THE IMPACT OF INDUSTRIAL WASTE DUMPS ON THE ENVIRONMENT IN THE AREA OF MOLDOVA

IMPACTUL HALDELOR DE DEŞEURI INDUSTRIALE ASUPRA MEDIULUI DIN ZONA MOLDOVEI

LUCA M.[1]*, TOMA D.[1], MARCOIE N.[1], DOMINTE (CROITORU) Violeta

*Corresponding author e-mail: mluca2015@yahoo.com

Abstract. In the area of Moldova there are a number of industrial warehouses with a special impact on the environment due to poor management of the maintenance process. Landfills come from steel plants, mining, power plants, industrial products factories, etc. Representative in this case are the waste dump from the Galati steel plant, the tailings dumps from the mining operations in the north of the Eastern Carpathians, the ash dump from CET Holboca Iași, etc. The paper summarizes a series of research on the impact on the environment and in particular on surface and groundwater by these polluting objectives.
Key words: multiple pollution, steel waste, liquid waste

Rezumat. În zona Moldovei se află o serie de depozite industriale cu un impact deosebit asupra mediului din cauza unui management defectuos al procesului de întreținere. Depozitele de deșeuri provin de la combinate siderurgice, exploatări miniere, centrale electro – termice, fabrici de produse industriale etc. Reprezentative în acest caz sunt haldele de deșeuri de la combinatul siderurgic Galați, cele de steril de la exploatările miniere din nordul Carpaților Orientali, halda de cenușă de la CET Holboca Iași etc. Lucrarea prezintă în sinteză o serie de cercetări privind impactului asupra mediului și în special asupra apelor de suprafață și subterane de către aceste obiective poluante.
Cuvinte cheie: poluare multiplă, deșeuri siderurgice, deșeuri lichide

INTRODUCTION

The environment represents the set of natural components of the Earth as well as their conditions of existence. The components are defined by air, water, soil and subsoil, flora and fauna, as well as the social-human component. A process of alteration of biotic and abiotic living environments, but also of the values created by human society is anthropogenic pollution. The last hundred years have seen an increase in pollution caused by human activities (Bica, 2000).

An example of disaster pollution is that produced by industrial waste dumps (solid and liquid) in various stages of operation and post-conservation. Industrial landfills are a national and international problem of negative environmental impact. The pollution phenomenon at these warehouses is present both during the

[1]Technical University "Gheorghe Asachi" of Iași, Romania

exploitation and conservation period. There are about 820 industrial landfills in Romania (Bălan, 2010). The most dangerous industrial waste dumps are those from the metallurgical industry, the mining industry, the chemical industry, thermal power plants, etc. (Bălan and Luca 2010; Sofronie *et al.*, 2007).

The closure and conservation of industrial waste landfills is a difficult problem to solve in Romania given the economic and political situation (Law 137, Technical Norm on waste storage – 2004).

The paper presents a series of results of research on environmental degradation in the area of industrial landfills and in particular the negative impact on soil and surface water.

STUDY AREA AND RESEARCH METHOD

The research was carried out in the area of the industrial waste landfill (slag dump) from the Galati Steel Complex. The construction of the slag dump began in 1968 and continued until 2007, when it was decided to close it. The slag dump was not closed until 2021 either.

The industrial waste landfill (fig. 1) is located in the western part of the steel plant and borders with Mălinei Pool to the north, west and south, and to the east of the exploitation road of Şendreni commune City Hall. The location of the dump starts from the elevation of 10.00 m on a plateau located between the Cătuşa and Mălina valleys and on the agricultural lands of Smârdan and Movileni localities, Galați county.

Fig. 1 General view of the slag dump and Balta Mălina, year 2021 (image Google earth):
1 - slag dump; 2 - Balta Mălina nord; 3 - Balta Mălina sud; 4 - the Siret river.

Theoretical and experimental research was carried out in the following fields:

1. Studies and research on the evolution over time of the landfill in the exploitation phase and after that in the absence of conservation works.

2. Studies and research on the polluting impact on the natural environment (air, surface and groundwater, soil and subsoil) and anthropogenic.

3. Water pollution in Balta Mălina and influence on water quality in the Siret River.

4. Research of current natural and anthropogenic risk factors with influence on the evolution of the parameters of pollutants in the deposit and emitted by it in the environment.

