a discharge rate of 2,000 t/h.

The conveyor belt system has a total length of 22 km. Two of the main conveyor belts are 1.5 km long and have a productivity of 4,000 t/h each, and the third, inaugurated on 01.08.2006, has a length of 2 km and a productivity of 4,000 t/h.

The electrical equipment transmits the information to a PLC-controlled system connected to the data transfer network.

From the unloading area the goods can be transmitted through the conveyor belt system to the main warehouse, to the barge loading machines, to the CF wagon loading terminal or can be unloaded on the quay in the pre-stock area.

The loading quay consists of 3 berths with a total length of 600 m and a water depth between 6.6 – 7 m.

The loading equipment consists of three barge loading machines with an average load capacity of 2,000 t/h each, simultaneous loading of 2 barges of 3,000 tons capacity is possible.

The storage space covers an area of approx. 600,000 m^2 of which 155,996 m^2 are located along the sea quay (pre-stock).[2]

- Total storage capacity:
- Iron Ore: 3,500,000 tonnes.
- Coal: 2.000.000 tonnes.
- Bauxite: 3.200.000 tonnes.

2. Sources of mineral waste generation

One of the port activities present both in the ports in the country and abroad is the operation (unloading and loading) of sea and river vessels transporting bulk raw materials.

This activity is carried out with high capacity means such as: unloading bridges, belt conveyors, combined stacking and removal machines, storage spaces, handover machines, loading station in railway wagons, etc.

The cleaning activities of machinery and storage spaces over time generated waste (mineral mixtures), sometimes together with other types of waste that have been deposited in port premises.

Within this work, and not only, observation actions were carried out and determination of factors influencing waste generation as well as generation mechanisms. All these studies have established the following waste generation mechanisms.

Adhesion of bulk raw materials to surfaces with which they come into contact of grippers, bucket wheels, hoppers, connecting elements, conveyor belts, etc. This is dependent on material moisture, granulation, atmospheric temperature and humidity, magnetic and electrical properties of bulk materials, etc. It is estimated that it is generated by this mechanism approx. 50% of the total amount of mineral waste.

Regarding the adhesion of bulk materials, a large generator of mineral waste, studies and research have been made to reduce it and, finally, to reduce the amount of waste generated. As a result of these actions, various cleaners were designed, some simple, others complex, real cleaning machines. With all these financial and human efforts, effective technical solutions against this generation mechanism have not been found. The reason is its complexity and the multitude of influencing factors.

A reference paper in this field is entitled "A new approach regarding the behaviour in operation of belt conveyors" - PhD thesis - University of Galati - 2001[1]. In this paper, special reference is made to the mechanism of generating mineral waste by adhesion to the rubber conveyor belt and metal surfaces with which bulk materials come into contact during handling.

In this paper were highlighted the main factors influencing adhesion and among the most important are:

- Material humidity - it is specified that in the area of high humidity (>15%) the adhesion phenomenon is carried out with great intensity, reaching very high adhesion values, up to 80 kg/m^2.
- Conveyor belt wear level - adhesion of transport materials is higher with increasing wear of conveyor belts. It is kept within acceptable limits (<100 g/m^2) for normal wear of the upper rubber layer and registers very high values (1303.7 g/m^2), when wear includes the belt reinforcement (cloth).
- Nature of surfaces - refers to the type of materials from which the surfaces of the transited materials come into contact, and which lead to different degrees of adhesion phenomenon are made. Usually they can be rubber surfaces, mixed (rubber + canvas), textiles (cloth), PES / PA type, i.e., synthetic polyester yarns in warp and synthetic polyamide yarns in weft, metal surfaces (are surfaces of hoppers, connecting elements, rollers, drums and others) etc.
- Material granulation - small granules polarize in the area of low humidity and, due to striations, adhere easily to contact surfaces. They also penetrate cracks or caverns of surfaces and increase their roughness. The material with the highest degree of adhesion has a grain size between 0¸3 mm. The factors influencing the adhesion of the material to be transported have greater action at this grain to which electrostatic forces are added.
- Surface temperature - material in contact with warmer surfaces dries by evaporation of water and there is an increase in adhesion in the humidity zone 0-5% and a decrease in adhesion in the humidity zone 5-15%. The material with temperatures higher than 0°C, in contact with surfaces that have negative temperatures, registers high adhesion values by freezing the water in the vicinity of the contact surface. The thickness of the layer of material frozen and adhered by this mechanism increases with increasing humidity, contact time, thermal conductivity and decreasing temperature, decreasing grain size, etc.
- Nature of the material transported - this is due to physical and chemical properties that differ from one material to another.

