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The Environmental Footprint of Abandoned Asbestos Mines in Zimbabwe, Opportunities for Repurposing and Recovery of Mg And Other Metals from Gaths Mines

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ABSTRACT

Asbestos mining in Zimbabwe left vast tracts of unrehabilitated land characterised by heaps of potentially carcinogenic tailings dumps. The research sought to trace the abandoned mines' environmental footprint, establish the tailings' tonnage, and explore the possibility of resuscitation against repurposing one of the prominent Gaths Mines for recovery of metals from the tailings. The mine a been under closure for two decades. the research findings indicated that over 2600km^2 of land has potentially been contaminated by asbestos tailings within the abandoned Gaths Mines. The research concluded that resuscitating Gaths mines for asbestos extraction was not feasible given the international scrutiny on asbestos as a hazardous substance. However, after confirming that the Gaths mines hosts over 140 million tonnes of asbestos with 40.3% Mg content and traces of platinum group metals and Al among other recoverable metals, the research concluded that repurposing the site was feasible. The overall estimate for the capex for a 50 000t/pa Mg Plant 25-year project was estimated at US$416,7 million against an estimated net cash flow of US$1 billion. The NPV for the project was estimated to exceed US$95,5 million at a discount rate of 10%. The project's Internal Rate of Return was estimated at 16.14%. Overall, the research concluded that the site can potentially be converted from a liability to a legacy that will transform the host communities toward the creation of a sustainable city in Mashava, Zimbabwe.

1. INTRODUCTION

Southern Africa's historical legacy as a mining hub left vast tracts of abandoned mining sites across the region. South Africa has over 6000 unrehabilitated mines across the country. In Zimbabwe, the spread of abandoned mines across the country is yet to be ascertained. This is the case across most SADC nations. However, there are vast tracts of unrehabilitated mines within the country and former asbestos mines are chief among them. Abandoned mines constitute a huge financial liability for the State. As the custodians of the mineral resources, the responsibility to rehabilitate such mines ultimately becomes the State's. The cost of rehabilitating abandoned mines in South Africa has been estimated to exceed R48 billion rands. The environmental and social threats posed by these sites are vast [1][2][3][4]. Abandoned open pit lakes are often characterized by toxic water conditions [5].

1.1 Gaths Asbestos Mines in Zimbabwe

The Gaths Asbestos Mines is near Masvingo, Zimbabwe. The site was first discovered in 1904. The Gaths Asbestos Mine was a surface and underground mining operation. Initial production took place in 1916. Gaths Mine as it is now collectively known as is a combination of three mines: King Mine, Temeraire, and Gaths. The mine once had a record 1500 employees at its peak. It was once an extension of the Shabani Mine under the operation of the Rhodesian and Management Asbestos Corporation. Gaths Mines was officially shut down in 2004 without any significant attempts to rehabilitate the land. The mine was once the backbone of the nation's attempts to industrialise and a major supplier of asbestos towards the world war [6][7][8].

1.2 Abandoned Asbestos Mines a legacy and a liability.

Mine rehabilitation in Zimbabwe remains a huge legacy challenge for the State. Several Underground and open pit

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mines across the country were left unrehabilitated and to this day there has not been many efforts to address this challenge. (The Standard., 2021) No mapping has been done to ascertain the number of unrehabilitated abandoned mines across the country and their socioecological imprint\. For instance, Shabani Mine, Mashava Mine, Kamativi Tin Mine, Mhangura Mine, and Gaths Mine have since been closed for a significant period awaiting rehabilitation and or resuscitation. The Environmental hazards posed by unrehabilitated legacy mines across the country need to be evaluated to develop sustainable solutions.

Abandoned mines' liabilities can be lowered by harnessing their potential end uses. This can be achieved through repurposing the pits and underground excavations for viable end-uses. The technical and financial feasibility of repurposing such sites is a function of the local hydro-geological characteristics [9][10][11][12].

1.3 Metal recovery from abandoned mines as a repurposed end-use.

Highly acidic and metal-laden pit lakes and abandoned mining sites that could otherwise be declared a liability can be converted into legacies through the extraction of the metals. The extraction of metals from water is not a new phenomenon. . Technologies continue to be developed to facilitate this form of mining from water bodies with recent developments targeting the extraction of lithium from ocean water. The most easily extractable metal from pit lakes is copper although research targeting economic ways to extract zinc from pit lakes is still underway. The Berkley Pit provides an interesting case on metal recovery from pit lakes [13][14][15].

The extraction of magnesium from asbestos tailings is of particular interest for this study whose focus is on the Gaths Asbestos mine. Attempts for Mg extraction from chrysotile asbestos have been advanced in Quebec, Canada whose orebody's geological occurrence is similar to that of the Gath's and Shababani Mines in Zimbabwe [16][17]. Given that magnesium market demand is expected to double by 2026, repurposing or co-purposing novel low-cost competitive, environmentally friendly magnesium production projects can be adopted in Mashava and Zvishavane for transforming the asbestos tailings into magnesium. The manufacturing of electric cars for which Mg is a critical metal will significantly reduce greenhouse emissions. Further, magnesium production from asbestos tailings using hydrometallurgy and pyrometallurgy processes effectively lowers emissions by 80% compared to conventional approaches that contribute 85% of the global magnesium supply.