For the analysis of the situation in the field, a documentary study and an experimental research were carried out on the location of the slag dump and the technological ponds Mălina South and North, as well as of Mălina Pool. The research analyzed the adjacent area of the slag dump formed by Mălina Creek, Mălina Pool, agricultural land, etc. The data collection from the field was done through specialized analyzes on fields, material samples, photo surveys, etc.

The primary data were processed using statistical, hydrological, hydraulic calculation programs applicable to the case study (Bălan, 2010; Charbeneau, 2000).

RESULTS AND DISCUSSIONS

Waste, especially industrial, is a source of health risk due to its content in toxic substances such as heavy metals (lead, cadmium), pesticides, solvents, waste oils, etc.

Removing land for landfills from the natural or economic circuit is a process that can be considered temporary. But in terms of the concept of "sustainable development" this process extends over at least two generations, if you add up the periods of development (1-3 years), operation (15-30 years), economic recovery and post-monitoring (15-20 years).

The most difficult problem is hazardous materials (including toxic sludge, petroleum products, paint residues, metallurgical slag) that are stored in common with municipal solid waste. This situation can lead to flammable, explosive or corrosive mixtures and combinations; on the other hand, the presence of easily degradable household waste can facilitate the decomposition of complex hazardous components and reduce environmental pollution. A negative aspect is that many recyclable and useful materials are stored together with non-recyclable ones, being mixed and combined from a chemical and biological point of view, and their recovery is difficult.

The main forms of impact and risk determined by industrial landfills, in the order in which they are perceived by the population are: air pollution, surface water pollution, changes in soil fertility, changes in the composition of biocenoses on neigh boring lands, changes in landscape, discomfort visual and olfactory, particle deposits, etc.

In order to exemplify the above, an analysis performed at an existing industrial landfill in Romania is presented. The warehouse was created within the Galați Steel Plant, and after 1990 it was taken over by the "Arcelor Mittal" Trust and then by the "Liberty Steel" Trust. Waste resulting from the technological process of producing cast iron, crude steel, flat rolls, metal agglomerates, thick sheet, casting equipment, etc. is deposited in the landfill.

The dump is located to the west of the plant and has an area of approx. 110 ha. The height of the landfill is variable, but on average it is 50 m. The surrounding land, located outside the perimeter approved for storage, is partially and even completely covered with waste. The dump began by occupying the eastern shore of Pond Mălina, advancing to the other directions covered with water. The advancement occurred horizontally and vertically, and currently presents an advanced non-uniformity due to metal recoveries.

a b

Fig. 2 Galați slag dump: a - north side; b - the southern side (Bălan, 2010).

The technological process has resulted in large amounts of toxic residues, depending on their nature, but which involve special problems through processing and storage. Blast furnace slag contains the following substances: SiO_2 = 36 – 38%; $A1_2O_3$ = 10 – 12%; CaO = 43 – 46%; MgO = 3 – 5%; MnO = 0.5 – 0.7%; CaS =3.1 – 3.6%; S = 1.4 – 1.5%; FeO < 1%. Blast furnace slag becomes chemically inert about 6 (six) months after production.

The volumes stored in time stages were the following (approximate values) (Bălan, 2010):

- in the years 1968 - 1999, 34 million tons of blast furnace slag and 12 million tons of steel slag;

- in the years 2000 - 2004, 3.0 million tons of blast furnace slag, 1.50 million tons of steel slag and 700,000 tons of other waste;

- in the years 2005 - July 2009, until the closure of the dump and the cessation of the storage activity, 2.8 million t of slag and 900,000 t of other waste.

Waste storage after 2009 was carried out in an enclosure of the steel complex arranged in the Valea Lupului area. The landfill was supposed to be closed in 2014, but the plant obtained a postponement until 2023. At present, there is approximately 54 million tons of steel waste in the landfill.

The type of percentage of waste deposited (estimated) are: blast furnace slag approx. 47%, steel slag 30% and refractory waste and others 23%. In the slag dump there is an uncontrolled exploitation process through which metal components are extracted which are used as raw materials. It is estimated that a quantity of 5 million

tons of slag is processed annually, from which a quantity of approximately 740,000 tons of iron is taken. In the last period of time, the amount of iron extracted has decreased (Bălan, 2010; Geoconsulting, 2009; ICPDM Deva, 2004).

