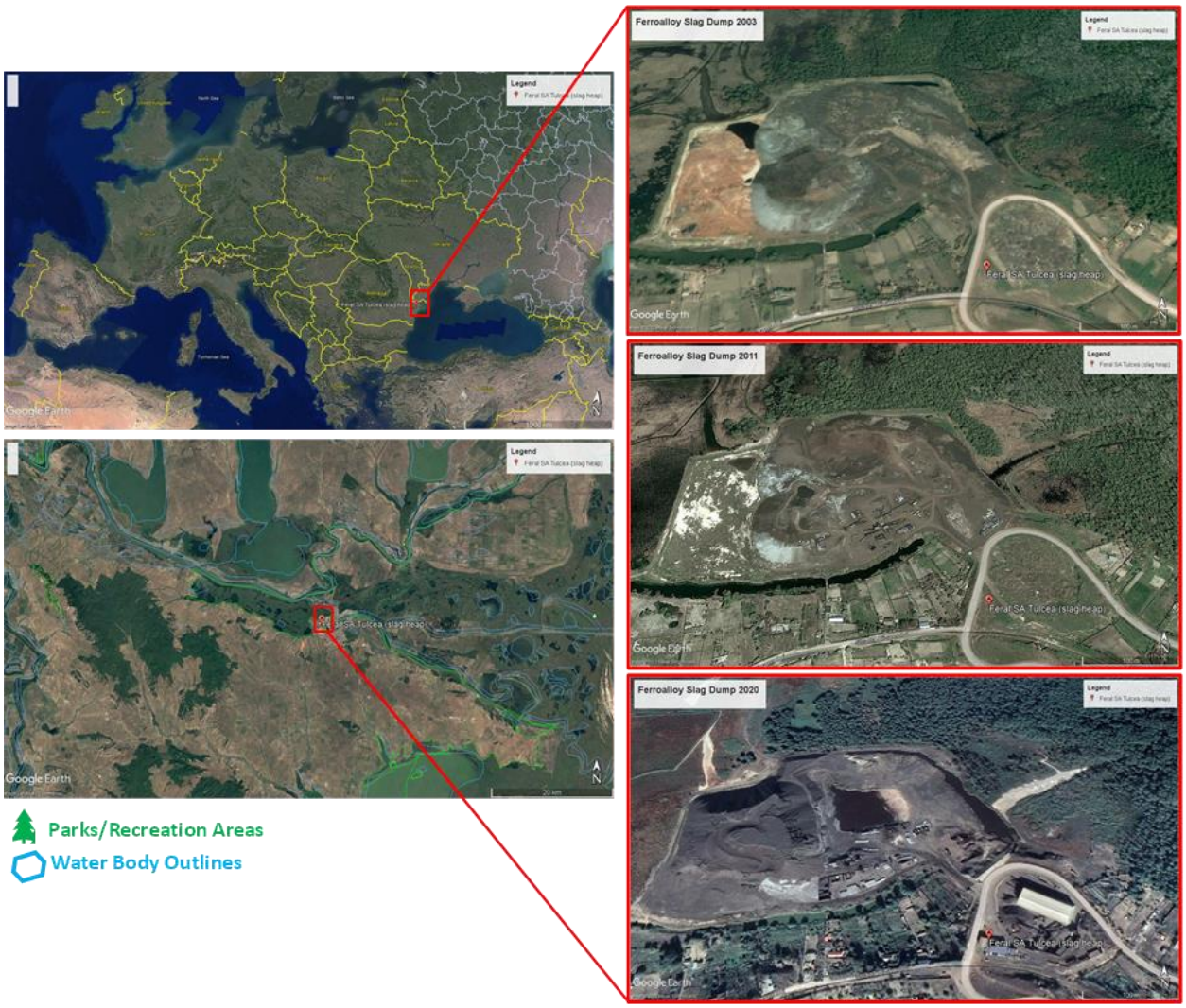

Fig. 1: Map of the sampling site location.

As can be observe in Figure 1, images done with Google Earth, the evolution of the dump since 2003 until 2020 and the increase of the large amount of ferroalloy waste slag dumped in landfill with negative effects on the environment. In in the left picture in can be seen the parks and recreation areas with green line and the water body outlines with blue line on the borders of the dump area.

3. Valorification of Ferroalloy Slag Waste

For a quantitative determination of major and trace element concentrations in solid waste material using a calibration with matrix-matched standards the ferroalloy slag waste was characterized by X-ray Fluorescence (XRF). The chemical composition of the waste slag is presented in Table 1. From the results one we can notice that the main oxides are consisting in silica, magnesium oxide and in small percentage alumina, calcium oxide and potassium oxide.

Table 1: Chemical composition determined with XRF (wt%) of the waste slag.