2. METHODOLOGY

2.1 Earth observations, drone imagery and field surveys

Field research was conducted to collect primary data. The research leveraged satellite observations to document the environmental, geological, and social data of Gaths Mines. Satellite and drone image processing and observations were used to observe ground movement, geotechnical stability, water conditions, environmental damage, proximity to settlements, existing land use, and size among other parameters. The satellite imagery was then analysed to derive conclusive information pertaining to the state of the abandoned mines. The satellite observations were also used for identifying target points for field surveys to complement the generated data. Earth observations were also used to delimit the scope of the field survey.

2.2 Geological data

Reports from the Ministry of Mines were analysed to establish the in-situ asbestos deposit at Gaths Mines. The analysis comparatively analysed the data with reports from the United States Geological Survey (USGS). The tonnage of the Gaths Mines tailings dumps was also estimated from the reports from the Ministry of Mines together with the percentage composition of the metals in the tailings. To validate the data, USGS reports on similar deposits to the Gaths Chrysotile were studied. Historical production statistics for the mine were analysed to estimate the volume of tailings occupying the Gaths mines.

2.3 Feasibility of further asbestos extraction

Zimbabwe has continuously shown its interest to reopen the mines for the extraction of asbestos. The research sought to assess the viability of such prospects against the recovery of Mg from the tailings. The research used mineral supply and demand statistics to assess the viability of resuscitating the abandoned Gaths mine for asbestos production. Further, the researcher analysed geological data to develop an understanding of the geological quantity and quality of the mineral in situ. Historical global and domestic consumption of asbestos was compared with the current statistics. The research sought to fully establish whether the asbestos deposit can be declared redundant to facilitate repurposing without sterilizing any mineralization. The extent of asbestos substitutes was also studied.

2.4 Capital Expenditure for Mg Plant

The research analysed the Capex costs of known Mg plants to estimate the capital cost for the Gaths Mg Plant. Based on the global Capex cost of magnesium plant, the Gaths mines capex was set at $US8 334/t of Mg. The research analysed the Capex costs of Mg plants across the globe with the Africa to establish if there was a significant difference in Capex for a Mg Electrolytic Plant. After careful consideration of the Capex Cost of two Mg plant Mg Plants in Congo and Egypt. The research assumed insignificant Capex variations across Africa. The comparison was used to adjust the Capex in Zimbabwe.

2.5 Operating Expenditure for Mg recovery

Similarly, known Operating costs of known Mg plants were analyzed. The costs were adjusted using the rates of the project countries against that of Zimbabwe. The primary Opex cost driver for a Mg Plant is electricity and labour. Therefore, the Opex cost was adjusted using the cost of labour/electricity in Zimbabwe against the cost of the same in the country to which the known projects were from. Costs were adjusted by a factor calculated using the formula:

$$Adj.factor = \frac{E_z}{E_x} \, x \, 100 \tag{1}$$

$$Adj.factor = \frac{L_z}{L_x} \, x \, 100 \tag{2}$$

Where EZ is the cost of electricity in Zimbabwe per Kwh., EX Cost of Electricity in Country X per Kwh., LZ is the labour costs in Zimbabwe and LX is the labour costs in Country X. The labour costs in Zimbabwe were determined using the gazetted national employment council for the mining industry rates of pay from January 2023. To get to the hourly rate, an 8-hr. shift working 21 days a month was assumed. The hourly minimum wages for the other countries were adopted as they were and applied into the formula.

2.6 Operating Expenditure

To facilitate a cost-benefit analysis of the proposed magnesium processing plant, two similar projects by Mag One Technologies and Magnesium Alliance were analyzed. The research assumed a 50 000tpa Magnesium plant with a 25-year life. The first two years were reserved for trials and development work and full production was assumed to start in the 3rd year. Given that the mine has been under closure for over a decade, the research assumed that the value of existing infrastructure is insignificant in offsetting the Capex. The following formula was used to calculate NPV.

$$NPV = C_o + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \cdots \frac{C_t}{(1+r)^t} \qquad (3)$$

Where, C1 C2 …Ct are the initial cash inflows in year 1, 2 and t respectively. R is the rate of return and NPV is the Net Present Value.

2.7 Operating Expenditure

To assess the feasibility of the projects, the Internal Rate of Return was calculated using Equation 4 below. The IRR was computed for a 10-year, 15-year, 20-year, and 25-year project life. Ct is the net cash flow for the project life t.

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} \qquad (4)$$

2.8 Operating Expenditure

Sensitivity analysis of the Net Present Values of the projects and the respective IRR was done using excel spreadsheets. Sensitivity was tested against the rate of discount by varying it from 0.0% to 15% and the simulated results were plotted. Similarly, sensitivity of IRR and NPV was tested against project life and the price of magnesium in US$/t.

