Efficacy of activated MgO, metakaolinite and their composite on the treatment of real acid mine drainage: A comparative study

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Presentation Outline

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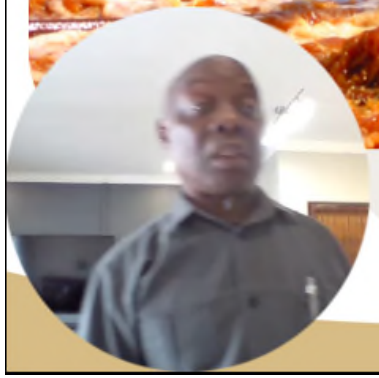
01 Introduction

02 Methodology

03 Results & Discussion

04 Conclusion

Background



AMD associated with gold and coal mines

Formed through oxidation of sulfur bearing minerals

It is associated with acidic and metal-rich water with elevated sulfate salts

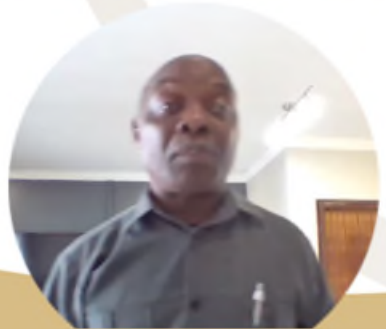
Salinization of water resources by AMD among contributors to declining water quality

The prevention of formation and treatment of AMD is key to protect the environment

Prevention of AMD formation has been a challenge as it occurs naturally

Treatment of AMD prior to discharge into the environment is recommended

Background… Cont'd



- There are different AMD treatment technologies.
- Precipitation, filtration, ion exchange, adsorption, distillation, crystallization, bio-remediation, and phyto-remediation are among the others.
- Periclase and brucite nanoparticles offer an advantage of sequential recovery of minerals efficiently and effectively.
- Some techniques employ either hybrid or combined mechanisms in sequential of synergistic manner.
- These mechanisms have the advantages and disadvantages with adsorption having the challenges of limited adsorption capacity, quick saturation, and selectivity ability.
- The regenerant from the adsorbent pose secondary pollution and this poses challenges with the disposal of the adsorbent unless if valorization is explored.
- Filtration and desalination has high efficiency but at the expense of the environment since it produces brine and consumes energy.

Background… Cont'd

Moreover, some platforms have drawbacks that limits their application.

- Ca-based minerals used in the remediation platforms pose challenge of producing highly mineralized and toxic sludge.

- Na-based minerals produce highly mineralized sludge and sulfate is kept in solutions as sodium sulphate complex.

Sampling

Study area

Study design and sample

- AMD was collected from a dysfunctional coal mine shaft near Witbank, Mpumalanga Province, South Africa.
- Metakaolinite clay was obtained from CSIR.
- MgO procured from Sterkfontein carbonates.

Methodology

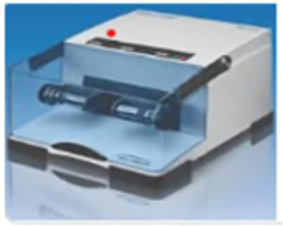
Metakaolinite clay

+

MgO

milled

@1600rpm
for 30min



Retsch RS 200 millerv

Precursors

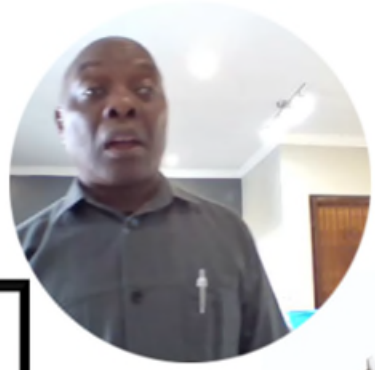
milled

Fine material

Synthesis

Vibratory ball-miller

Physical- chemical analyises



pH
EC
IC I
ICP-OES
SRM 1643f

Results

Elemental analysis

Metakaolinite

Si
Al

Mg
Ca
K

Post AMD contact: Al, Si, Fe, S, K, and Ca

MgO

Mg
Ca

Si

MgO - metakaolinite composite

Trace: Mg, Si, Al, and Ca

Results

Elemental analysis

Metakaolinite

Si
Al

Mg
Ca
K

MgO

Mg
Ca

Si

AMD post contact: Fe, S, Ca, and Mg with the traces of Mn, Si, and Al

MgO - metakaolinite composite

Trace: Mg, Si, Al, and Ca

Results

Elemental analysis

Metakaolinite

Si
Al

Mg
Ca
K

MgO

Mg
Ca

Si

MgO - metakaolinite composite

Trace: Mg, Si, Al, and Ca

AMD post contact: have elevated levels of Fe and S whilst Al, Si, Mg, Ti, and Ca were observed to have reduced

