INDUSTRY BRIEF

Unlocking value from waste foundry sand

Turning problematic waste streams into economic opportunities

Main insights

For foundries

- Foundries can benefit from the diversion of waste foundry sand (WFS) from landfill through cost savings whilst simultaneously reducing environmental impact.
- Opportunities exist for the recycling of WFS at the foundry site and through synergies with off-takers able to utilise WFS as a secondary material input.
- To realise these opportunities foundries (and WFS off-takers) need to ensure that the relevant legal processes are adhered to and may also need to invest into reclamation and separation equipment.

For waste management companies

- Waste management companies can support customers with achieving their sustainability and landfill diversion targets by facilitating the secondary use of WFS into beneficial and safe applications.
- By offering best practice services, waste management companies can retain their position in the market or even gain a competitive edge.

For potential off-takers: users of silica and other sands

- Potential off-takers can benefit from cost savings on raw materials through the use of a secondary material as an alternative to costly virgin material.
- It is important to develop an understanding of relevant legislation, technical applications and any potential risks of handling or using the material.

Target audience

This industry brief is written for:

a Foundries in South Africa with WFS looking for potential opportunities to reduce costs and/or seeking alternatives to landfill. Waste management companies with contracts to remove WFS from foundries and an impetus to divert waste from landfill.

b Manufacturing, construction or other companies that use silica or other sands as a raw material input and could potentially incorporate WFS as a secondary raw material.

Background

Various South African foundries use sand moulds as casts for metal formation. Two main categories of sand are used: green moulding sand (GMS), which is bonded with clay, and chemically bonded sand (CBS), which is bonded with resin. The size of post-use crushed WFS varies between foundries due to the type of separation technology, plant processes and region, but, the average size of crushed WFS typically ranges from 0.05 to 2mm. Although there are key differences in the chemical composition between GMS and CBS, for the purposes of this industry brief WFS is discussed as a single waste stream. However, a case-by-case assessment would be required to determine suitability as a secondary material for any particular application.

Owing to the large volumes and hazardous nature of WFS, it is considered a problematic waste stream. At the same time, many companies that use silica or other sands are unaware of the potential for reduced raw material costs that can be enabled through industrial symbiosis, which is the sharing of resources between companies for mutual benefit. At a regional level, the uptake of WFS in other industries has the potential to play a large role in driving circularity[1].

This brief highlights the opportunity in using WFS in manufacturing and other processes for the benefit of foundries and companies that use silica or other sands. At a regional level, it addresses the challenge of diminishing landfill capacity and supports a shift to a resource efficient and circular economy. Although the focus of this brief is on the Western Cape, and the City of Cape Town specifically, the learnings could be applied nationally.

[1] *A circular economy minimises waste, regenerates ecosystems and keeps products, components and materials at their highest use and/or value for as long as possible.*

The Challenge

WFS is a substantial and hazardous waste stream. It is still largely destined for landfill and expensive to dispose of. Opportunities exist for landfill diversion, and cost savings / additional revenue. However, the various stakeholders at each stage of the value chain are not necessarily aware of these opportunities. This is partly due to the perception of WFS as waste rather than a (secondary) raw material asset.

Concurrently, various sectors require the use of natural sand, a resource that can become increasingly scarce. Should its extraction continue at the current rate, it is likely that the resource in Cape Town will be exhausted by 2035.[2] A secondary use of WFS could reduce the rate of unsustainable sand extraction.

Achieving the diversion of WFS from landfill would reduce disposal costs for a foundry and enable access to cheaper raw material inputs for the recipient company. This would facilitate improved business competitiveness and efficiency of natural resource use.

Some of the complexities surrounding the diversion of WFS are outlined below:

Quantity

The Western Cape is home to six foundries. The largest of these uses GMS and the remaining five use CBS. It is estimated that these foundries collectively produce 75 000 - 80 000 tonnes of WFS per year.

On average, foundries produce one to two tonnes of WFS for every tonne of metal moulded. However, this fluctuates internally and varies between foundries.

Current practice

With a hazard rating of type 2, 3 or 4[3], WFS disposal is costly. This requires the services of a registered waste management company. Such waste management services ensure that no dust is blown off or material spilled during transport, through the use of a covered vehicle. Sanitary landfills ensure that the material is isolated from the surrounding environment.

Some foundries use a reclamation plant to recycle spent foundry sand, reducing the demand for fresh sand and the disposal of WFS.

In some instances, there are portions of the WFS stream being diverted from landfill (either directly or post-reclamation) for use as a form of aggregate in the built environment.

