WASTE GASIFICATION FOR POWER GENERATION: ASSESSMENT OF INDUSTRIAL AND NON-INDUSTRIAL ALKALINE RESIDUES AS SORBENTS FOR ACID GAS REMOVAL

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ABSTRACT: The search of sustainable and affordable materials for the cleaning of acid gas in biomass gasification is one of the many challenges for the development of commercial gasification-based waste-to-energy plants. This study presents the potential sorbents identified in the literature. An analysis of these alkaline residues is done inspired by the Draft Specifications for the Application of UNFC to Anthropogenic Resources (UNECE/2017/SED/78). The classification is based on three categories: technical performance, societal-economic impact and environmental impact. The most interesting residue for its use in the acid gas removal of waste gasification power generation is the red mud followed by seafood shells.
Keywords: sorbents; waste gasification; alkaline residue; circular economy

1 INTRODUCTION

The search of sustainable and affordable materials for the cleaning of acid gas in biomass gasification is one of the many challenges for the development of commercial gasification-based waste-to-energy plants. In the literature, a variety of residues has been analyzed.

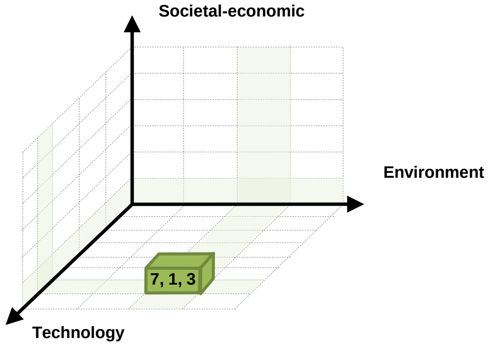
However, these studies have been usually limited to industrial residues.

Table I shows the identified alkaline residues in the literature.

2 CRITERIA FOR THE SELECTION OF THE SORBENTS

The classification is based on three categories: technical performance, societal-economic impact and environmental impact. The description of these specific criteria is shown in Figure 1.

1. The residue is not managed as indicated by the most exigent criteria for sustainability and circular economy
2. There is some interest in the economic valorization of the residue or for a reduction in disposal costs
3. There is some societal opposition to current management (production and/or disposal); or the costs incurred are considered excessive nowadays or expected to be in a near future
4. There is a strong societal opposition to current management and some alternatives are under consideration by regulation bodies
5. The considered alternative for the management of the residue is among the considered alternatives by the producer and/or regulation bodies
6. The residue is already managed by the considered alternative



1. There is an environmental impact from the production of disposal of the residue
2. The considered alternative management reduces the environmental impact of the residue
3. The considered alternative compares favorably with limestone
4. The considered alternative has the best environmental impact compared to other residues and limestone

1. The residue has an alkaline behavior and it is produced in the surroundings
2. The production of the residue is enough for the considered alternative management now and in the near future
3. The quality of the residue is acceptable, there are no relevant associated risks and the residue is localized
4. The residue is well characterized in the literature
5. There are studies on the technical performance of the considered alternative for the residue
6. There is no pretreatment of the residue or it is conventional
7. There is an available technology for the considered alternative
8. The residue is commercially used in the considered alternative

Figure 1: Classification criteria, inspired by the UNECE/2017/SED/78. In the example, the green box represents a residue with a 7 for technology, 1 for societal-economic and 3 for environment.

3 IDENTIFIED SORBENTS

Most relevant residues (Table I) can be classified in two groups: those having a current use (e.g. clinker industry) and those constituting a residue (e.g. being landfilled). From Table I, the composition of the residues is very variable but in all cases, there is a potential to capture S and Cl species.

Table I: List of identified alkaline residues.