Results… Cont'd

Mineralogical properties

Metakaolinite

Quartz, cristobalite, hematite, kaolinite, rutile, and calcite

Al-Si mineral + Impurities

- Post AMD contact: quartz, cristobalite, hematite, kaolinite, rutile, and basanite.
- Introduction of basanite in the resultant solid residue indicates possible mineralogical transformation during AMD treatment.

MgO - metakaolinite composite

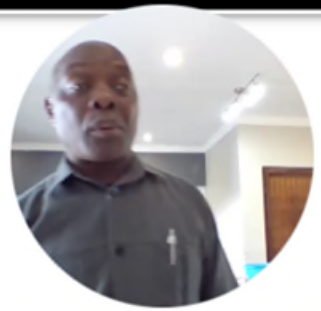
- Periclase, quartz, mullite, calcite, cristobalite, magnesite, kaolinite, and kieserite.
- Si species will significantly contribute.

MgO

Periclase, brucite, quartz, calcite, and magnesium oxide.

Results… Cont'd

Mineralogical properties



Metakaolinite

Quartz, cristobalite, hematite, kaolinite, rutile, and calcite

Al-Si mineral + Impurities

MgO - metakaolinite composite

- Periclase, quartz, mullite, calcite, cristobalite, magnesite, kaolinite, and kieserite.
- Si species will significantly contribute.

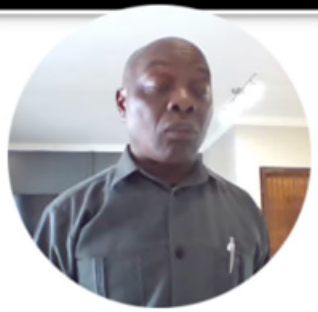
MgO

Periclase, brucite, quartz, calcite, and magnesium oxide.

- Post AMD contact: gypsum, quartz, brucite, epidote, sjoegrenite and nordstrandite.
- Introduction of new mineral phases in the resultant solid residue indicates possible mineralogical transformation during AMD treatment

Results… Cont'd

Mineralogical properties



Metakaolinite

Quartz, cristobalite, hematite, kaolinite, rutile, and calcite

Al-Si mineral + Impurities

MgO - metakaolinite composite

- Periclase, quartz, mullite, calcite, cristobalite, magnesite, kaolinite, and kieserite.
- Si species will significantly contribute.

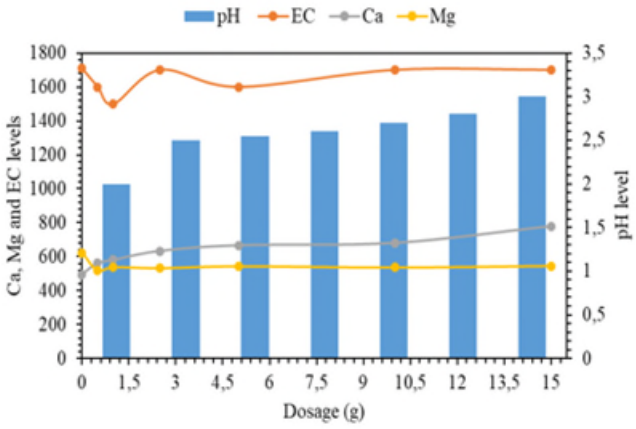
- Post AMD contact: Gypsum, cristobalite, quartz, mullite, and kaolinite.
- The noisy signal in the spectrogram of the resultant sludge denotes the presence of amorphous phases in its matrix as the mineral phase

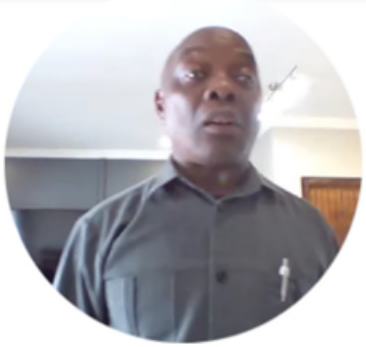
MgO

Periclase, brucite, quartz, calcite, and magnesium oxide.