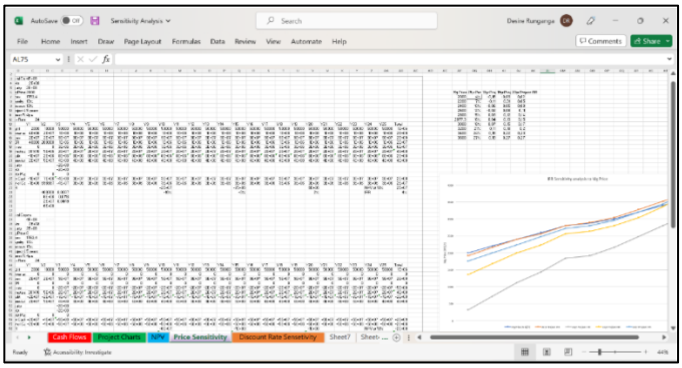

Fig. 1. IRR and NPV Sensitivity Analysis in Excel

3. Results and Analysis

3.1 Site geotechnical integrity and ground subsidence

Fig. 2. Observed ground subsidence at Gaths' abandoned mines.

The abandoned mine is also characterised by post abandonment ground subsidence as shown in figure 2. The site is characterised by an ongoing ground subsidence over a 2.3 km stretch and 353 000 m2. Ground subsidence poses a major risk to both the inhabitants and their livestock. Further, it increases the risk of induced movement in tailing facilities and waste dumps as seen in Figure 2.

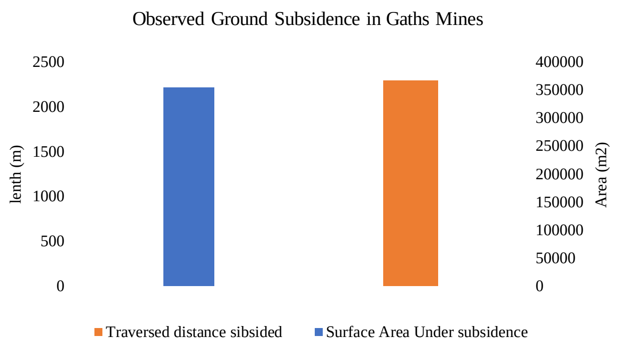

Fig. 3. Ground subsidence

3.2 Environmental footprint of asbestos tailings.

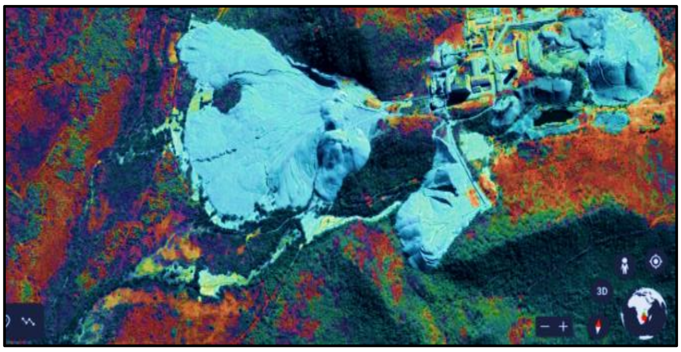

Fig. 4. Environmental footprint of asbestos tailing visible downstream within Mashava Catchments

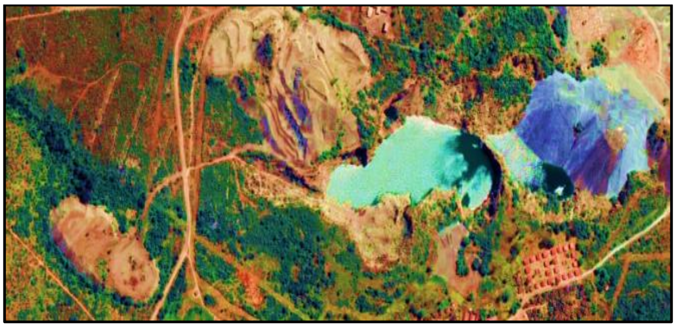

Fig. 5. Waste and tailings contamination of Pit Lakes in Gaths mines

Asbestos tailings often contain toxic substances which as seen in Figure 3 and Figure 5 end up in open pit lakes and the surrounding water catchment of Mashava. Figure 28 shows the general close proximity of open pit lakes to waste facilities. The interaction of tailings and waste material inhibits the open pit lakes from attaining neutral conditions overtime as suggested by Gwenzi (2020). The residual ground subsidence of open pit and underground mines and movement in waste facilities may not be noticed in the absence of proper management of the abandoned mines.

3.3 *Geological Evaluation*

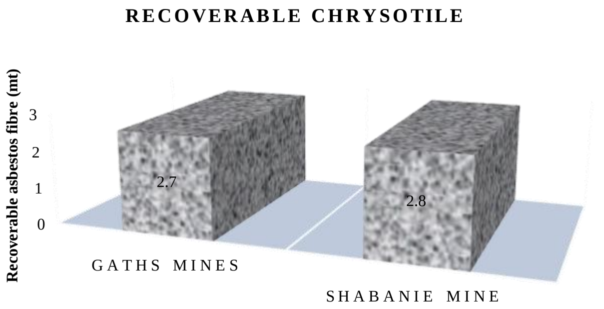

Fig. 6. Estimated volume of chrysotile tailings in Zimbabwe (mt)