[2] *Cole, DI and Viljoen, JHA; 2001; Building sand potential of the greater Cape Town area; Council for Geoscience, Number 129.*

[3] *According to GNR 635, Norms and Standards for the Assessment of Waste for landfill (2013), types 2-4 hazard rating are determined by the total and leachable concentrations of a variety of chemicals. According to GNR 636, Norms and Standards for the Disposal of Waste to Landfill (2013) these require disposal to Class B, C or D landfill, respectively.*

Legal requirements

Common WFS contaminants such as barium, nickel, manganese, mercury, chrome (III, VI), benzene and others, can occur at concentrations above the thresholds of the Globally Harmonised System (GHS) of classification and labelling of chemicals. WFS therefore presents environmental and health risks if not safely managed or disposed of.

The composition of contaminants and subsequent hazard rating of WFS varies between foundries. WFS must therefore be classified in terms of the *Waste Classification and Management Regulations* (GNR 634 of 2013[4]). Disposal of WFS to landfill must be carried out based on that classification, and in accordance with the disposal requirements for Type 2,3 or 4 waste set out in the *Norms and Standards for Assessment of Waste for Landfill Disposal* (GNR 635 of 2013[5]) read with the *Norms and Standards for Disposal of Waste to Landfill* (GNR 636 of 2013[6]). Disposal of WFS also requires an authorised waste transporter, and must be undertaken at a licensed waste disposal facility.

Landfill alternative solutions may require a waste management licence (WML) (or other environmental authorisations) which could be a barrier to the use of WFS as a secondary raw material, particularly if the effort and costs of obtaining such an authorisation is prohibitive.

The following measures are relevant to diverting WFS from landfill.

01 **Reclassification of WFS** to a lower hazard rating or as general waste (in terms of GNR 634): (i) if the inputs or waste production process is changed so that the waste characterisation changes, or (ii) if the waste material is processed to remove/reduce the contaminants which trigger the GHS thresholds. A waste licence would still be required to use the WFS in a secondary application (as explained below), however the mitigation requirements of the waste licence may be less stringent and the technical barriers to beneficiation of the WFS may be removed.

02 **Treatment of WFS for use in secondary processing**. Depending on whether the thresholds of the relevant listed activity are triggered (GNR 921 of 2015[7]), a WML is likely required for:

- **a.** a foundry to process WFS which it produces to remove hazardous contaminants (in order to change it from a waste into a raw material); and
- **b.** an off-taker to use unprocessed WFS in its production process.

03 **Exclusion of WFS from the definition of "waste"** for certain applications in terms of the *Regulations regarding the exclusion of a waste stream or a portion of a waste stream from the definition of waste* (GNR715 of 2018[8]). The criteria for exclusion are summarised as follows:

- **a.** there is a demonstrated beneficial use of the material;
- **b.** a risk assessment is undertaken, to identify potential risks of the proposed activity; and
- **c.** a risk management plan is developed, responding to identified risks and provided with any delivery of the excluded waste to the user.

The South African Institute of Foundrymen (SAIF) in partnership with the National Foundry Technology Network (NFTN) and the Council for Scientific and Industrial Research (CSIR) previously submitted an application for the exclusion of all WFS in South Africa. However, this application was declined due to the high variability between WFS from different foundries (given the range in risk profile and application opportunities of WFS from different foundries). The Department of Forestry, Fisheries and the Environment (DFFE) indicated that foundries should apply for exclusion separately, or in collaboration with other foundries that use the same process of sand mould construction.

Since that time, the CSIR in Stellenbosch with support from the NFTN and SAIF has begun a new project to apply for the exclusion of WFS from certain foundries that use GMS. This may lead to the availability of WFS for certain applications in the near future.

[4] *GNR 634 of 2013 - Gazette 36784 of 2013 - Waste Classification and Management Regulations*

[5] *GNR 635 of 2013 - Gazette 36784 of 2013 - Norms and Standards for the Assessment of Waste for landfill*

[6] *GNR 636 or 2013 - Gazette 36784 of 2013 - Norms and Standards for the Disposal of Waste to Landfill*

[7] *GNR 921 of 2013 - Gazette 37083 of 2013 - List of Waste Management Activities That Have or are Likely to Have a Detrimental Effect on the Environment*

[8] *GNR 715 of 2018 - Gazette 41777 of 2018 – Regulations Regarding the Exclusion of a Waste Stream or a Portion of a Waste Stream from the Definition of Waste*

Costs

There are a number factors which contribute to the high cost of disposal of WFS. These include:

- An registered waste management service is required to ensure safe disposal of the material at a designated landfill site.
- Landfill gate fees for hazardous waste are also typically high.
- Transport costs are also a consideration, and thus the location of the foundry in relation to an appropriate landfill site could have cost implications.
- Logistics costs may vary due to global and local dynamics and any associated fuel price fluctuations.