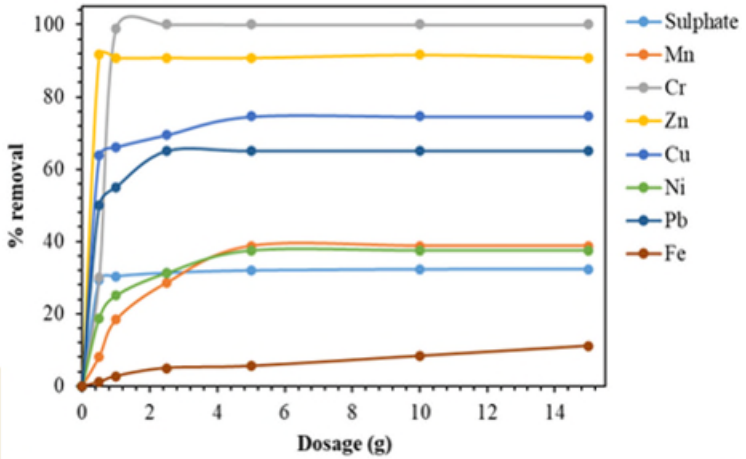
Results… Cont'd

Effect of metakaolinite dosage



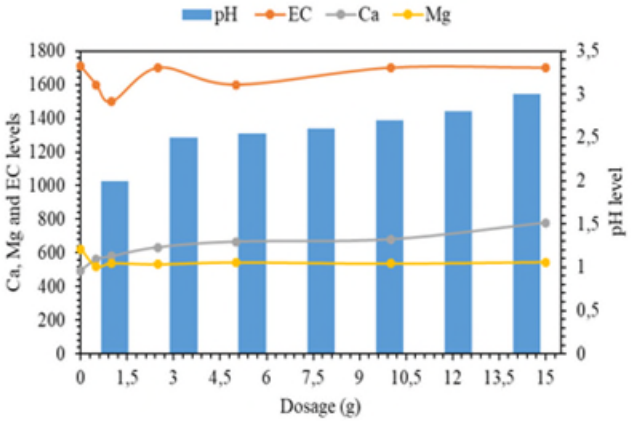


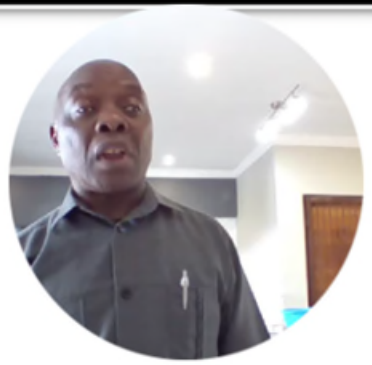
Increase in the % removal of inorganic contaminants with metaokaolinite dosages - an availability of the adsorption sites.



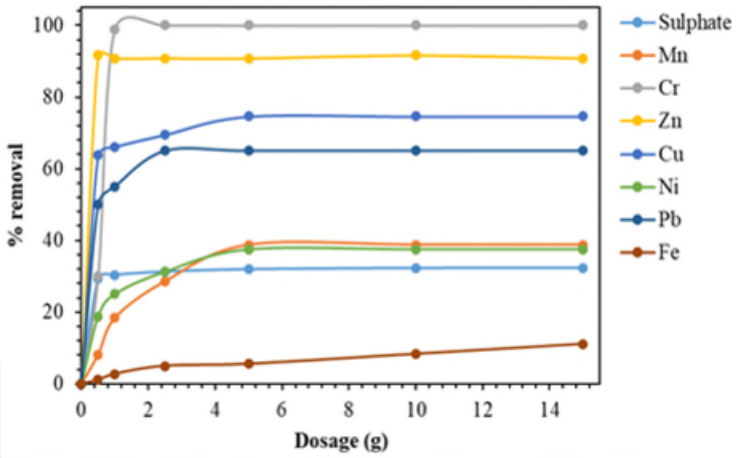
Results… Cont'd

Effect of metakaolinite dosage



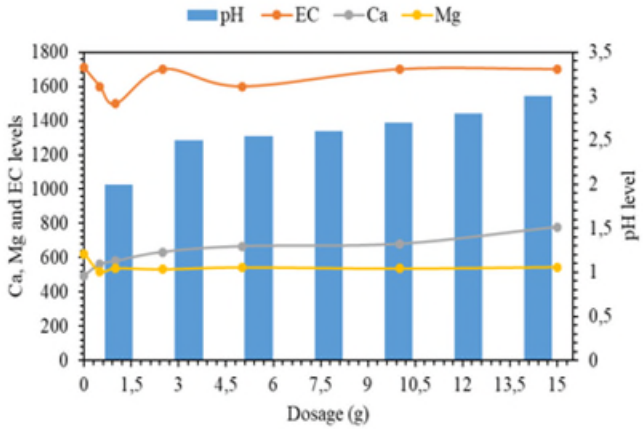


Sulphate removal increased from 1 g till 15 g to 32% - the formation of gypsum or any other metal-(oxy)-hydrosulphate.