The action of atmospheric factors such as: the action of atmospheric currents and the action of heavy rains. Two mechanisms can be presented that generate mineral waste caused by atmospheric factors:

- Wind action, especially for periods of the year with low rainfall and strong wind, specific to the weather conditions of the area, generates on the surface of ore / coal / coke stacks, transhipment stations, conveyor belts, etc., conditions for load bearing drive of dust particles. The amount of dust entrained depends on wind speed, moisture of materials, surface area of stacks exposed to wind (in some cases over 10,000 m^2), amount of dust existing, etc. This dust is transported close to entrainment areas and deposited over other dust previously generated from other materials. It is estimated that approximately 5% of the total amount of mineral waste occurs through this route.

- The action of rains is manifested by the entrainment of significant quantities of materials from the piles of materials at a liquid/solid dilution of approx. 10/1¸ 1/1, the solid being deposited at the base of the stack by the natural settling effect when reducing the speed of travel. About 5% of the total amount of mineral waste is generated through this mechanism.
- Repair and cleaning activities of means of operation and transport, access ways, roads, platforms, cleaning of adjacent surfaces, etc. can produce approx. 10% of the total amount of mineral waste.
- Accidental discharges, through the occurrence of exploitation incidents, along the entire length of technological flows (decentring and breaking of conveyor belts, blocking of connecting elements, various clogging, etc.) can generate about 10% of the volume of mineral waste.
- Cleaning activities of storage spaces, changing cargo sorts and other causes can generate about 19% of the total amount of mineral waste.
- Manual and sometimes mechanical deployment during the cleaning of bunkers and connecting elements, whenever necessary, to maintain operational capacities and to ensure the quality of operations when changing sorts, produces quantities of waste in a proportion of about 1%.
- Cleaning storage spaces (dumps) when changing the grade of raw material, cleaning bunkers and connecting elements, cleaning all machinery before repairs and as a maintenance activity, cleaning adjacent surfaces, cleaning roads, etc. are necessary activities in order to maintain the operating capacity of the terminal. These activities result in quantities of mineral waste that will be deposited in available spaces, adjacent spaces and sometimes in storage spaces.

In conclusion, we can say that the adhesion of bulk materials to the surfaces of operating equipment with which they come into contact and the cleaning of storage spaces are the main mechanisms for generating mineral waste.

A summary calculation shows that these quantities of waste represent less than 1% of the total quantity of raw materials operated, from commissioning until now.

All these losses of materials manipulated since the establishment of the company until now fall within the permissible limits of technological losses provided by the legislation in force (Regulation of Commercial Exploitation of Ports, edition 1954, and Government Decision no. 111 of 07.02.2002).

3. Features of the mineral waste deposit

The main characteristic of the waste from Constanta Port is given by the mineral composition and the fact that it is a mixture of goods specific to the Romanian industry. This waste is composed of more than 99% iron ore, coal, coke, bauxite and limestone. We can say that this type of waste is unique in the world because it was obtained from the losses of bulk raw materials that were circulated in Constanta Port and are specific to the Eastern European industry.

3.1. Location and volume of the waste heap

The waste is located in Constanta, the port of Constanta, inside the operator Comvex SA. The waste was stored in Heap No. 5. The volumetry was performed by Topominiera SRL using the following:

For topographic measurements was used equipment:

- GPS systems "Nikon Epoch L1/L2 25" that ensure the following accuracy:
  ± 5 mm + 0.5 ppm horizontal RMS in Static and Fast Static mode.
  ± 5 mm + 0.5 ppm vertical RMS in Static and Fast Static mode.
  ± 10 mm + 1 ppm horizontal RMS in Real Time Kinematic mode.
  ± 20 mm + 1 ppm vertical RMS in Real Time Kinematic mode.
- 3D laser scanner system "ILRIS-3D" with the following technical specifications:
  In data acquisition the laser system uses a class 3B laser.
  Accuracy from ±4 mm to ±10 mm depending on the measuring distance in static mode.

