Constructed scales: full range

These are the full constructed scales used to evaluate the different processing alternatives for the reuse of sulfide-enriched coal mine waste, as was used in the rating sheet that the experts used to evaluate the different processing options. The companion document contains a truncated version of the constructed scales, which was created to accommodate the reduced range of rating for some alternatives during the weighting exercise.

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| **Constructed scales** | **0** | **1** | **2** | **3** | **4** |  |
| **Technical Total** |  |   |  |   |  |  |
| Simplicity of chemistry & process control | The process will be difficult to control and be sensitive to fluctuations in the operating environment and feed compositions, but relatively low-level staff will be able to make adjustments under supervision/guidance from experts. | The process will be relatively difficult to control and be sensitive to fluctuations in the operating environment and feed compositions, but relatively low-level staff will be able to make adjustments with guidance of experts available from time to time. | The process will require adjustments to be made to account for differing operating conditions or inputs, but relatively low-level staff will be able to make the adjustments. | The process will require some adjustments to be made periodically, but not constantly, and low-level staff will be able to make the process adjustments. | Process control will be simple and the process will be relatively unaffected by changes in operating conditions or feed compositions. |  |
| System complexity | The process will be complex, incorporating many recycle streams and interacting unit operations, as well as employing technically advanced unit operations. | The process will be complex, incorporating many recycle streams and interacting unit operations or employing technically advanced unit operations. | The process will be moderately complex, incorporating some recycle streams and incorporating the use of moderately advanced technology. | The process will be moderately complex to simple, incorporating few recycle streams and employing simple technology. | The process will be simple, requiring no recycle streams and have low-tech unit operations. |  |
| Technical maturity | The technology has never been implemented and is still being developed in the lab. Little development work has been done on this. | This technology has received a lot of R&D attention in the lab and has been implemented on a mini-plant scale. | The technology has been proven on a pilot or demonstration scale. | The technology has once or twice been successfully implemented on a commercial scale. | The technology is well-known and has been successfully implemented internationally for a number of years/commercially proven. |  |
| **Social total** |  |   |  |   |  |  |
| Direct job creation | 5-10 | 11-20 | 21-45 | 46-60 | 61 or more |  |
| Operating environment health & safety | Workers will periodically be at risk of exposure to some hazardous (toxic, corrosive) and some moderately harmful materials, high temperature and pressures, as well as dangerous machinery and situations. | Workers will be at risk of exposure to moderately harmful materials with possible serious long-term side-effects, moderate temperatures and pressures and/or heavy duty machinery. | Workers will periodically be at risk of exposure to moderately harmful materials with possible serious long-term side-effects, moderate temperatures and pressures and/or heavy duty machinery. | Workers will be at risk of exposure to some corrosive or slightly toxic chemicals, machinery, etc. | Workers will be exposed to non-hazardous materials, ambient temperature and pressure. |  |
| Community health & safety | The community living near to the production area will almost certainly experience negative health & life style effects, due to air, soil or water pollution, noise and dust creation. They may also be influenced by physical dangers, such as nearby tailings dumps. | The community living near to the production area will face risk of local contamination of land, water or air in case of accidental leakages or spills, in addition to dust and/or noise (Tailings dumps?). | The community living near to the production area will face some negative consequences from living near to the plant, such as noise and dust, but not chemical pollution-related issues. | The community living near to the production area will be at low risk, but may experience some physical disturbances. | The community living near to the production area will in no way be adversely affected by the nearby production processes. |  |
| Skills development potential | Majority of the jobs created will require unskilled labour (Gr. 9 or less). | Majority of the jobs created will require semi-skilled labour, with some unskilled. | The jobs created will require a mix of semi-skilled (majority), unskilled and highly skilled labour. | Majority of the jobs created will require highly skilled labour (eg. graduate diploma holders), with some semi-skilled labour. | Vast majority of the jobs created will require highly skilled labour (eg. graduate diploma holders). |  |