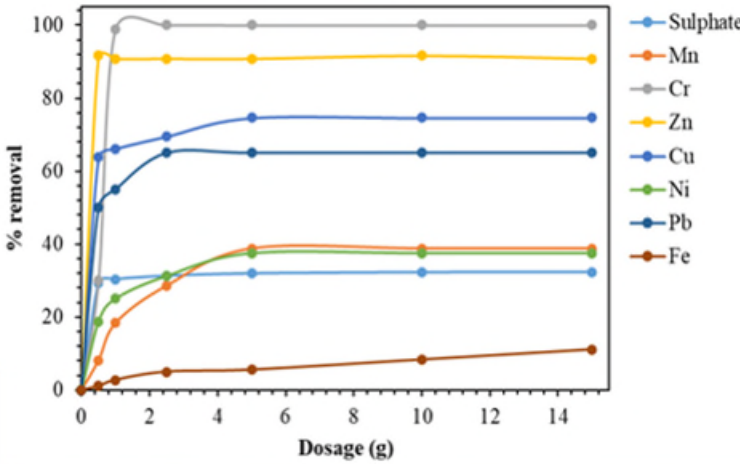


Results… Cont'd

Effect of metakaolinite dosage

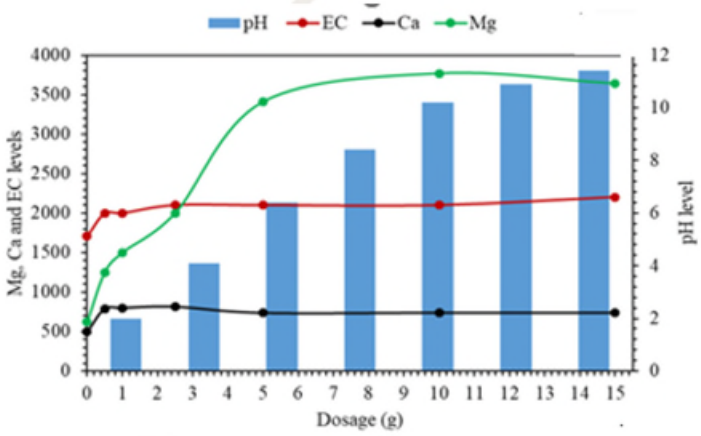


▪Removal order: Cr ≥ Zn ≥ Cu ≥ Pb ≥ Ni ≥ Mn ≥ sulphate ≥ Fe (99.9, 91.6, 74.5, 65, 38.7, 37.5, 32.3, and 8%) - poor removal efficacy of chemical species due exhaustion of adsorption and exchange site on the metakaolinite matrices.