The extraction method is defective, uncontrolled and influences the geometry and stability of the dump. The repeated collapse of the deposition fronts led to the production of flood waves in the Mălina North Technological Pond. Also, the collapse of a slope of the dump led to the dam of the Mălina Creek bed (fig. 3), a situation that caused floods in the riparian area (Bălan, 2010). The floods disrupted the operation of technological ponds through discharges between treatment plants.

a b

Fig. 3 Phenomena of slag heap collapse in Mălina Creek: a - riverbed blockage; b - works to restore the riverbed (Bălan, 2010).

The industrial landfill is an "environmentally bomb" for the environment. Its realization was made without respecting the specific structure of industrial waste landfills. The polluting impact is manifested on air, surface and groundwater, soil and the human environment.

Air pollution is caused by solid particles picked up by the wind and transported in the form of clouds of dust on the surrounding land and often over the city. Clouds of solid particles (calcium oxide, heavy metals) are deposited on agricultural land and have led to a decrease in production in contaminated areas.

Surface water pollution is intense by making the location of the slag dump in Lake Mălina. The Mălina stream continues this process downstream to the Siret River. The water quality in Pond Mălina is influenced by the wastewater discharged from the technological ponds Mălina North and Mălina South. But, Pond Mălina also drains the waters from the dump in case of heavy rainfall. In the technological ponds, the industrial wastewater collectors taken from the steel complex are evacuated.

A study carried out by ISPAT SIDEX-Laboratory Environment-Waters (cited by Bălan, 2010 and ISPE, 2007) on the water samples taken during 6-

12.12.2003 from point D1 (discharge Mălina pond in Siret River) highlights the state of quality parameters of the water discharged into the emissary (tab. 1)

Table 1

Quality parameters of the discharged water from Balta Mălina in the Siret river (ISPE, 2007)

Nr. crt	Indicator analyzed	U.M.	Value measured	VLA
1	pH		8.74	7-9
2	Suspension	mg/l	10.8	40
3	Filterable residue	mg/l	871	1250
4	CCOCr	mg O_2/l	29	70
5	Chloride	mg/l	119.64	200
6	Sulphate	mg/l	**436.33**	500
7	Nitrates	mg/l	3.2	15
8	Ammonium	mg/l	**9.933**	10
9	Total iron	mg/l	0.346	5
10	Calcium	mg/l	168.14	250
11	Magnesium	mg/l	12.77	100
12	Phenol	mg/l	0.027	0.1
13	Total cyanides	mg/l	0.0234	0.05
14	sulphides	mg/l	**0.992**	1.2

From the analysis of the presented data it results that the allowed limit values (VLA) established by the Water Management Authorization are not exceeded. A number of parameters are close to the limit value, such as ammonium concentrations (9.933 mg/l), sulphides (0.992 mg/l) sulphates (436.33 mg/l) and pH (8.74). A comparative analysis would have required the taking and processing of samples by a laboratory subordinated to the environmental agency.

a b

Fig. 4 Lake Mălina North with the location of the wastewater treatment ponds: a - general view (image Google earth, 2021); b - general view, year 2008 (Bălan, 2010).

From the field studies (Luca and Bălan, 2008) it was found a state of intense pollution of Lake Mălina North in the area of the treatment ponds, but also of the Mălina stream downstream of the ponds (fig. 4).

In the southern part of the dump is the Mălina South tailings pond. Through it, the industrial wastewater collected from the perimeter of the steel complex is discharged into Lake Mălina. The Mălina South technological pond (fig. 5) has several compartments separated by earth dams and slag. The functions of the pond are to decant and accumulate the suspensions from the wastewater discharged through the collectors C8 and C - sludge furnaces. By unclogging the pond by dredging the sludge is recovered, which is introduced in the steel technological process.

a b

Fig. 5 Mălina Sud pond with the location of wastewater treatment ponds: a - general view (image Google earth, 2021); b - general view, year 2008 (Bălan, 2010).

The quality of the underground water from the perimeter of the dump is variably influenced by the physic-chemical parameters of the water from Pool Mălina and from the precipitations that percolate the slag dump. Depending on the water level in the Mălina pond and the level of the water layer present in the dump, a circulation is made in both directions with pollutant transport. Groundwater control was achieved through two boreholes, but they were destroyed in 2007 by moving the slag mass (Bălan, 2010).

Physic-chemical analyses performed on groundwater near the slag dump also indicated an increased turbidity above the permissible limits for drinking water distributed to consumers.