The acquisition radius of points starts from 2 m reaching up to 1500 m, having a reflectivity of up to 4% at 350 m, increasing proportionally with the distance.

The field of vision of the scanner is 40° x 40°.

At a radius divergence of 0.00974º, minimum spot pitch (X and Y axes) of 0.00115º and laser wavelength of 1500 nm, the data collection rate (actual measurement rate) is 2500 points per second.

Data acquisition

- New topographical points were determined in areas of interest.
- Measurements in areas devoid of vegetation, especially waste stocks with a greater relief in terms of both their size and height, were made with the Ilris 3D scanner.
- Measurements in areas with more abundant vegetation were made with Nikon Epoch L1/L2 25 GPS.

Topographic calculations

- Data processing was carried out exclusively on computer, using the following calculation and editing programs: Briscad, Excel, Word, PolyWorks.
- The results of these calculations were stored in data files for printing and possible further processing.

Data processing

- Given the high density of points purchased by the scanner and GPS in the millions, after their post-processing, situation plans were made on areas of interest quoted in point grids with equidistance of 5m at the scale of 1:500.
- The raw data purchased in the field with the above-mentioned devices were the basis for achieving both the situation plans and the volumes achieved by sectors in the project.

Depending on the reference elevation, Heap no.5 was divided into two sectors and three-dimensional measurements were made that led to the following results:

- Sector 1 (Fig. 1) - having the reference elevation +4.65 m.
  A flat area of 42388 m^2.
  Inclined area of 44972 m^2.
  A volume of 163283.92 m^3.

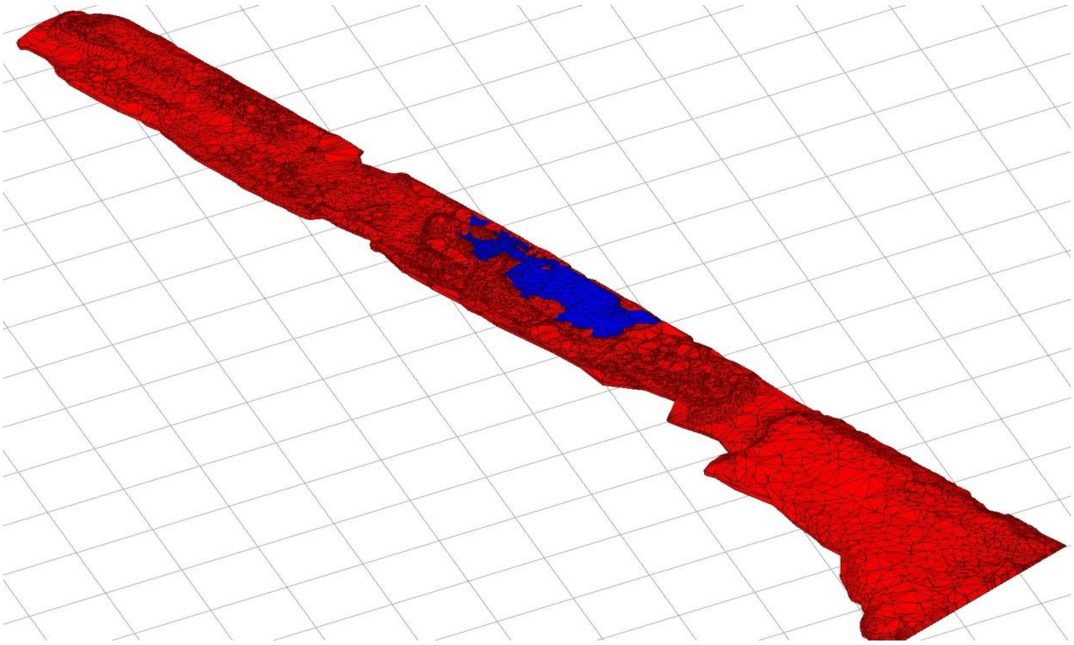

Fig. 1. Sector 1 (extracted from the calculation of digital 3D models)

- Sector 2 (Fig. 2.) - with reference elevation +4.95 m.
  A flat area of 9939,63 m^2.
  Inclined area of 10458.96 m^2.
  A volume of 33706.26 m^3.