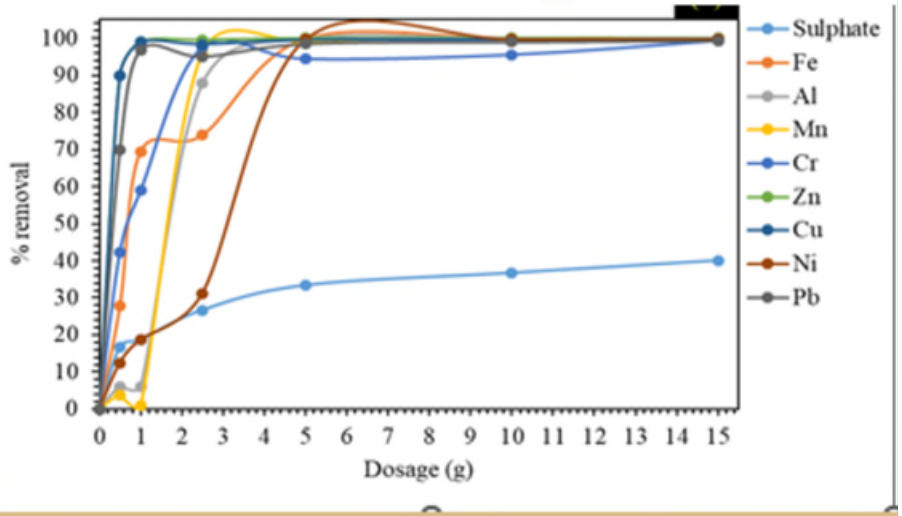


Results… Cont'd

Effect of MgO dosage

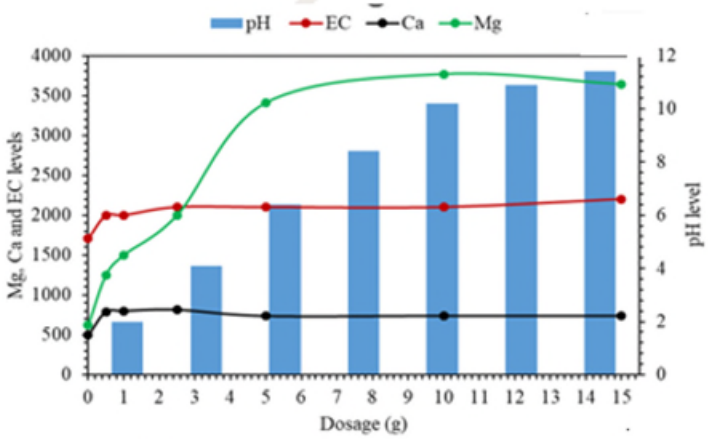


- Increase % removal of inorganic contaminants with MgO dosages – due to the additional alkaline generating ions, i.e., Ca and Mg.

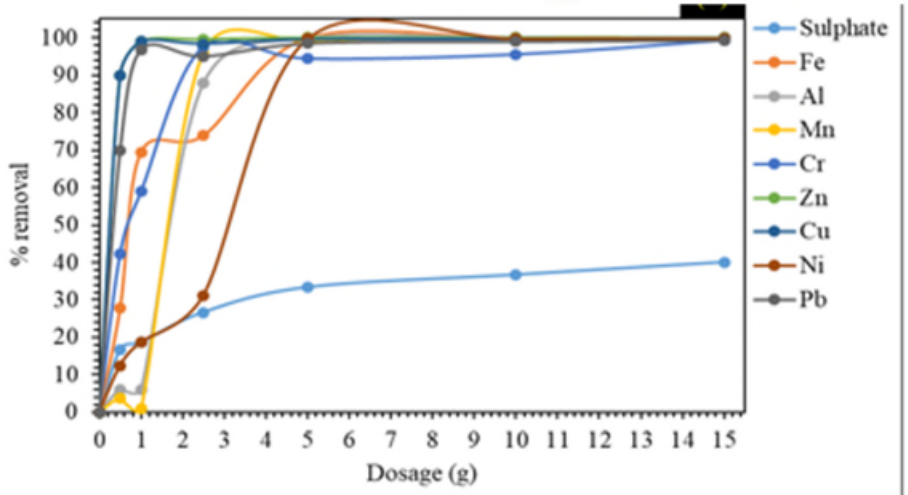


Results… Cont'd

Effect of MgO dosage

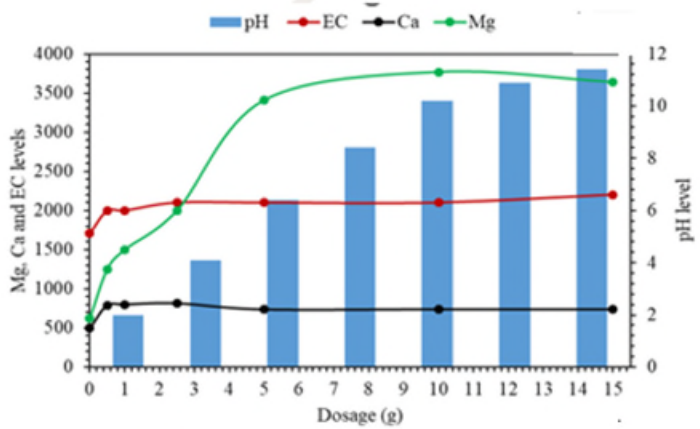


- Within the first 5 grams, significant metals were removed (≥95%).