| Entrepreneurial activity development | The products and production process does not lend themselves to being exploited by small/medium businesses or local entrepreneurs i.t.o. support-industries or further beneficiation of products, but only to large, established companies. | Some aspects of the products or process lend themselves to exploitation by small- or medium size business i.t.o. support industries and down-stream beneficiation or use, but only with the provision of significant support. | Some aspects of the products or process lend themselves to exploitation by small- or medium size business i.t.o. support industries and down-stream beneficiation or use. | The products and process lend themselves to exploitation by micro to small enterprises i.t.o. support industries, actual production and further downward beneficiation or use of the product. The enterprises will require support. | The products and process lend themselves to exploitation by micro to small enterprises i.t.o. support industries, actual production and further downward beneficiation or use of the product. | Explanatory panel 2 |
| **Economic/financial total** |  |   |  |   |  |  |
| Expected profitability | IRR <-10% | IRR -10%-0% (comparable to not implementing any process and discarding the waste in tailings impoundments) | IRR 0%-15% | IRR 15%-25% | IRR >25% | Explanatory panel 3 |
| Is the product currently sold on the South African market? | No known local market: Potential customers will have to be introduced to the product and convinced of its efficacy. | Limited & sporadic local market: The product is sold on the market, but only a few companies buy it from time to time. | Limited but consistent local market: The product is sold on the market, but only a few companies regularly buy it. | Moderate local market: The product is sold to a moderate number of customers and a few uses for the product exists. | Extensive local market: The product is sold to multiple different customers and multiple uses for the product exist. It is bought and sold freely. |  |
| SA deficit | South African producers currently export the product or struggle to cover expenses due to oversupply in the country. | Imports or exports - supply and demand are relatively evenly matched. | Small volumes are imported (eg. 1000t-10,000t). South African producers are mosty able to supply the demand. | Medium volumes of the product is imported (eg. 10,000t-100,000t of imports). | Most of the product is imported due to severely limited supply in the country (eg. 10,000t- 2,000,000t of imports). |  |
| Scale of use | The product is typically bought in measures of kg. | The product is typically bought in measures of 10's of kg. | The product is typically bought in measures of 100's of kg. | The product is typically bought in measures of t. | The product is typically bought in measures of 10's of t or more. |  |
| **Environmental total** |  |   |  |   |  |  |
| Waste generation | The process will produce medium to large volumes hazardous waste. | The process will produce small volumes of hazardous waste and/or large volumes of moderately hazardous waste. | The process will produce small volumes of moderately hazardous waste and large to moderate volumes of benign waste. | The process will produce small volumes of moderately hazardous wasteor moderate volumes of benign waste. | The process will only produce small volumes of benign waste or no waste at all. | Explanatory panel 4, 5 |
| Mineral recovery | Less than 10% of the inherent mineral value is recovered. | 10%-40% | 40%-60% | 60%-90% | 90%-100% | Explanatory panel 6 |
| Energy consumption | more than 100kWh/t processed | 60-100kWh/t processed | 30-60kWh/t processed | 0-30kWh/t processed | 0kWh/t processed - net energy production | Explanatory panel 7 |
| Water consumption | more than 4ℓ water/kg processed | 2-4ℓ water/kg processed | 1-2ℓ water/kg processed | 0.5-1ℓ water/kg processed | 0-0.5ℓ water/kg processed | Explanatory panel 8 |

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| **EP 1: Estimation of total available sulphide-rich coal tailings** |  |  |  |  |  |  |  |
| Stream size:  | 1 820 000,00 | t/annum total |  | 236,9792 | t/hour of sulphide-rich coal tailings fraction |  |
| Total coal ultra-fines production | 14 | Mt per annum |  |  |  |  |  |  |
| Fraction of ultra-fines reporting to sulphide-rich fraction | 0,13 | (from Kazadi Mbamba et al. 2012 & Amaral Filho et al. 2012 slurry 2) |  |  |  |  |
| Number of plants processing ultra-fines | 1 |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Pyrite | 54600 | tonne/annum |  |  |  |  |  |  |
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| **EP 2: Indication of company category based on turnover, balance sheet and employment indicators** |  |  |  |  |  |  |