Element/Oxide	Percentage
Si / SiO_2	20.74 / 44.44
Mn / MnO	24.26 / 31.33
Al / Al_2O_3	3.36 / 6.36
Ca / CaO	4.02 / 5.63
K / K_2O	3.87 / 4.67
Fe / Fe_2O_3	1.55 / 2.21
Mg / MgO	1.28 / 2.12
Na / Na_2O	0.74 / 1.00
Ba / BaO	0.81 / 0.90
S / SO_3	0.17 / 0.42
Zn / ZnO	0.26 / 0.32
Ti / TiO_2	0.12 / 0.21
Cr / Cr_2O_3	0.11 / 0.16
P / P_2O_5	0.05 / 0.09
As / As_2O_3	0.05 / 0.07
Pb / PbO	0.05 / 0.06
Cu / CuO	0.01/ 0.01

Landslides are a major hazard in most mountainous and hilly regions, as well as in coastal areas or riverbanks. Their impact largely depends on the size and their speed, the elements at risk and the vulnerability of these elements. Every year, landslides cause deaths and cause severe damage to infrastructure (roads, railways, pipelines, artificial reservoirs, etc.) and property (buildings, agricultural land, etc.). Under the current economic circumstances, the number of landslides areas that require rehabilitation has grown [10]. Therefore, rehabilitating landslides areas in an environmentally sustainable and cost-effective manner is an engineering challenge [11]. Typically, landslides require a relatively low-strength material compared to other civil engineering structures. Landslides most often occur in areas where the soil is made of different types of clay (clay has the property of swelling during periods of heavy rainfall). Also, the most frequent landslides occur in spring and autumn, when the snow melts, but also when the amount of precipitation is higher. It is very important to mention that landslides are a major threat to human life and have devastating effects on construction, but also on the environment. But more serious is the fact that the importance given to these phenomena is incredibly low, especially if their production does not manifest itself obviously and with an increased speed.

In this study, we propose the re-use of ferroalloy slag waste in areas with landslides. In Figure 2 is presented the map of Romania with the areas which are predisposed to the landslides. The most affected areas are Prahova, Buzau and Vrancea which are at about 300 kilometres distance from slag dump. In present, crushed ferroalloy slag aggregate (FeSiMn and FeCr) is used in roads, foundations, concrete (good replacement of classical aggregates).

It is well known that over 95% of the commercial use of silicon oxide, silica (SiO_2) is in the construction industry, e.g., for concrete production. From the XRF analysis, it can be seen that the most important compound in slag waste is SiO_2, which indicates the use of slag as an additional cementitious material in areas at risk of landslides.

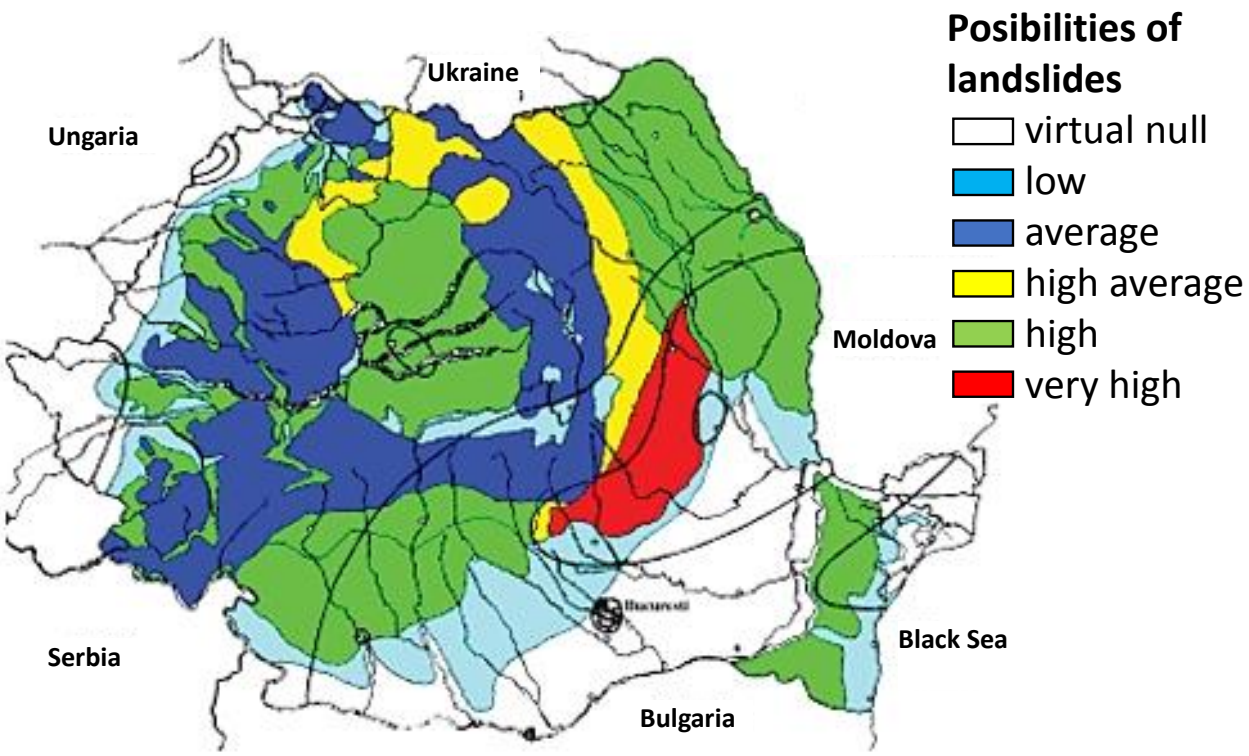

Fig. 2: Map of the Romania country [9]