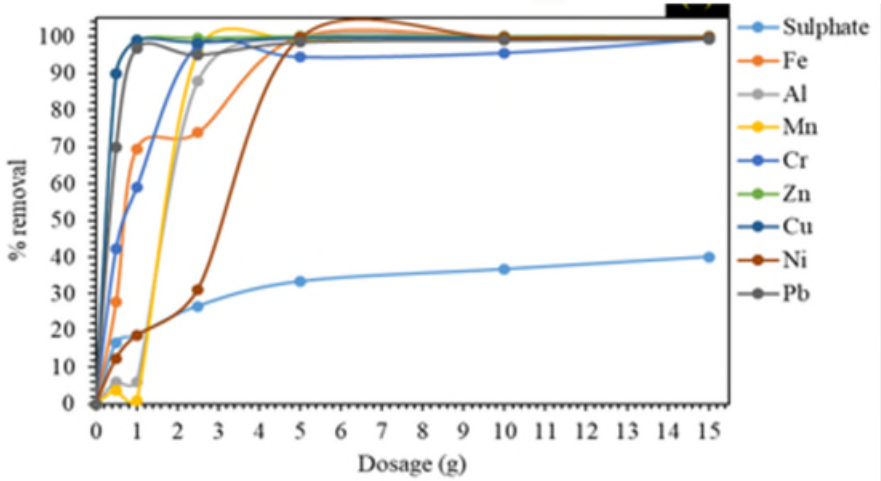


Results… Cont'd

Effect of MgO dosage

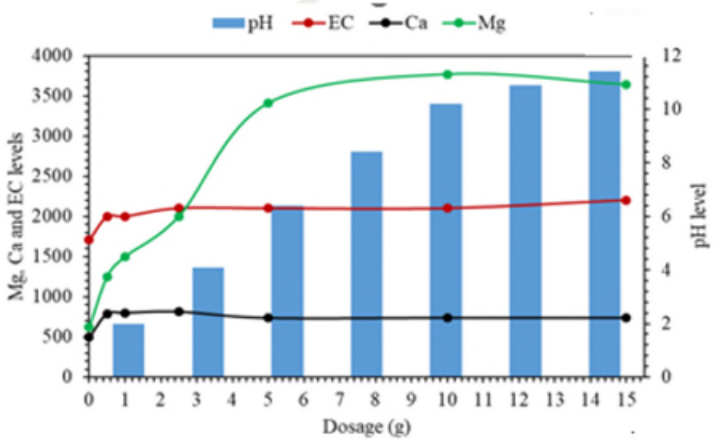


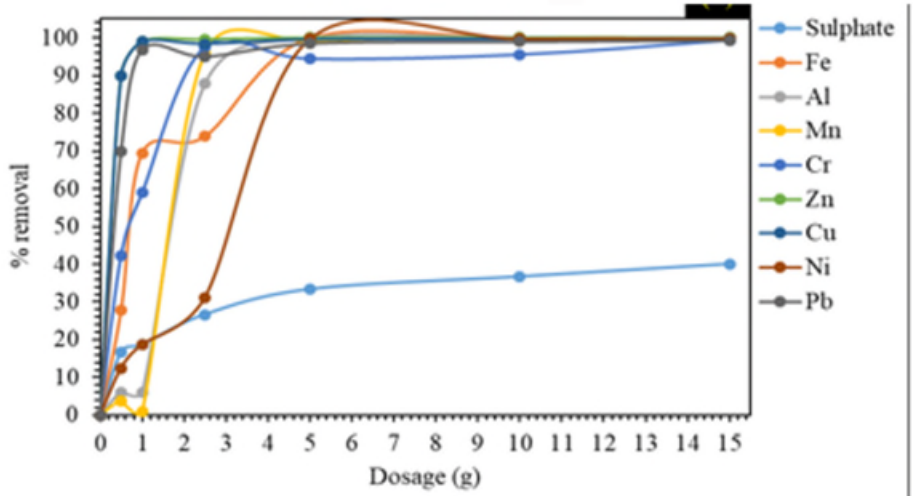
- The removal of sulphate increased from 1 g till 15 g, with a maximum removal efficacy of 40% - due to the formation of gypsum when reacting with real AMD rich in sulphate.