Gaths Mines has a combined demonstrated recoverable asbestos reserve close to 2.7mt which when combined with that of Shabani gives Zimbabwe a reserve tonnage close to 5.8mt. However, restoration chances for the Gaths Mines are very slim due to the international scrutiny on the use and extraction of asbestos. Chrysotile the main asbestos type from the Gaths Mines is included with other forms of asbestos classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and by the U.S. Department of Health and Human Services.* Asbestos now has more than 100 substitutes across all its uses. Its global demand has almost fallen to zero. In 2003 the demand sat at 2,2 mt yet the current global consumption sits at 1.2 mt produced and consumed in four countries with no exports. Zimbabwe is producing around 16 000t/year for domestic use only a drastic decline from over 150 000t/year and a domestic demand of over 50000Mt/year in 2003. (See Figure 7) This is providing conclusive evidence that the feasibility of resuscitating Gaths Mines for extracting asbestos is very slim hence repurposing the abandoned mining site should be considered.

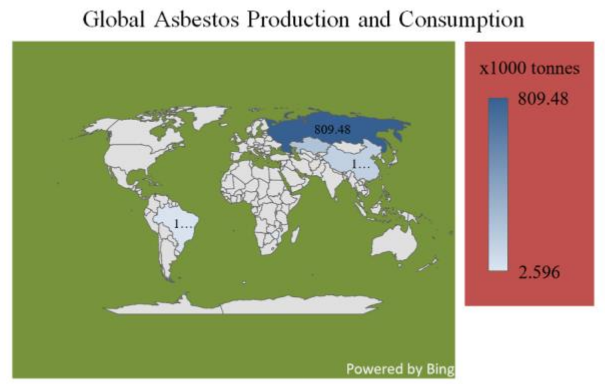

Fig. 7. Global consumption of asbestos limited to four producing countries (Data obtained from Garside 2021).

3.4 *Spread of abandoned open pits across Gaths Mines*

Figure 8 shows the spread and extent of open pit lakes within the Mashava area. It is evident from the figure that most pit lakes are in close proximity to the tailings and waste facilities. Most pits are less than 500 meters from the tailings. One extreme pit shows a significant accumulation of tailings in the pit, ultimately contaminating the pit lake and the surrounding aquifers as most of the pits form flow through pit lakes (See figure 2.5). Notably, most abandoned pits within the area have formed pit lakes, some of a perennial nature. Although the figure does not exhaustively show all the pit lakes within the area, it provides a significant image of the environmental footprint of abandoned mines, the interaction between waste facilities, and open pit excavations filled with water.

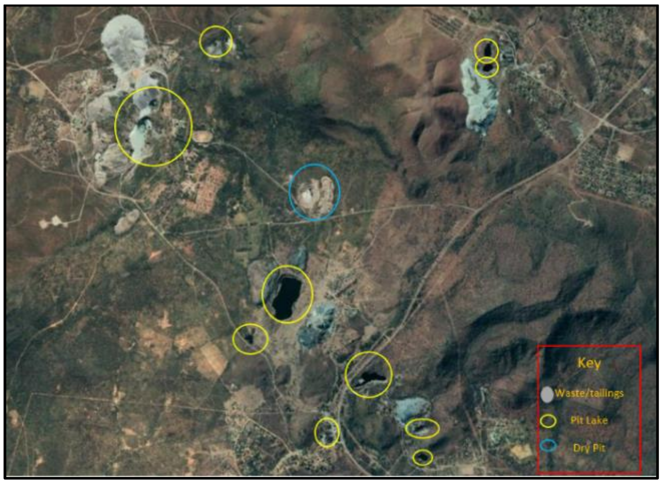

Fig. 7a. Extent of abandoned open pits across the Gaths Mine

3.5 *Metal Concentrations in Gaths Asbestos Tailings*

Generally, asbestos tailings are known to contain several metals including magnesium and Nickel. The asbestos tailings in Zimbabwe contain Magnesium Oxide (MgO) in excess of 40 percent. (See figure 34). The tailings contain traces of gold and platinum group metals. The chrysotile asbestos tailing contains

* International Agency for Research on Cancer (1998), (2008).

at least 6% Ni which can be extracted within the same unit process with Mg.

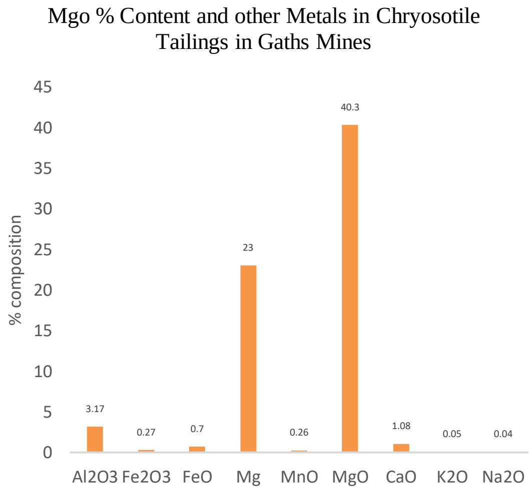

Fig. 8. Composition of magnesium oxide in Gaths Asbestos tailings

3.6 Estimated tonnage of Mg and other recoverable metals

The combined tonnage of the Gaths and Shabani Asbestos tailings is estimated to be above 143 million tons. Hence the estimated magnesium in the tailings dumps sits at 33 million tonnes while that of MgO, Ni, Chromite and magnetite is around 9mt, 1mt and 10mt respectively. Both the Gaths asbestos deposits are known to contain unascertained amounts of platinum which can also be commercialised depending on the quantities.