Residue	**Main components**	**World Production ($Gt·a^{-1}$)**	**References**	**Notes**
Red mud	Iron/titanium oxides, Na(Ca)-aluminosilicatos, Na_2CO_3, $CaCO_3$ and NaOH	120	[1-9]	Residue form the Bayer process for aluminum production.
Paval (wardal)	Alumina, SiO_2, MgO, CaO, Na_2O, Fe_2O_3, (Ba, Cu, Zn)	N/A	[10-11]	Residue from an alternative aluminum production process and from the recycling of aluminum cans.
Steelworks slags	CaO, MgO, Ca-silicatos, óxidos Ca–Fe(Al) y Mg–Fe(Mn)	170–250	[8, 11, 12]	Currently used in the clinker industry.
Fly ashes (coal combustion)	SiO_2, $MgFeO_4$, $CaAl_2Si_2O_8$, $CaSO_4$, Fe_2O_3, $Al_6Si_2O_{13}$, CaO	415–600	[8, 12, 13]	Currently used in the clinker industry.
Incineration ashes (WtE plants, APC residues)	$CaCO_3$, $CaSO_4$, CaClOH, $Ca(OH)_2$, CaO, $Ca_6Al_2(SO_4)_3(OH)_{12}·26H_2O$, SiO_2	1.2	[8, 14]	In direct competition with waste gasification.
Solvay process waste	$CaCO_3$, CaO, $CaSO_4·2H_2O$, $Mg(OH)_2$, Cl, metales	0.0155	[15-17]	Small production and limited to specific locations.
Chromite ore processing residue (COPR)	CaO, $Ca(OH)_2$, $Mg(OH)_2$, $CaCO_3$, $Ca_4Al_2(OH)_{12}CrO_4·6H_2O$, MgO	6 (China)	[18-20]	Only produced in China.
Egg shells	$CaCO_3$, materia orgánica (proteínas), $MgCO_3$, $Ca_3(PO_4)_2$	62	[21, 22]	Only considered the residue from the food industry.
Acetylene production residue	$Ca(OH)_2$, sulfuros, Cl, $(PO_4)^{3-}$, SiO2, Al	130 (China)	[23-25]	
Construction and demolition waste	SiO_2, $CaCO_3$, Na(Ca)-aluminosilicatos, $NaAlSi_3O_8$, $Ca(OH)_2$	497–2095	[8, 26]	Little to none capacity for S removal at the analyzed conditions.
Olives processing	NaOH, materia orgánica, $Ca(OH)_2$	(Spain)	[5]	Local residue with very small production.
Seashells	$CaCO_3$, MgO, SiO_2, Al_2O_3, S, óxidos de Fe	0,08 (Spain, for mussels)	[27]	Local residue.
Phosphogypsum residue	-	N/A	-	Local residue.

N/A: not available

4 RESULTS

The results of the analysis of the alkaline residues are presented in Table II and Figure 2.

Table II: Overview of most relevant alkaline residues analyzed in the study.

Residue	Technical performance	Societal-economic impact	Environmental impact
Red mud	+ +	+	+ +
Solvay process residue	+	+	+ +
Egg shells	- -	~	-
Acetylene production residue	+	+	+
Sea shells (mussels)	+ +	+	-

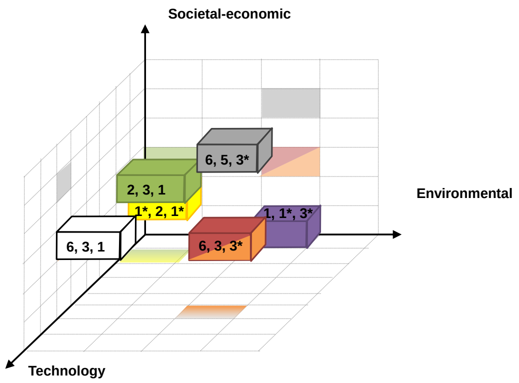


Figure 2: Classification of the selected alkaline residues (red: red mud, Green: paval, purple: Solvay, orange: acetylene, gray: phosphogypsum, white: mussels). The star shows a potentially higher level regarding specific local conditions.

5 CONCLUSIONS

Red mud stands out as a sorbent in gasification-based power plants using wastes. A viable alternative is the residue from acetylene production process. Phosphogypsum residue and mussel shells are also suitable for S and Cl removal. However, their limited amount or local production deters its use at large scale.

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