Results… Cont'd

Effect of MgO dosage

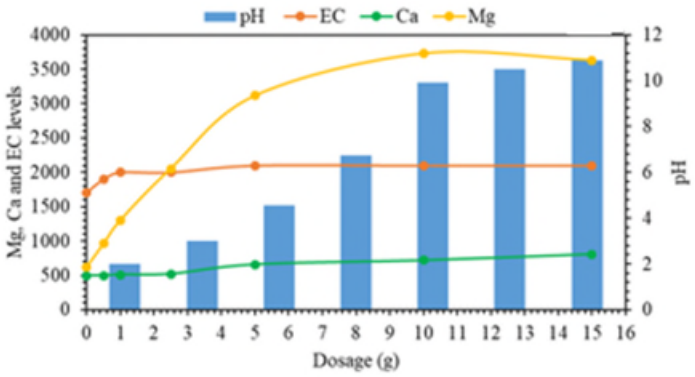




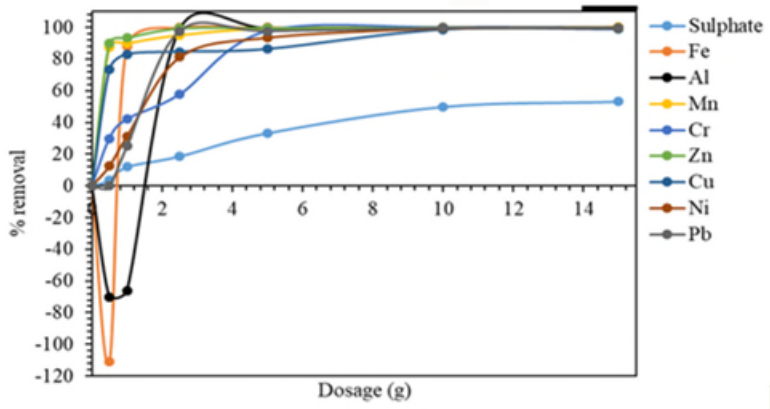
- From 5 – 15 grams of MgO, no significant changes in metals removal except for sulphate which was gradually reducing.

Results… Cont'd

Effect of composite dosage

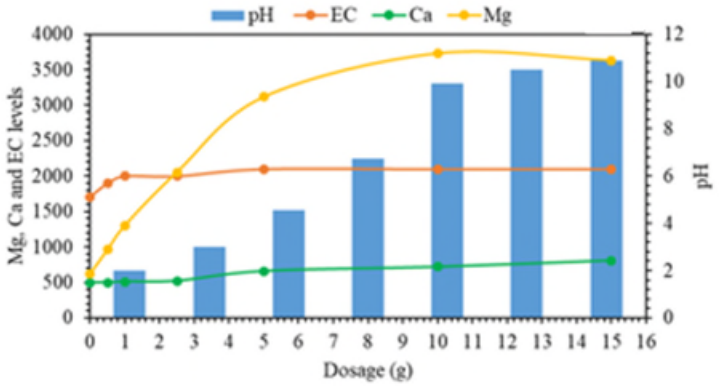


- Increase in % removal of inorganic contaminants with composite dosages.

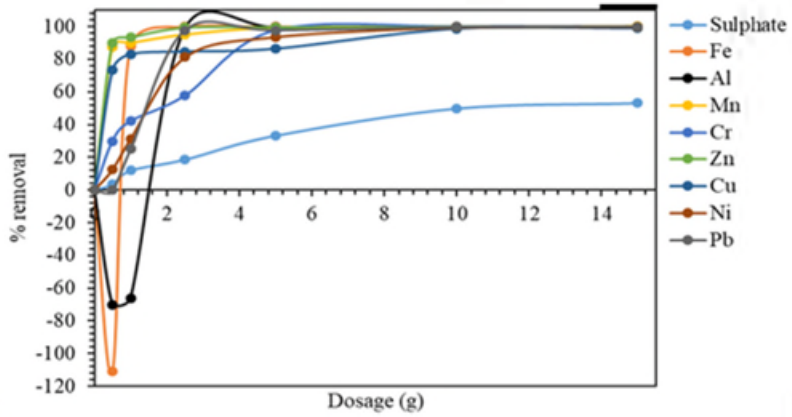


Results… Cont'd

Effect of composite dosage

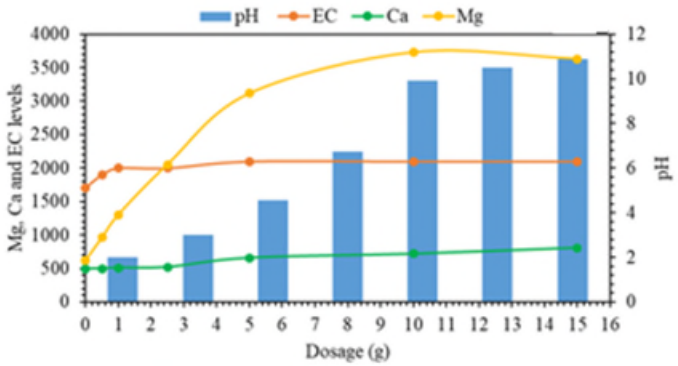


- Increase in dosage = increase in the adsorption rate for adsorption of contaminants from AMD.