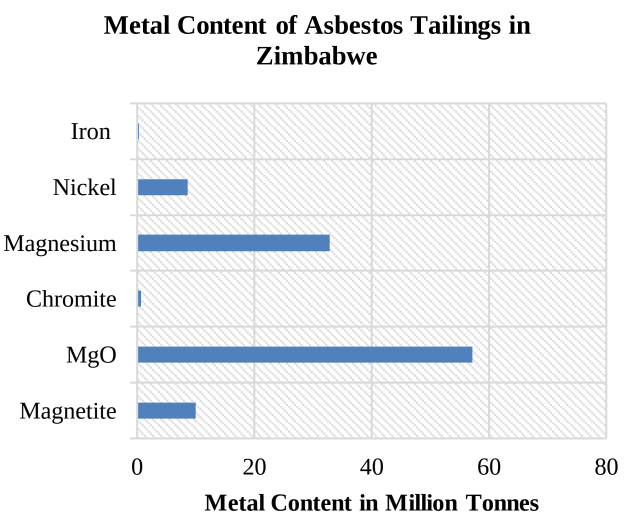

Fig. 1. Estimated metal content in the Gaths and Shabani Mines Tailings Dumps

3.7 Estimated value of the tailings dumps

Approximately 33mt of Magnesium and 10mt of Nickel are contained in the Gaths and Shabani Mine asbestos tailings dumps. With the price of magnesium staggering around US$2500 per tonne this translates to approximately US$80 billion revenue potential from the recovery of the metal. Nickel on the other hand is fetching around US$2888 per tonne thus ultimately giving a potential US$240 Billion revenue income.

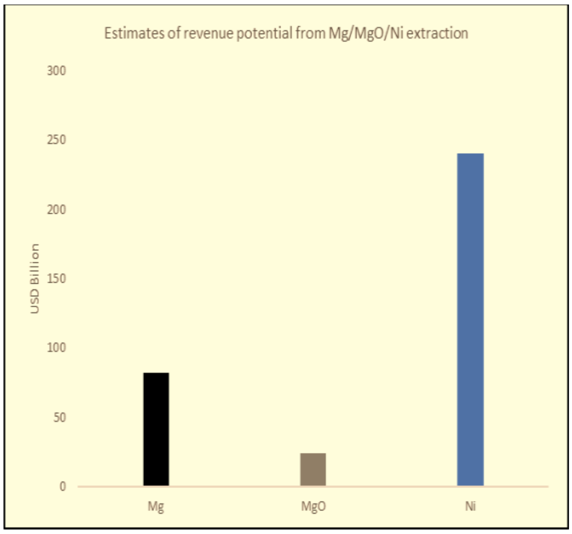

Fig. 2. Estimated revenues from the extraction of magnesium/ MgO and nickel

3.8 Estimated Capex for the repurposing plant.

The capital expenditure (capex) for setting a typical repurposing project and plant for the extraction of magnesium from asbestos tailings at a rate of 50 000t/year is estimated to be around US$650 million depending on the prevailing circumstances. This cost assumes a project starting to construct infrastructure from scratch. Both Gaths and Shabani have existing infrastructure that can be used to offset the capex. The adjusted cost was found to be slightly above US$1 760/t Mg.

Table 1. Capex Costs Comparison between Western and African economic jurisdictions

Location	Plant Capacity t/y	Plant Cost US$ million	Plant Cost $K/t
Canada	50000	445	8,9
Congo	60000	500	8,33
Egypt	43000	360	8,4

Table 2. Projected operating expenses per tonne of magnesium

Item	$US/lb	Proportion %	Adjusting factor	Adj. $US/lb	Adj. $US/t
Consumables	0,056205	6,455892	1,000000	0,056205	123,932
Utilities	0,415700	47,74868	0,957658	0,398098	877,8067
Maintenance	0,236000	27,10774	1,000000	0,236000	520,3800
Other	0,094000	10,79715	1,000000	0,094000	207,2700
Labour	0,068695	7,890535	0,222000	0,015250	33,62689
			Total	0,799554	1763,016

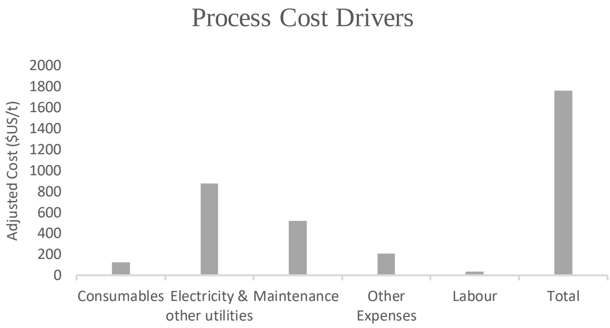

Fig. 3. Projected Cost Drivers

3.9 *Projected Cash Flows*

Table 3 shows the projected cash flows for repurposing the Gaths mines abandoned mine sites. The overall estimate for the capex for a 50 000t/pa Mg Plant 25-year project is estimated at US$416,7 million against an estimated net cash flow of US$1 billion. The NPV for the project is US$95,5 million at a discount rate of 10%. The project Internal Rate of Return is estimated at 16.14%. This projection only accounts for the recovery of magnesium however, it should be noted that the tailings dump under study also contain nickel as well as traces of platinum, gold, and copper.