Moreover, as can be seen from the Map of Romania (Figure 2), the entire eastern part, some areas in the centre, but also the southern part of Romania are exposed to a high landslide hazard, being close to the epicentre, according to the report "National Disaster Risk Assessment (RO-RISK)", published by the General Inspectorate for Emergency Situations (IGSU, 2016). Thus, according to the specialists, the most exposed cities would be those located on the northeast direction: Focsani, Galati, Bacau, Vaslui and Iasi, as well as those located on the southwest direction: Buzau, Ramnicu Sarat, Ploiesti, Bucharest, Targoviste, Pitesti, even Giurgiu and Alexandria.

4. Conclusions

Since 2003 until 2020 was observed the increase of the large amount of ferroalloy waste slag dumped in landfill with negative effects on the environment. Every year, landslides cause deaths and cause severe damage to infrastructure. Therefore, an engineering challenge from an environmentally sustainable and cost-effective manner is the rehabilitating landslides areas.

In this research study, we proposed in situ cementitious rehabilitation using waste slag dumped in landfill from two points of view, namely is considered a cheaper and potentially environmentally sustainable solution because it recycles existing waste materials. Therefore, the ferroalloy slag waste can be used as prime materials for rehabilitation of landslides areas should be cleverly engineered as a potential environmentally and structurally sustainable solution.

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References

[1] I. Mavroudis, F. Petrides, E. Karantali, S. Chatzikonstantinou, J. McKenna, A. Ciobica, A.-C. Iordache, R. Dobrin, C. Trus and D. Kazis, ”A voxel-wise meta-analysis on the cerebellum in essential tremor”, *Medicina Lithuania,* vol. 57 (3), pp. 264, 2021.
https://doi.org/10.3390/medicina57030264

[2] C. Statescu, C. Honceriu, R.N. Jurcau, and C. Trus, ”An Original Study on the Correlations Between Magnesium and Depression and their Cardiovascular Relevance”, *Rev. Chim.*, vol. 70(11), pp. 4102-4104, 2019.
https://doi.org/10.37358/RC.19.11.7711

[3] C. Statescu, C. Honceriu and C. Trus, ”Does Magnesium Deficient Diet and its Associated Metabolic Dysfunctions Induces Anxiety-like Symptoms Further cardiovascular relevance”, *Rev. Chim.*, vol. 70(10), pp. 3579-3581, 2019.
https://doi.org/10.37358/RC.19.10.7600

[4] H. Qasrawi, ”The use of steel slag aggregate to enhance the mechanical properties of recycled aggregate concrete and retain the environment”, *Construct Build Mater,* vol. 54, pp. 298–304, 2014.
https://doi.org/10.1016/j.conbuildmat.2013.12.063

[5] J. Ayala, and B. Fernandez, ”Recovery of manganese from silicomanganese slag by means of a hydrometallurgical process”, *Hydrometallurgy,* vol. 158, pp. 68-73, 2015.
https://doi.org/10.1016/j.hydromet.2015.10.007

[6] B.B. Lind, A.M. Fallman and L.B. Larsson, ”Environmental impact of ferrochrome slag in road construction”, *Waste Management*, vol. 21(3), pp. 255–264, 2001.
https://doi.org/10.1016/S0956-053X(00)00098-2

[7] A. Rai, J. Prabakar, C.B. Raju and R.K. Morchalle, ”Metallurgical slag as a component in blended cement”, *Construction and Building Materials* vol. 16, pp. 489–494, 2002.
https://doi.org/10.1016/S0950-0618(02)00046-6

[8] D.L. Buruiana, C.-D. Obreja, E.-E. Herbei and V. Ghisman, ”Re-Use of Silico-Manganese Slag”, *Sustainability*, vol. 13, pp. 11771, 2021.
https://doi.org/10.3390/su132111771

[9] https://forestdesign.ro/index.php/ro/blog/53-alunecarile-de-teren, Accessed at 10.06.2022.

[10] Y. Huan, K. Siripun, P. Jitsangiam, and H. Nikraz, ”A Preliminary Study on Foamed Bitumen Stabilisation for Western Australian Pavements,” *Sci. Res. Essays*, vol. 5, pp. 3687–3700, 2010.

[11] P. Jitsanigam, W. K. Biswas and M. Compton, ”Sustainable Utilization of Lime Kiln Dust as Active Filler in Hot Mix Asphalt with Moisture Damage Resistance,” *Sustain. Mater. Technol.*, vol. 17, e00071, 2018.
https://doi.org/10.1016/j.susmat.2018.e00071

[12] T.Suwan, P. Jitsangiam, H. Thongchua, U. Rattanasak, T. Bualuang and P. Maichin, ”Properties and Microstructures of Crushed Rock Based-Alkaline Activated Material for Roadway Applications,” *Materials*, vol. 15, pp. 3181, 2022. https://doi.org/10.3390/ma15093181