Companies that use silica sand in their products can typically pay above R140 per tonne of sand, in Cape Town. If substituted with WFS, this can result in a cost saving for the user, in addition to the savings for the WFS generator.

Variability and implications of chemical composition

As indicated, WFS (both GMS and CBS) is typically classified as a level 2 - 4 hazardous waste material, requiring safe disposal. The exact chemical composition typically varies between foundries meaning that foundries would each individually need to have their material tested and classified for the exact hazard rating. Similar action must be taken for declassification, for obtaining a WML or with respect to exclusion of the material from the definition of waste.

Due to the variability in foundry sand and since it is incumbent on the regulator to ensure that hazardous chemicals, minerals or metals do not leach into the environment, certain foundries may find it more difficult to divert their WFS for beneficial use. However, the potential business benefits, as well as the potential for enabling wider regional sustainability benefits, suggests that there is value for foundries and users of silica and other sands in exploring the potential for diversion of WFS from landfill and its beneficial use.

The Opportunity

WFS holds potential as a secondary material in a variety of beneficiation options, some of which are under ongoing research while others are in various stages of trialling or implementation. The use of WFS in the construction and built environment sector, particularly as an aggregate, holds great potential.

The beneficiation opportunities can typically be realised through collaboration between the generator and potential user, and can provide business benefits to both.

Examples of uses and under development solutions are provided on the subsequent pages, while beneficiation options are depicted in **Figure 1** below.

KEY

Waste material | Sub-category | Process | Endpoint

- All known flows are cited
- tpa - tonnes per annum
- wt% - weight percent concentrate (by mass)