Table 3. Projected cash flows for a 25-year magnesium plant assuming magnesium only is sold
(Zimbabwe's tax rate at 24%, Adj Opex of 1763,37 and assumed first two years are for development work with minimum trials)

Total Capex		416700000										
Mg Price		2877,33										
Opex		1763,37										
Royalty		10%										
Discount Rate		10%										
Project Life		5 years										
Intrest Rate		4pa										
Tax Rate		24										
	Y1	Y2	Y10	Y11	Y15	Y16	Y19	Y20	Y23	Y24	Y25	Total
Mg(t)	2000	10000	50000	50000	50000	50000	50000	50000	50000	50000	50000	1162000
Revenues	5754660	28773300	143866500	143866500	143866500	143866500	143866500	143866500	143866500	143866500	143866500	3343457460
Opex	16668000	17633700	88150000	88150000	88150000	88150000	88150000	88150000	88150000	88150000	88150000	2061770200
NSR	57546,6	287733	1438665	1438665	1438665	1438665	1438665	1438665	1438665	1438665	1438665	33434574,6
Taxes	0	0	13569458,75	13569458,75	13569458,75	13569458,75	13569458,75	13569458,75	13569458,75	13569458,75	13569458,75	312092926,3
Armotisation	301410,4882	4822567,812	18708001,19	18708001,19	18708001,19	18708001,19	18708001,19	18708001,19	18708001,19	18708001,19	18708001,19	416700000
Profit	-10970886,6	10851867	40708376,25	40708376,25	40708376,25	40708376,25	40708376,25	40708376,25	40708376,25	40708376,25	40708376,25	936159759,2
Cumulative Capex		5000000	416700000	416700000	416700000	416700000	416700000	416700000	416700000	416700000	416700000	416700000
Net Cash Flov	-10669476,11	15674434,81	59416377,44	59416377,44	59416377,44	59416377,44	59416377,44	59416377,44	59416377,44	59416377,44	59416377,44	954867764,9
PV of Cash Fl	-1066947,611	1567443,481	5941637,744	5941637,744	5941637,744	5941637,744	5941637,744	5941637,744	5941637,744	5941637,744	5941637,744	95486776,49
IRR			6362210,324		36070399,04			65778587,77		NPV at 10%		95486776,49
		400000	4%		13%			15%		IRR		16%

3.10 *Life of Project sensitivity analysis.*

Figure 12 above illustrates the sensitivity of the project's Net Present Value and Internal Rate of Return to the project's life cycle. As seen in the figure, the longer the project life span the more attractive it becomes. At 10 years, the project feasibility is significantly low characterized by an almost negative NPV and IRR below 5%. At 25 years the project IRR rises to over 16% and the NPV is slightly below US$100 million.

This indicates that the viability of the project is largely dependent on the availability of feedstock. At 50 000t/pa, the available tonnage of tailings of approximately 143 million tonnes (Approx. 55mt Mg.) will be exhausted in over 1000 years. Therefore, there is reasonable confidence in the viability and continuity of the project.

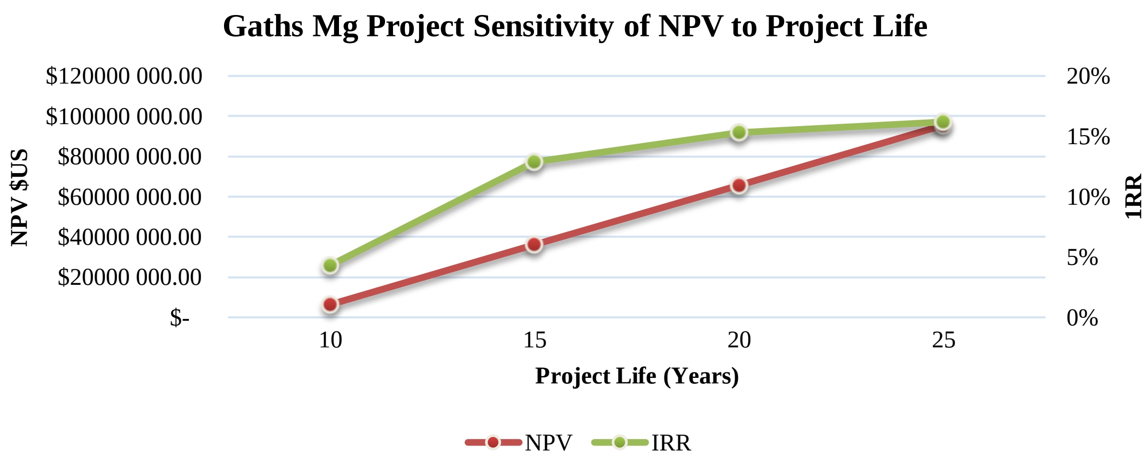

Fig. 12. Sensitivity Analysis to Project Life

3.11 Sensitivity analysis to Mg Price volatility

Figure 13 illustrates the sensitivity of the Internal Rate of Return to the price of Magnesium. A ten-year project results in negative IRR for any magnesium prices below US$2500/t. A fifteen-year project requires Mg prices above US$2250/t to yield an IRR above 0.0%. For the rest of the project life spans any Mg prices above US$2000/t results in an IRR above 0.0% hence the project will be viable for Mg above this price.

