WATER SCARCITY OF RECYCLING SHATTERED GLASS DUE TO THE MASSIVE BEIRUT EXPLOSION

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ABSTRACT

After the massive explosion of the Beirut port, the streets were blanketed with broken glass which rained down from the crumbling buildings. In a circular area of about 6.5 square kilometers, all windows and façades were blown out and streets were littered with glass rubble. Hundreds of tons of broken glass have been collected for recycling following the Lebanese traditional method to recycle the glass. This process accounts for the collection of glass, the transportation of the collected glass from Beirut to the manufacturing plant in the north of Lebanon, the manufacturing process, as well as the packaging phase. This work aims at assessing the water scarcity through the estimation of the use of water resources, following the Available WAter Remaining (AWARE) methodology from the WULCA working group [1, 2]. The water scarcity is computed in m^3 world equivalent for each used process, by multiplying the quantity of water consumed by the AWARE factor specific to the country where the process takes place[3]. In line with this, the direct water consumption (e.g. irrigation, cooling, etc.) and the indirect water consumption (e.g. transport, power generation, etc.) are considered. Indirect water consumption is determined using the Ecoinvent (V3.7) database. Accordingly, the water scarcity, as the sum of water scarcity for all the considered life cycle processes, is then evaluated. The results of this study show that the manufacturing life cycle stage has the highest contribution; 89.6% of the total contribution. Consequently, in order to mitigate the water scarcity of the Lebanese traditional scenario to recycle the broken glass, the amount of electricity consumed within the blowing sub-stage must be reduced since it has a contribution of 98.3% of the total contribution of the manufacturing life cycle stage.

KEYWORDS

Water Scarcity, Glass Recycling, WULCA, Sustainability, Life Cycle Assessment (LCA), Lebanon.

1. INTRODUCTION

The Beirut explosion on August 4, 2020, ravaged more than 40,000 buildings that were partly or severely damaged, or completely destroyed [4]. As a result, high quantities of debris were scattered within the affected circular area of a radius of about 6 kilometers. Although several difficulties were encountered in sorting plastic, glass, and other recyclable materials, volunteers, non-governmental groups, and entrepreneurs have attempted to salvage at least a part of the tonnes of glass littering the streets, some of which to be recycled into jars and jugs in a glass factory located 93 km north of Beirut. Although the environmental impacts of the reuse of glass in the construction field have been evaluated [5], the environmental and water impacts of the traditional Lebanese method of recycling glass in jars and pitchers following a Life Cycle Analysis (LCA) approach were never addressed to date.

Furthermore, water being one of the key environmental aspects to be considered in general and in the glass manufacturing/recycling sector in particular [6], this paper aims to assess the water scarcity of the traditional Lebanese scenario of recycling broken glass due to the massive explosion in the port of Beirut – Lebanon.

2. METHODOLOGY

At the time of writing this paper, approximately 77 tonnes of glass shattered due to Beirut's blast have been recycled in the northern glass factory where glass is melt in a furnace that burns at 900 – 1,200 degrees Celsius.

In this context, the recycling option should be carefully examined due to the complexity of the production process and its interconnection with many other additional operations, which requires an objective evaluation of the different stages of the process life cycle.

The functional unit for the current study is set at 3 tonnes of glass to assess the impacts of the recycling process from a water scarcity perspective and recommend beneficial modifications to the process. The system boundaries are represented in Figure 1.

The envisaged glass recycling process involves the following life cycle stages:

1- Transport of shattered glass.
2- Recycling.
3- Packaging.

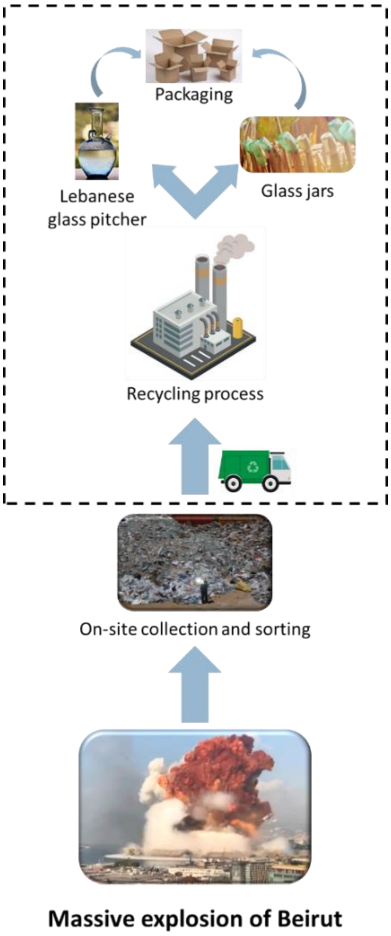

Figure 1. Recycling glass system boundaries

The processes of on-site collection and sorting of broken glass, which in this case are considered as raw material rather than waste [7], are not taken into account due to their randomness and inconsistency. It is worth mentioning that this phase is particularly sensitive because the improper collection and poor sorting of impurities such as small stones, ceramics, and magnetic metals will harm the quality of the final product and will corrode the furnace.

The process of transporting broken glass from the explosion site to the glass factory (93 km) is modeled as a one-way.

The recycling life cycle stage includes the manual removal of polluting bodies (e.g. plastic bags and bottles) in the glass factory (Figure 2). In the Lebanese context, a manual sieving process is also performed to intercept ferrous metals, remove light objects (e.g. paper and wood), eliminate nonferrous metals (e.g. aluminum, copper, lead), and eradicate non-melting scrap (e.g. ceramics, rocks, porcelain).