The slag dump does not have a system for draining, collecting, treating and evacuating rainwater. Rainwater seeps through the dump, triggers chemical reactions (for example the hydration of calcium oxide) and transports a large amount of heavy metals underground. The run-off water on the slope of the dump causes an erosion phenomenon, after which it evacuates into the Mălina pond. Some of the water is absorbed by the mass of the dump or the soil in the adjacent area.

Soil pollution is achieved in three directions: by air, by the advance of the dump on agricultural land and by surface and groundwater. The agricultural land is

polluted by the residues taken by the wind from the surface of the dump. Dump advanced in time on the agricultural land through uncontrolled deposits and landslides. Soil pollution was caused by the pouring of surface and groundwater from the dump, as well as water from technological treatment ponds.

Due to the nature of the waste and the storage technology used, the material that constitutes the structure of the slag landfill is particularly inhomogeneous both physically and chemically. On the other hand, the dump has impressive dimensions both horizontally and vertically. As such, a characterization of its physic-chemical composition by laboratory analyses would be very laborious and the conclusions less relevant and with a high degree of uncertainty. As a result, it was considered useful to take samples from the stored material, the waste being each characterized by analyses performed by the manufacturer.

The soil samples were taken from the area adjacent to the deposit, in its immediate vicinity, from 4 points (two samples each: one surface and one at a depth of 30 cm) located approximately on the four cardinal directions to the dump.

The location of the dump as well as the predominant direction of the wind in the area was taken into account. The choice of the 4 sampling points allows the analysis of the polluting effect of the deposit activity on the soil environmental factor (Bălan, 2010).

Considering the nature and chemical composition of the deposited waste and taking into account the recommendations from Annex 3.1 to the MAPPM Order 184/1997, laboratory analyses of soil samples aimed to determine the concentration in heavy metals (Pb, Cd and Mn), sulphates and pH. In June 2004, a series of analyses were performed by ISPAT SIDEX (cited by Bălan, 2010) by taking soil and water samples at the plant's location and outside it. Some of the results of the analyses for soil samples taken from the east and south sides of the researched area are presented in table 2 and table 3.

Table 2

Chemical characteristics of the soil samples inside the plant steel (Bălan, 2010)

Soil sample code	Parameters analysed				
	pH	**Cd**	**Mn**	**Pb**	**SO_4^{2-}**
m.u		mg/kg	mg/kg	mg/kg	mg/kg
E1- surface	8.18	***1.42***	1370	***53.2***	460.2
E1- 30 cm in ground	8.15	***1.25***	793	***44.35***	593.14
S1- surface	8.43	***1.56***	831	***49.2***	198.6
S1-30 cm in ground	8.27	***1.63***	814	***47.7***	202.1
Normal values		1	900	20	-
Alert threshold		5	2000	250	5000
Intervention threshold		10	4000	1000	50000

The analysis of the data shows that the soil samples have a pH value above 8.0, which gives the soil in the area an alkaline character. The concentration of lead and cadmium in all samples analysed is above normal values, without exceeding the intervention threshold for sensitive uses.

Considering the location of the sampling points in relation to the slag dump and the predominant direction of the wind, the negative effect of its activity on the soil environmental factor can be highlighted.

Table 3

Chemical characteristics of outdoor soil samples location of the steel complex (Bălan, 2010)

Soil sample code	Parameters analysed				
	pH	Cd	Mn	Pb	SO_4^{2-}
m.u.		mg/kg	mg/kg	mg/kg	mg/kg
E1- surface	8.26	***1.61***	***1270***	***38.2***	601.4
E1- 30 cm in ground	8.20	***1.58***	1399	***46.7***	880.2
S1- surface	8.39	***1.48***	795	***37.4***	187.9
S1-30 cm in ground	8.47	***1.97***	755	***38.3***	193.7
Normal values		1	900	20	-
Alert threshold		3	1500	50	2000
Intervention threshold		5	2500	100	10000

The slag dump produces a pollution of the human environment through the following aspects and phenomena: the reduced distance from the habitable perimeter, the unsightly relief form, clouds of dust and smoke from fires transported in the city area, aerosols and the smell of burnt substances, etc. (Bălan, 2010; Luca and Bălan, 2008).

The slag dump in Galați is one of the 68 unclosed warehouses for which the Romanian state was convicted by the Court of Justice of the European Union, in 2018. The conviction was handed down for failing to fulfil its obligation as an EU Member State to close hazardous waste landfills as soon as possible.