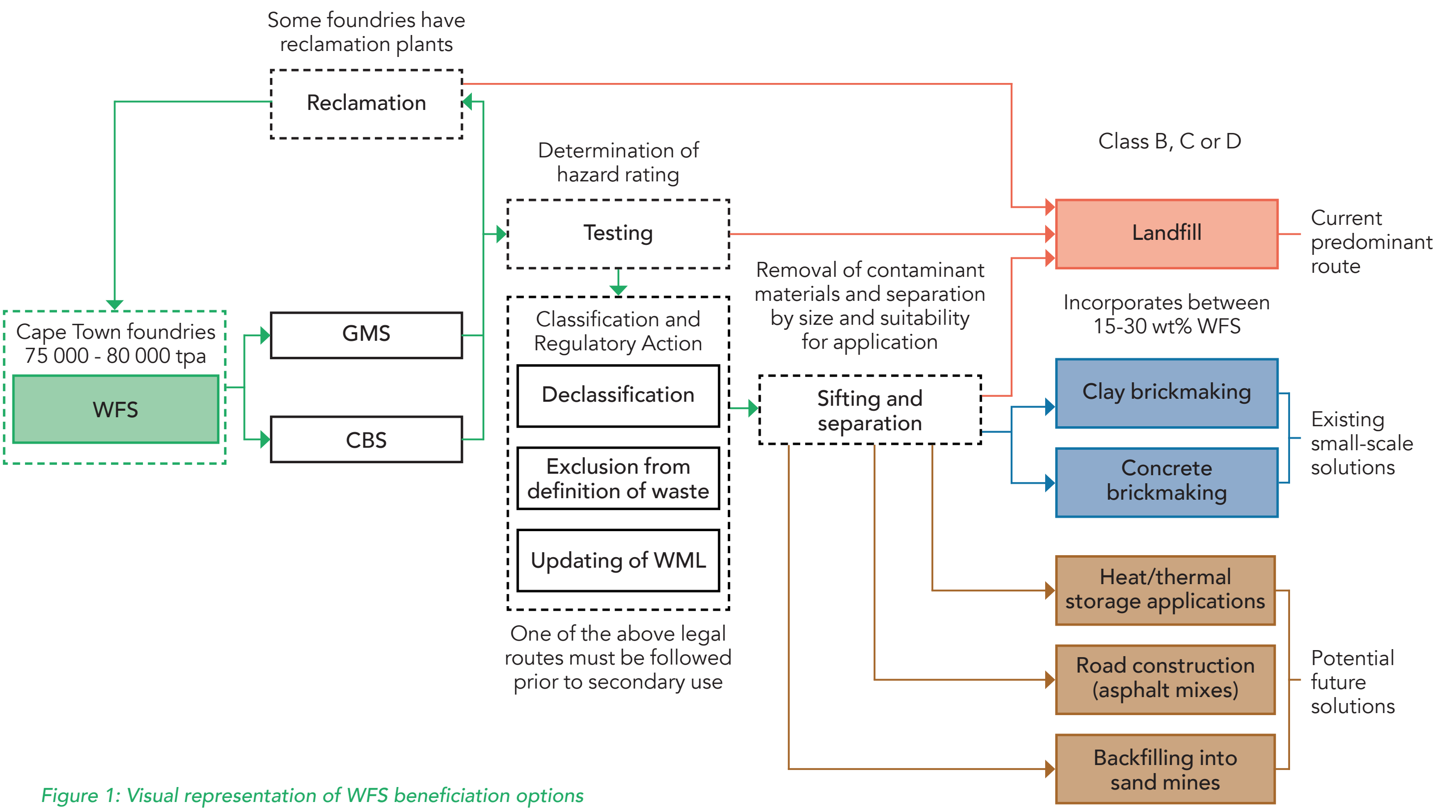

Figure 1: Visual representation of WFS beneficiation options

Clay brickmaking

One proven opportunity is to use WFS as an aggregate or filler in clay brickmaking. There are working examples, both globally and locally, of clay bricks using WFS as an aggregate.

Although quartz sand (silicon oxide) is often found in clay deposits forming a natural portion of the clay mixture, and is a critical element thereof, the concentration varies. In some cases, more sand needs to be incorporated.

Clay bricks typically contain sand in concentrations ranging from 15% to 30% which naturally occurs in clay deposits. If the sand content is too low and clay content too high, the bricks may not have enough structure to retain their shape when being extruded or fired. Too little sand may result in high plasticity during firing, which leads to shrinkage. The inclusion of sand works to counteract this contraction.

Sand in the clay mixture does reduce the brick strength, particularly quartz causes softening through a double expansion known as the quartz inversion. However, its addition can be useful as clay bricks with very high clay material blends are overdesigned i.e. have strength properties in excess of requirements. Fine aggregate material (plaster brick - <2mm, face brick - <1mm) can be added to clay brick mixtures as a bulking agent without negating the strength.

GMS uses clay, often bentonite, as a bonding agent. Clay has a strengthening effect when added to clay bricks. However, clay may include small quantities of calcite which, if nodular, may contribute to the risk of "lime popping", i.e. cracking and peeling. During heating, calcite turns into calcium oxide. Upon cooling, the calcium oxide absorbs water to form calcium hydroxide which expands and could crack the brick. The risk continues throughout the lifespan of the brick with potential exposure to moisture. Sifting or crushing to remove or reduce the size of any calcite inclusions could mitigate this risk.

The use of WFS as a filler component could present a strong business case for reducing the raw material costs for clay brick-makers. It could also offer cost saving opportunities to foundries through the diversion of waste from landfill.

Concrete brickmaking

The applicability of WFS as an aggregate in the concrete brickmaking industry has been investigated through research, specifically in South Africa (for example, the University of Johannesburg (UJ), Metal Casting Technology Station, EffSAFound2 project, 2016). A further finding from UJ[9] is that concrete bricks supplemented with 30% WFS exhibited improved strength and durability properties. Despite the benefit, the opportunity remains under-explored on an industrial scale in South Africa.

Concrete bricks require an aggregate material which typically contains a mix of fine and coarse sand.

The fine sand portion which can constitute up to 30% of the mixture consists of aggregate with particles <1mm in size. Non-uniform particles are preferred as this contributes to a coarser aggregate enabling increased surface area and improved bonding. Clay negatively affects the strength of concrete bricks. Concrete bricks that incorporate WFS with a low clay (bentonite) content perform better than those with a high (> 2%) clay content. If GMS is to be incorporated into concrete bricks, steps should be taken to remove the clay content, otherwise it would be better to consider CBS for inclusion in concrete bricks.

The dark colour of WFS is seen as a benefit to concrete bricks as the darker colour is often desired by builders and consumers. To ensure consistent product, WFS would need to be screened for contaminants such as metal particles which may oxidise and reduce brick strength.

[9] *Iloh, P.I.; 2018; The Effect of Waste Foundry Sand (WFS) on Concrete Properties; University of Johannesburg*

Other potential options

There are a handful of additional innovative solutions for secondary use of WFS which are either under research or being trialled at small-scale. One particular application is the use of WFS for thermal storage. A start-up is investigating various aggregate materials with respect to heat storage. Smaller particle sizes fare better in terms of thermal storage and insulation and are therefore favourable for this application. As such, fine sand, similar to that of WFS, is a potential option. At this stage, further research and analysis of the material is required to assess its suitability for thermal storage and to identify any health and safety concerns that would need to be managed.