The total volume of waste in both sectors obtained from the volume calculations carried out is 196990.18 m3. And this value is valid only for the waste above the ground, an estimation for the total waste including the waste below the reference quota of the port platform is approx. 650000 tons.

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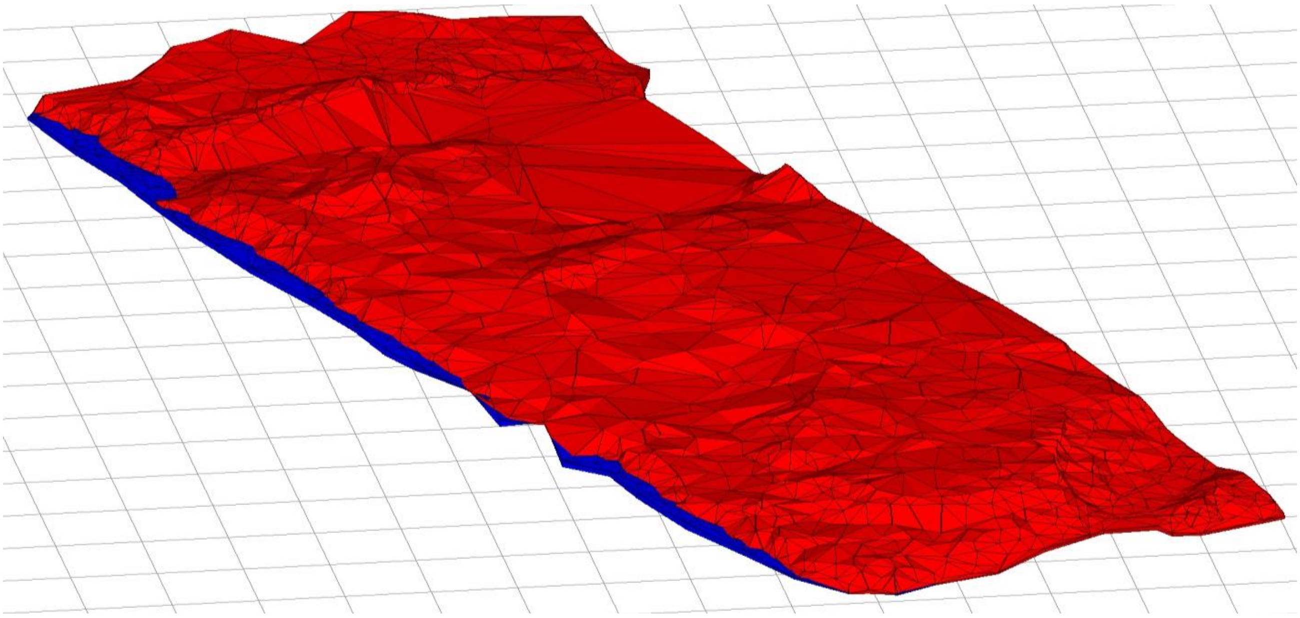

Fig. 2. Sector 2 (extracted from the calculation of digital 3D models)

3.2. Mineral composition

These types of waste consist mostly of raw materials, minerals, of the kind operated by various port operators. In particular, the waste from the port of Constanta consists of a mixture of raw materials that were necessary for industries in Romania.

A noteworthy aspect that adds to the complexity of waste analysis is that certain chemical elements are commonly divided between several assortments of raw materials present in the waste. This mixing of chemical elements is a challenge when trying to establish assortment composition. Consequently, relying solely on chemical analysis of a representative sample would give us only approximate information on the composition of the waste.

In order to overcome this challenge and gain a comprehensive understanding of the composition of the waste, it was necessary to carry out an assortment analysis. Assortment analysis allows a more accurate determination of specific minerals and their proportions in the analysed material.

Through the aforementioned analysis, it becomes possible to discern each mineral component and quantify its relative contribution to the overall composition.

Assortment analysis serves as an indispensable tool in optimizing resource use and facilitating effective waste management strategies. By acquiring detailed knowledge of the assortment composition, informed decisions can be made about separation and recovery processes. This information helps develop customized methodology to extract useful minerals from existing waste while maximizing the degree of recovery of useful resources. [3]

The assortment analysis was carried out on a representative sample consisting of more than 100 increments collected from the waste mass. The collection was done mechanized by excavation samples being taken from various depths. The sample was homogenized and quartered to a mass of approximately 100 kg. The representative sample thus obtained was sieved on the site to obtain a grain size of 6.3 – 50 mm, this grain was chosen due to the possibilities of visual identification of the granules. Following the assortment analysis made, I was able to identify the constituents of the waste as shown in table no. 1.