The realization of the conservation structure of the slag dump would ensure a limitation of the pollution phenomenon in the environment.

The efficient solution indicated by the specialized regulations is to shape the geometric shape and cover the surface of the dump with a layer of topsoil. An adequate sewerage and drainage system must be provided for the collection and evacuation of rainwater. The examples made nationally and internationally can be similar in this case.

For a strict supervision of the operation and conservation of the industrial waste landfill, a strict monitoring of liquid, gaseous and solid emissions must be performed (Luca *et al.*, 2012; Bălan, 2010; Bica, 2000). It aims to verify the compliance of the emissions with the conditions imposed by the competent authorities (environmental permit, water management permit, etc.).

CONCLUSIONS

1. Industrial landfills are permanent sources of pollution of the natural and man-made environment during the period of exploitation and conservation in the absence of measures to limit the emission of gaseous, liquid and solid pollutants.

2. The slag dump from the Galați Steel Plant is an "ecological bomb" due to the way it is made, exploited and due to the absence of conservation works according to the regulations in force at national and international level.

3. The slag dump from the Galati steel plant produces complex pollution of air, soil and subsoil, surface and groundwater by its location on the edge of a city, chemical content, heavy transport of air pollutants - ground water and the absence of works conservation.

4. The degree and physic-chemical characteristics of the slag emissions are not continuously monitored by a modern system of analysis and forecasting, which assesses the impact on the environment at all times,

5. The management of industrial waste landfills must be carried out according to national regulations, but also correlated with the provisions of European legislation in order to limit the negative impact on the environment.

REFERENCES

1. Bălan R.P., 2010 - *Contribuţii la creşterea siguranţei în exploatare a haldelor de steril în privinţa reducerii potenţialului de poluare*. Teză de doctorat, Universitatea Tehnică

2. Bica I., 2000 - *Elemente de impact asupra mediului*. Edit. Matrixrom, Bucureşti.

3. Charbeneau R.J., 2000 - *Groundwater Hydraulics and Pollution Transport*. Prentice Hall, New Jersey, SUA.

4. Luca M., Bălan. R.P., 2008 - *Pollution monitoring of the industrial waste dump*. Bulet. Ştiinţ. al Univ. "Politehnica" Timişoara, tom 53 (67), I, Fascicola 2, seria Hidrotehnica, ISSN 1224-6042, p. 11-16.

5. Luca M., Bălan R.P., Luca Al., Mănescu A., 2012 - *Modelling pollution transport of the industrial waste underground*, Processing of the 15th Conf. on Modelling Fluid Flow (CMFF'12), Budapest, Hungary, p. 525-530.

6. Sofronie C., Bohuş C., Cadar B., 2007 - *Siguranţa în exploatare a depozitelor de deşeuri din bazinul hidrografic Someş – Tisa*. Conferinţa Internaţională, „Monitorizarea Dezastrelor şi Poluării CI.MDP.3", Universitatea Tehnică „Gh. Asachi" Iaşi.

7.* *Legea 137*-1995 -** *privind protecţia mediului cu completările şi modificările ulterioare*

8.*** *Studiu hidrogeologic, hidrochimic, Bilanţ de Mediu nivel II pentru Halda de zgură ArcelorMittal Galaţi,* 2007 - Institutul de Studii şi Proiectări Energetice Bucureşti, 2007.

9.*** *Normativ Tehnic privind depozitarea deşeurilor* – 2004, Ordin M.M.G.A. 757/2004

10.*** *Technical Documents, Studies and Analyses* - S.C. ARCELOR MITTAL S.A. Galaţi.

11.* 2004 -** *Exploatare şi amenajare ecologică a haldei de zgură şi stabilire a planului de închidere şi monitorizare postînchidere a haldei de zgură,* Institutul de Cercetare, Dezvoltare şi Proiectare Minieră – S.C. CEPROMIN S.A. Deva.

12.* 2009 -** *Evaluarea stării de siguranţă în exploatare a iazului de decantare Mălina Nord,* S.C. Geoconsulting International LTD S.R.L. Bucureşti.

13.* 2009 -** *Evaluarea stării de siguranţă în exploatare a iazului de decantare Mălina Sud,* S.C. Geoconsulting International LTD S.R.L. Bucureşti.