| **Company category** | **Employees** | **Turnover** | **Balance sheet total** |  |  |  |  |
| Medium-sized | < 250 | ≤ € 50 m | ≤ € 43 m |  |  |  |
| Small | < 50 | ≤ € 10 m | ≤ € 10 m |  |  |  |
| Micro | < 10 | ≤ € 2 m | ≤ € 2 m |  |  |  |
| http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/ |  |  |  |  |  |  |
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| **EP 3: Typical South African IRRs** |  |  |  |  |  |  |  |  |
| Bank loan | 5 |  |  |  |  |  |  |  |
| Government bond | 8 |  |  |  |  |  |  |  |
| Property | 10 |  |  |  |  |  |  |  |
| Shares | 13 |  |  |  |  |  |  |  |
| Projects | 20 |  |  |  |  |  |  |  |
| (Stander 2013) |  |  |  |  |  |  |  |  |
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| **EP 4: Classification of element toxicity** |  |  |  |  |  |  |  |  |
| **Group description** | **Estimated environmentally significant available concentration levels (mg/kg)** | **Elements** | **Classification** |  |  |  |  |  |
| I: Potential for environmental risk if present at very low (trace) available concentration levels | < 10  | Te < Hg < Ag < Cd , Re < Se < In < Pt < Tl < Sb < As < Au< Mo | Hazardous if present |  |  |  |  |
| II: Potential for environmental risk if present at low (minor) available concentration levels | 10-100  | Pb, Bi < Be << Ge < Ni, U < W | Hazardous if present |  |  |  |  |
| III: Potential for environmental risk if present at moderate available concentration levels | 100-1000 | Sn, I< Co< Ta< Mn, B, Cr < Cu < Hf < REE << Zn< Br < Ba < Ga < Zr < Nb < V | Moderately hazardous if present |  |  |  |
| IV: Potential for environmental risk only if present at relatively high available concentration levels | A: 1000-10 000 | A: F < Sc < Li < Cl < Rb < Fe, Al < Ti < Sr < S < P | Moderately hazardous if present |  |  |  |
|  | B: >10 000 | B: Si < Mg < Na < K < Ca | Benign |  |  |  |  |  |
| (Broadhurst, 2007: 69) |  |  |  |  |  |  |  |  |
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| **EP 5: Classification of waste volume** |  |  |  |  |  |  |  |  |
| 1-2Mt is considered to be large | 10,000t-1000,000t is considered to be med | 0t-10,000t is considered to be small |  |  |  |  |  |  |
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| **EP 6: Indicatory composition of ultra-fine coal waste** |  |  |  |  |  |  |  |
| **Mineral** | **Fomula** | **%mineral in each phase** |  |  |  |  |  |  |
| Quartz | SiO2 | 34,9 |  |  |  |  |  |  |
| Gypsum | CaSO4.2H2O | 3,5 |  |  |  |  |  |  |
| Epsomite | MgSO4.7H2O | <1.0 |  |  |  |  |  |  |
| Kaolinite | Al2Si2O5(OH)4 | 59,4 |  |  |  |  |  |  |
| Pyrite | FeS2 | 1,6 |  |  |  |  |  |  |
| Jarosite | KFe(3+)3(OH)6(SO4)2 | <1.0 |  |  |  |  |  |  |
| Coal | CxHxNxOxSx | n.a. |  |  |  |  |  |  |
| Total mineral phase |   | 99,4 |  |  |  |  |  |  |
| (Kotelo, 2011) |  |  |  |  |  |  |  |  |
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| **EP 7: theoretical electricity consumption of most energy-intensive option** |  |  |  |  |  |  |
| Ferrous sulphate heptahydrate (worst case) | 3 | UV light tubes |  |  |  |  |  |  |
|  | 15 | W/light tube |  |  |  |  |  |  |
|  | 120 | hours |  |  |  |  |  |  |
|  | 1 | kg processed |  |  |  |  |  |  |
| UV light energy usage: | 5 | kWh/kg processed |  |  |  |  |  |  |
| Additional plant energy usage |  | kWh/kg processed |  |  |  |  |  |  |
| Total energy usage | 5 | kWh/kg processed |  |  |  |  |  |  |
| (Viganico et al., 2011) |  |  |  |  |  |  |  |  |
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| **EP 8: theoretical water consumption of the various processes without consideration of purging, wash water or other water sinks** |  |  |  |  |
| Water for cement is 0.4-0.7 of dry cement mass http://onlinelibrary.wiley.com.ezproxy.uct.ac.za/doi/10.1002/14356007.a05\_489.pub2/pdf | 0,411764706 | kg water/kg wet cement |  | 0,7 | kg water/kg dry cement |  |  |
| Water for pure sulphuric acid is 0.015 of total product (azeotrope is at 98.5% purity) + purge stream + washing water | 0,015 | kg water/kg conc sulphuric acid |  | 0,009 | kg water/kg pyrite excluding water for de-dusting. |
| Ferrous sulphate is input water, since the rest is evaporated to form crystals (liter/kg input? Is that reasonable in practice?) | 7,867820614 | kg water/kg ferrous sulphate heptahydrite | 3 | kg water/kg sulphide-rich tailings |  |
| Ferric sulphate is input water, since the product is used in dissolved form. (liter/kg input - is that reasonable in practice?) | 0,834047109 | kg water/kg ferric sulphate solution |  | 1,2 | kg water/kg sulphide-rich tailings |  |
| Cr(IV) reduction is zero, since it is going to be added to effluent | 1 | kg water/kg cleaned water |  |  | produces water, doesn't use water. |  |
| Soil amelioration is zero, since it is going to be added to soil | 0 | kg water/kg soil ameliorant (unless purification processes becomes important) | 0 |  |  |  |  |
| Facilitating heap leaching is the purge water | 0 | kg water/kg product |  | 0 |  |  |  |  |
| Cross reference with Mudd (2008) |  |  |  |  |  |  |  |  |
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