Similarly, WFS holds potential as an aggregate in asphalt mixes in applications where waste glass fines are currently being explored. The resulting asphalt is recommended for lightly trafficked roads and pavements. Owing to the fine particle size and close resemblance to silica or glass fines, WFS holds potential as a supplementary aggregate. A potential yet untested application is thus the inclusion of WFS into asphalt mixes. If successful, this synergy[10] between foundries and road builders would benefit the road construction industry through decreased raw material costs for the asphalt processors.

WFS may also be considered as fill material where it could be used as backfill at the originating sand mine. Importantly, the use of WFS as a filler in this way, requires legal guidance and authorisation, due to risks associated with the potential, for example, of surface and groundwater contamination.

A key element to unlocking all of the above opportunities may be the use of a reclamation plant, as is done by some foundries to enable recycling of spent foundry sand on-site.

Making the business case

Despite the range of potential opportunities for WFS as a secondary material and the benefits that it holds, various factors will ultimately determine whether there is a business case for implementation.

Technical factors

Technical challenges are a primary consideration for prospective off-takers. In cases where WFS may affect product quality and performance, there is a limit to the amount that can be added.

For clay bricks in particular, the inclusion of waste foundry sand is only viable with a raw material cost saving, where the saving must be balanced with the desired quality standard. In the case of concrete bricks, the inclusion of WFS requires processing or separation to ensure the correct particle size for the appropriate feedstock quality.

Owing to the difference in particle size needed by different off-takers, the potential exists for processing at the source of generation. The co-utilisation or sharing of existing separating equipment is a possibility to reduce costs for both the foundry and off-takers.

[10] *A synergy is a mutually beneficial exchange between two or more businesses.*

Legal factors

The hazardous nature of WFS requires legal authorisation to enable use as a secondary material or for backfilling at sand mines. The current regulatory landscape requires off-takers to obtain individual WMLs in order to utilise WFS. Should a group of foundries (generating similar waste) undertake the process to exclude their WFS from the definition of waste, the need for individual WMLs could fall away and the uptake of the waste as a secondary material could be streamlined.

There are typically contaminants in the waste foundry sand that would need to be removed. Currently, this is the responsibility of the user (e.g. brick-maker), however there is potential for further processing at the foundry before being transported to the user. This is particularly important as the risk of contamination is a concern for potential off-takers who require a consistent, high quality product output. How legal responsibility and costs are allocated between the parties would influence the business case for both parties, but there is potential for models that would unlock the opportunity and would enable both or multiple partners to be beneficiaries.

Although WFS is hazardous, the incorporation into bricks as an inert material reduces the risk of environmental contamination. However, appropriate case-by-case testing and risk assessments are required to ensure that the concentrations of hazardous components remain below the limits stipulated in the relevant regulations[11].

The process to uptake WFS by off-takers can be stalled by the lack of appropriate legal authorisation. It is therefore important that relevant legislation (from generation to use, including any transport) is consulted and properly followed to enable the effective establishment of a synergy between an off-taker and a foundry.

Logistical factors

Logistical considerations are relevant, particularly when there is volatility in the fuel price. Proximity of the respective off-taker to the foundry can therefore be a key factor for the business case that enables a successful synergy.

The separation of WFS into respective sized particles for specific applications is an important logistical consideration. This requires the acquisition of specialised separation equipment and the transport of appropriately sized particles to the correct off-takers. This may present a challenge for the business case with respect to ownership of equipment and associated costs.

Considering the recycling of foundry sand, many foundries, particularly smaller foundries, do not have the ability to reclaim used sand. This is particularly owing to the cost of installing specialised reclamation equipment. The return on investment for their own sand reclamation plants does not outweigh the benefit as the volumes are too low. The prospect of the uptake of their WFS as a secondary material in other sectors is therefore attractive to smaller foundries.

Outlook

The secondary use of WFS is an emerging solution that can help address the rising costs of landfill disposal and raw materials. This presents opportunities for local foundries, waste management companies and potential off-takers to improve cost competitiveness. There are growing examples where the use of WFS has mutually benefitted these stakeholders.

The insights shared in this industry brief seek to accelerate the uptake of landfill diverting solutions for WFS in South Africa. There is work underway by the South African Institute of Foundrymen (SAIF) which may improve the availability of these solutions by addressing the legal requirements for diversion. Relevant companies are encouraged to further investigate the opportunity for their businesses.

For further information and support, please contact GreenCape's WISP team at WISP@greencape.co.za

[11] *Testing is regulated in GNR.634 and risk assessments are stipulated GNR.715*

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