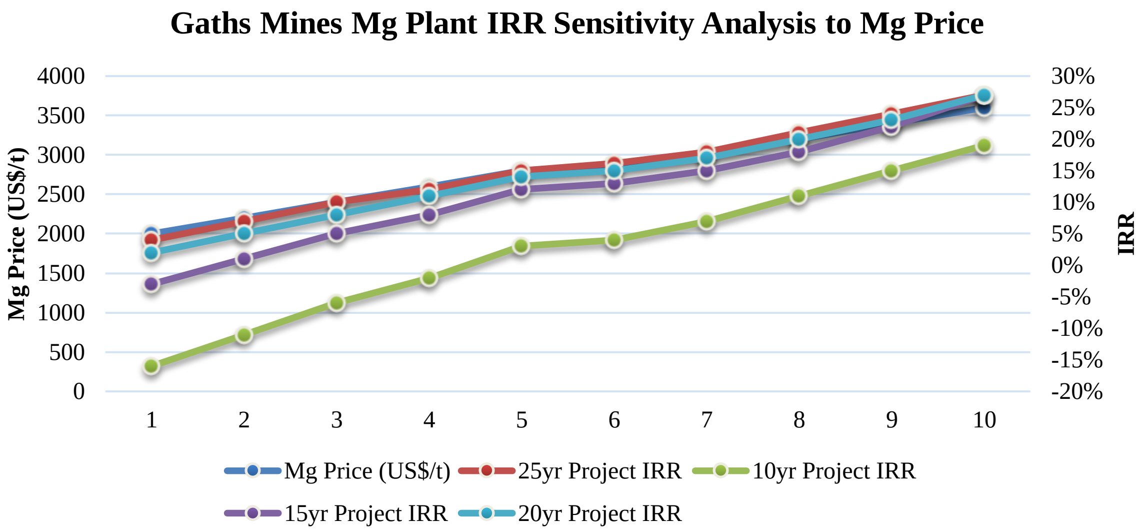

Fig. 13. Gaths Mines Mg. Project IRR Sensitivity to Metal Price

3.12 Sensitivity analysis to discount rate

The Table 4 illustrates the sensitivity of the proposed 50 000tpa Mg Project at Gaths Mines. At 10.0% discount rate, metal price of 2877,33/t the NPV is about US$95,5 Million. Whereas a discount rate above 10%, for instance 15.0% would increase the project's NPV significantly to US$143 Million. Revenues and profitability of the company depend heavily not only on Mg Prices but also the discount rate. As seen in the table, a discount rate of 3% at a Mg price of US$2000/t yields an NPV as low as US$4.9 Million while at US$3400 Mg price per ton, 15% discount rate the NPV rises beyond US$211 million. The project is highly sensitive to Mg prizes.

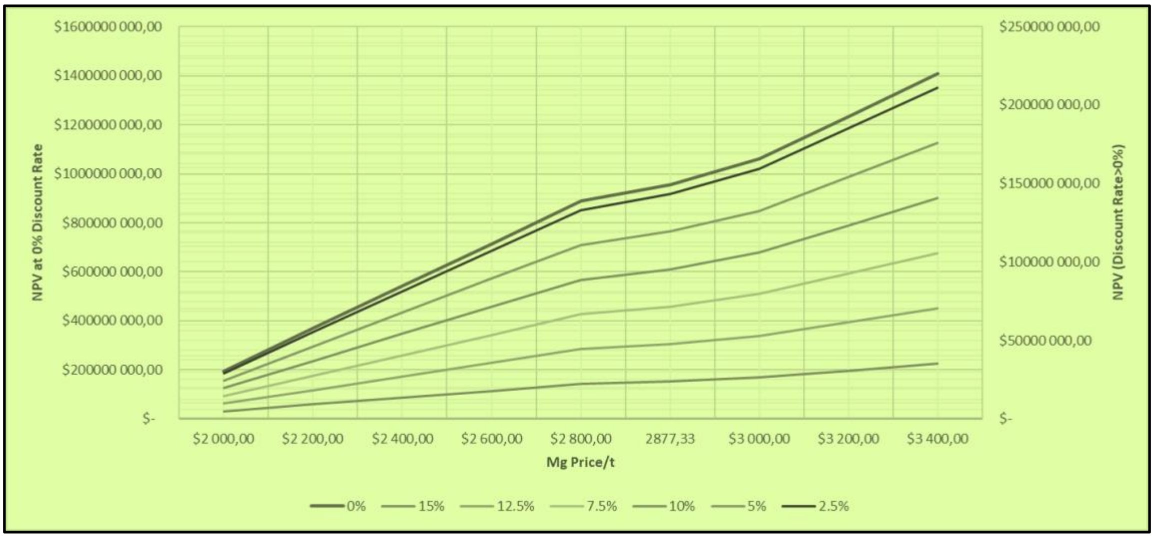

Fig. 1 Error! No text of specified style in document.**.** Project sensitivity to discount rate