Analysing the results, we notice a share of 34.9% is represented by iron ore lumps, it is worth mentioning that they, by colour, come from various established deposits located in various areas of the world, such as: Brazil, India, Ukraine, Canada, Australia and South Africa. The Fe content of these ores is between 55% Fe for Indian ore and up to 65% for Brazilian ore.

In the case of the other minerals, it is impossible to identify the deposits where they come from due to the lack of an identification method based on colour or other specific property. What we can say is that all the constituents of this waste come from established mineral resources and processed to be marketed as raw materials.

Following this analysis, it emerged that raw materials, which, although formed by mineral mixtures of the same type, but of different origin, have physical and chemical properties that place them in the area of raw materials with real potential for use in industry after their separation. Following this analysis, also taking into

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account how these types of waste are produced, we can say that port waste can be a source of raw materials if properly recovered and processed.

Table 1. Assortment distribution of waste from Constanta port

Constituent	Stake (%)
Iron ore lumps	34.9
Bauxite	21.9
Coal	14.4
Limestone	13.8
Iron Ore Pellets	10.4
Metallurgic Coke	4.6

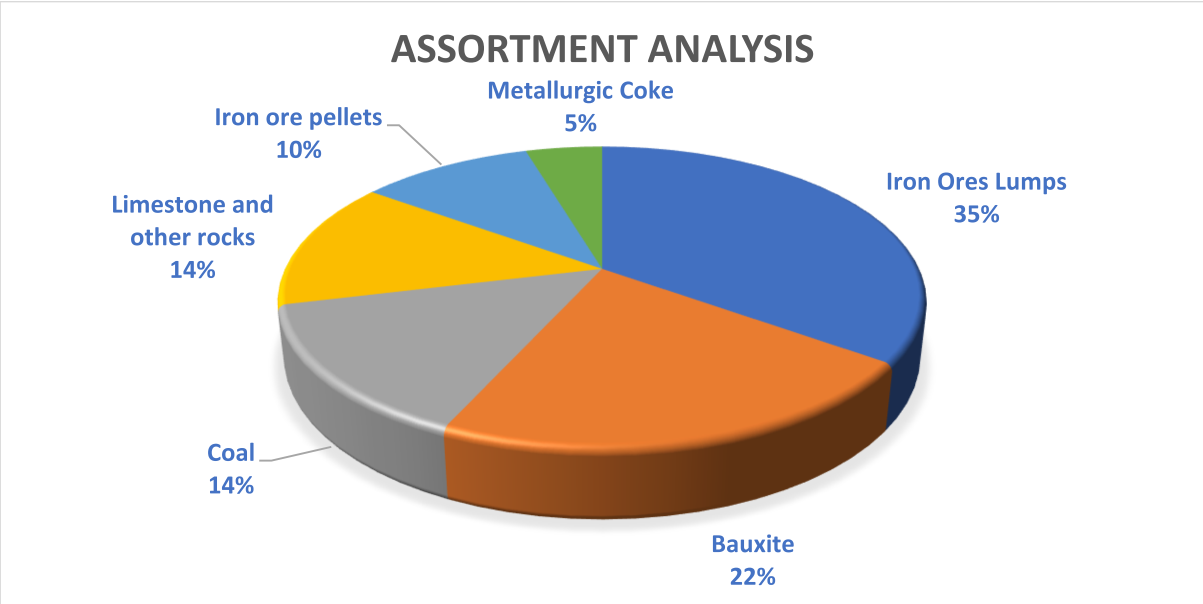

Fig. 3. Graph of assortment distribution of waste from Constanta Port

4. The importance of mineral waste recovery

Waste recovery is one of the practical activities with undoubted beneficial effects both in the economic field – by rationalizing non-renewable primary resources – and in environmental protection – by greening the areas affected by anthropogenic activities and is an imperative of Romania's sustainable development. This is why so much importance is attached to this area of activity.