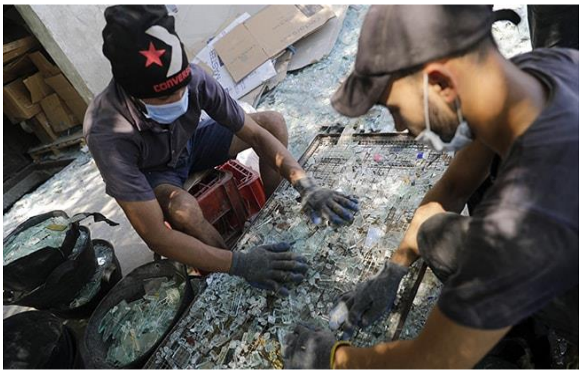

Figure 2. Manual sorting process (source: JOSEPH EID / AFP)

The third sub-stage of the recycling process is melting. In this phase, the crushed glass is heated in an oven at temperatures between 900 and 1200 °C, depending on the type of glass, the mixture is melted and becomes liquid glass. Through chemical reactions, silicate bonds are created, and gas is emitted [8,9]. Furnaces are in most cases heated using fossil fuels, rarely with electricity.

Furthermore, the traditional Lebanese scenario of glass recycling also includes blowing, cooling, and washing sub-stages. In the blowing and cooling phases, liquid glass is blown to be reshaped and then its temperature is lowered below the melting temperatures using electric fans. At this stage, the impurities are removed (Figure 3) and any remaining soluble bubbles are reabsorbed into the melt [9].

The following sub-stage is cooling where water is used for this purpose. A tank filled with tap water is used to cool the newly made glass [10]. After cooling, the edges of the glass are trimmed, and the glass is cut to the desired shape. Rims and broken glass are usually returned to the furnace to be re-melted (Figure 3).

Figure 3. A glassblower forms glass jugs at factory (source: JOSEPH EID / AFP)

Finally, the packaging life cycle stage encompasses transporting the corrugated cardboard to the recycling site along with their weighing.

3. RESULTS AND DISCUSSION

Tables 1 and 2 depict the quantity of water consumed by each process/life cycle stage, the AWARE factor, the country where the process takes place, and the water scarcity in m^3 world equivalent.

The total amount of water consumed to recycle 3 tonnes of glass is 5.15E+03 liters while its water scarcity is 4.34E+02 m^3 world eq.

The water scarcity of the blowing phase is 90.84% which is equivalent to 4.54E+00 m^3 world eq while the water scarcity of the packaging life cycle stage is 6.94% (4.72E-01 m^3 world eq). The remaining water scarcity is mainly due to the transportation process of the broken glass from the explosion site to the glass factory (1.28 %).

For the blowing phase, the amount and source (heavy fossil fuels) of electricity are at the origin of the high contribution of this phase. As for the packaging life cycle stage, the amount of used corrugated cardboard leads to the enormous water consumption of this stage (99% of the total water consumption of the stage).

Table 1. AWARE factors, amount of water consumed, and water scarcity impacts for the different life cycle stages and sub-stages.

Life Cycle Stage	***Sub-stage***	***Ecoinvent Process***	***Quantity per FU***		***Aware factor (m^3 world eq /m^3)***		***Water consumed per FU***		***Water scarcity per FU (m^3 world eq)***
Transport of shattered glass		Transport, freight, lorry 16-32 metric ton, EURO4 {RoW}	2.91E+02	tkm	Lebanon	86.81	6.40E-02	m^3	5.55E+00
Recycling	*Melting*	Diesel {RoW}| market for	1.14E+03	kg	Lebanon	86.81	4.64E-02	m^3	4.03E+00
	Blowing	Electricity, medium voltage {RoW}	7.82E+02	Kwh	Lebanon	86.81	4.54E+00	m^3	3.94E+02
	Cooling	Tap water {RoW}	3.01E+01	kg	Lebanon	86.81	3.01E-02	m^3	3.01E-02
Packaging		Corrugated board box {RoW	8.91E+01	kg	Lebanon	86.81	4.68E-01	m^3	3.01E+01
		Transport, freight, lorry 3.5-7.5 metric ton, EURO4 {GLO}	5.36E+00	tkm	Lebanon	86.81	4.24E-03	m^3	3.68E-01
		TOTAL					**5.15E+00**	**m^3**	**4.34E+02 *m^3 world eq***

Table 2. Amount of water consumed and water scarcity impacts for the different life cycle stages.

Life Cycle Stage	***Water consumed per functional unit***		***Water scarcity per functional unit***	
Transport of shattered glass	6.40E-02	1.24%	5.55E+00	1.28%
Recycling	4.62E+00	89.59%	3.98E+02	91.70%
Packaging	4.72E-01	9.16%	3.05E+01	7.02%
TOTAL	**5.15E+00**		**4.34E+02**	

4. CONCLUSIONS

In this study, the water scarcity analysis of recycling 3 tonnes of broken glass following the traditional Lebanese recycling scenario is conducted. This analysis is accomplished through the estimation of the use of water resources, following the Available WAter Remaining (AWARE) methodology from the WULCA working group. In particular, this study is performed to determine which life cycle stage shows the highest contribution.

The findings of this study show that the blowing sub-stage has the highest level of water consumption, i.e. 88.2% of the total water consumption (4.54E+00 out of 5.15E+00 m^3). As this sub-stage strongly depends on the consumption of electricity which in turn relies on heavy fossil fuels, therefore by increasing the share of renewable energies or sustainable alternatives, the water scarcity of the entire recycling process will be reduced.

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