Table Error! No text of specified style in document.**.** Gaths Mines Plant IRR Sensitivity to Discount Rate

Gaths Mg Plant Discount Rate	Mg Price (US$/t)							
	$ 2 000,00	$ 2 200,00	$ 2 600,00	$ 2 800,00	2877,33	$ 3 000,00	$ 3 400,00	$ 3 600,00
0%	$ 195 314 930,71	$ 368 465 930,71	$ 714 767 930,71	$ 887 918 930,71	$ 954 867 764,86	$ 1 061 069 930,71	$ 1 407 371 930,71	$ 954 867 764,86
3%	$ 4 882 873,27	$ 9 211 648,27	$ 17 869 198,27	$ 22 197 973,27	$ 23 871 694,12	$ 26 526 748,27	$ 35 184 298,27	$ 23 871 694,12
5%	$ 9 765 746,54	$ 18 423 296,54	$ 35 738 396,54	$ 44 395 946,54	$ 47 743 388,24	$ 53 053 496,54	$ 70 368 596,54	$ 47 743 388,24
8%	$ 14 648 619,80	$ 27 634 944,80	$ 53 607 594,80	$ 66 593 919,80	$ 71 615 082,36	$ 79 580 244,80	$ 105 552 894,80	$ 71 615 082,36
10%	$ 19 531 493,07	$ 36 846 593,07	$ 71 476 793,07	$ 88 791 893,07	$ 95 486 776,49	$ 106 106 993,07	$ 140 737 193,07	$ 95 486 776,49
13%	$ 24 414 366,34	$ 46 058 241,34	$ 89 345 991,34	$ 110 989 866,34	$ 119 358 470,61	$ 132 633 741,34	$ 175 921 491,34	$ 119 358 470,61
15%	$ 29 297 239,61	$ 55 269 889,61	$ 107 215 189,61	$ 133 187 839,61	$ 143 230 164,73	$ 159 160 489,61	$ 211 105 789,61	$ 143 230 164,73

4. Discussions

The research sought to assess the feasibility of implementing social entrepreneurial approaches to repurposing Gaths Mines. Two options A and B were analysed. Option A involved recovering metals from Gaths Mines' asbestos tailings. The research indicates that there is over 143mt of asbestos tailings that can be processed at Gaths. The tailings contain Mg, Ni, Sio, Pt, Au and other metal oxides. The MgO content was estimated above 60mt giving the project a life exceeding 1000 years at 50 000tpa. Setting up a Mg plant at Gaths mine requires a massive initial capital outlay exceeding 400 million (Approximately 10% of Zimbabwe's mining industry GDP contribution). The project is financially viable as supported by an NPV close to 100 million and IRR of 16% for a 25-year project at Mg price of 2800/t. Mg prices are however very volatile. The project cashflows indicate that the project can stay afloat for prices above 2000/t. Capital mobilisation may be the major obstacle. This however can be addressed by debt funding the project.

Gaths abandoned mining sites are posing a huge ecological challenge to the inhabitants of Mashava. Repurposing the site is feasible and there are several opportunities that can be harnessed. Among them, the recovery of metals from the asbestos tailings dumps presents the greatest economic potential. It is recommended that the State should seek investors to not only extract the dumps but also rehabilitate them. The Capex requirements are high therefore the following measures can be adopted to incentivise the project. The government should consider availing funding towards the initiative, awarding the site special economic zone status to afford investors some economic incentives. It is recommended that the Mg Plant should not be run in isolation but rather together with repurposing the site into a recreational and research facility. Although the costs of establishing recreational and research facilities are significantly lower, their viability is equally low given the low domestic tourism in Zimbabwe. Establishing a research site may also result in the mere occupation of abandoned buildings without much change to the state of the site.

5. Conclusion

The environmental footprint of Gaths Mine is massive. Ground subsidence is evident. Erosion and movement of tailings dams into the rivers and water bodies within the Mashava catchment was noted from earth observations. Several abandoned pits have developed into pit lakes of which most of them are too close to tailings dams. Accumulation of tailing sediments from tailings dams in pit lakes was observed. Resuscitation of Gaths Mines for the extraction of asbestos is almost close to impossible as the mineral has been rendered redundant by technology and health concerns. However, opportunities for repurposing are available.

The site can be repurposed into a recreational site or research centre. Further, recovery of metals from the asbestos tailings is feasible. The three can be done simultaneously and can be complimentary. A 50 000 tpa Mg plant will require an initial outlay exceeding US$400 million. The plant will also produce nickel. At 100000 tpa., the site will create more than 200 direct jobs. NPV and IRR analysis of the projected cashflows indicate that the project is highly sensitive to Mg price. Allowing a 50% debt to equity ratio makes the project even more viable. The project requires a Capex of 1883 per tonne of Mg and Opex of US$1733 per tonne of Mg. Mg price of US$2800/t afford the project an internal rate of return of 16% with a net present value or US$95,5 million. A 50% debt to equity ratio will increase the NPV and IRR to US$150 million and 28%. The research proves that the project is highly feasible.

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