We define waste *any material that, in its form, can no longer be used*. Any material (or object) defined as waste in its form can become reusable after a series of transformations are carried out on it. It is therefore necessary to find ways of transforming and reusing as much primary waste as possible.

Waste results from almost any type of activity and, especially depending on the source that generates it and imprints certain characteristics, can be classified into different groups according to certain criteria.

Undeniably, the main object of recovery is industrial waste, which constitutes huge deposits and – most of the times – also contains polluting elements, harmful to the nearby population. Even more it is necessary to desideratum to green those areas and at the same time, to capitalize on the material contained in them.

There are various technologies for the recovery of mineral substances from waste from port activities, resulting in raw materials for the steel, energy or cement manufacturing industries. The particularity of the mineral waste from Constanta Port is that it includes several components: iron ore, bauxite, coke, coal and limestone.

In the Netherlands, Rotterdam has a plant separating a similar waste consisting of a mixture of coal and iron ore.

Recovered, processed raw materials with a stable chemical composition can be used in metallurgical, energy and cement industries.

These raw materials obtained from recycling have a reduction in manufacturing costs, can partially meet the need for raw materials or fuels. They can also help maintain and create jobs.

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5. The concept of circular economy

In brief, the circular economy can be defined as a production and consumption model that aims to reduce waste production to a minimum. Basically, when a product reaches the end of its life cycle, it is used to generate new raw materials through recycling.

This concept is totally different from the linear economic model that can be represented as: raw material – product – use – waste, this model being based on large quantities and easy to obtain in the case of raw materials and energy. [4], [5].

Fig. 4. Circular economy infographic

The implementation of the circular economy concept brings important benefits in terms of:

- Environmental friendliness.

Reduced use of natural resources results in less impact on natural habitat, potentially helping to preserve the biosphere and biodiversity. At the same time, if we realize that in order to obtain natural resources in the traditional way, a quantity of greenhouse gases is generated, this concept helps reduce them and implicitly helps reduce global warming.

- Reducing dependence on raw materials.

In recent decades, the world's population has grown, and with it the need for raw materials, however, the reserve of raw materials is limited. Due to this, certain regions/countries/continents may be dependent in terms of raw materials, which has an impact on prices, availability and import dependency. Recycling raw materials can be a lever to mitigate the impact of raw material dependency.

- Social benefits

Recycling and reuse involve both labour and sustained research and innovation, especially due to the new challenges of finding efficient solutions. These aspects help the development of society in general and communities in particular.

- Economic benefits

Recovery of waste, including energy recovery. Compliance with the criterion on the quality of products resulting from the processing of waste minerals. We can estimate the following products resulting from the treatment of this mineral waste [6].

Homogeneous iron ore, granulation 0÷ 6.3 mm, humidity approx. 10%, iron content approx. 55%, used in the steel industry;

Homogeneous iron ore, granulation 6,3÷30 mm, humidity approx. 8%, iron content approx. 55%, used in the steel industry;

Homogeneous coal, granulation 0÷30 mm, humidity approx. 10%, calorific value approx. 5000 kcal/kg, ash approx. 20%;

Homogeneous bauxite, granulation 0÷30 mm, humidity approx. 10%, Al2O3 content approx. 35%, used in cement manufacturing industry and construction as filler;

Mineral wastes (Waste code: 19 12 09), rubber and plastics (Waste code: 19 12 04), scrap metal (Waste code: 19 12 02) etc. resulting from treatment.

6. Conclusions

A comprehensive analysis of these wastes elucidates a remarkable fact: regardless of the grain size encountered, there is an undeniable presence of a physical mixture, which includes a multitude of useful mineral substances. It is noted that this complex mixture possesses distinct characteristics that are intrinsically linked to the port or port operator concerned.

These characteristics are directly influenced by the broad spectrum of goods transported through the port, encompassing different types and quantities of cargo. In addition, this unique blend bears the imprint of industrial progress and development in the geographical vicinity served by the ports.

However, amidst the potential inherent in this composition, a pressing challenge arises that requires immediate attention and resolution. This challenge revolves around the crucial task of effectively separating compounds from the mixture.

The successful execution of this process holds the key to the recovery and recovery of valuable mineral substances contained in waste. The separation process plays a key role in the recovery and further exploitation of this waste, enabling it to be turned into a valuable resource.

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