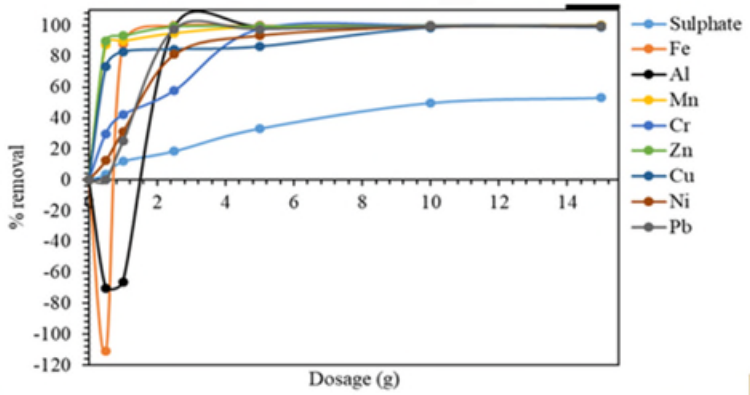


Results… Cont'd

Effect of composite dosage

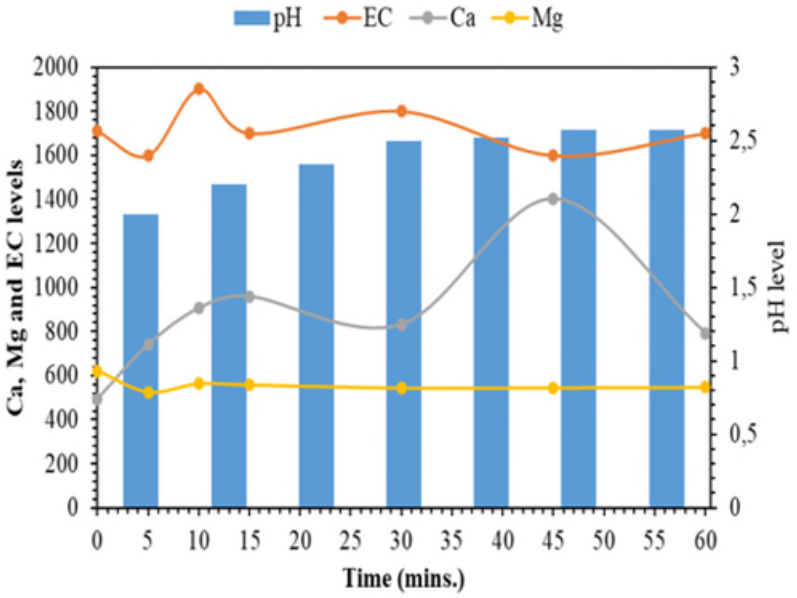


- The % removal for Al, Fe, Mn, Pb, Ni, Zn, Cr and Cu were observed to be ≥99.9% whilst the % removal of sulphate from real AMD was observed to be ≥50%.

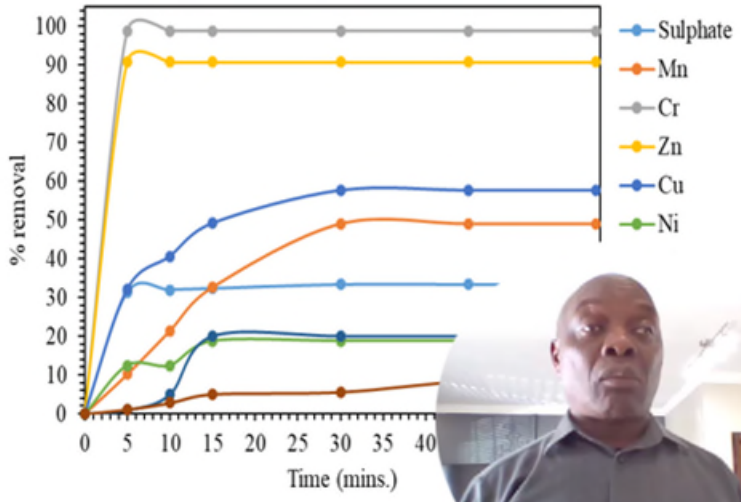


Results… Cont'd

Effect of contact time using metakaolinite clay

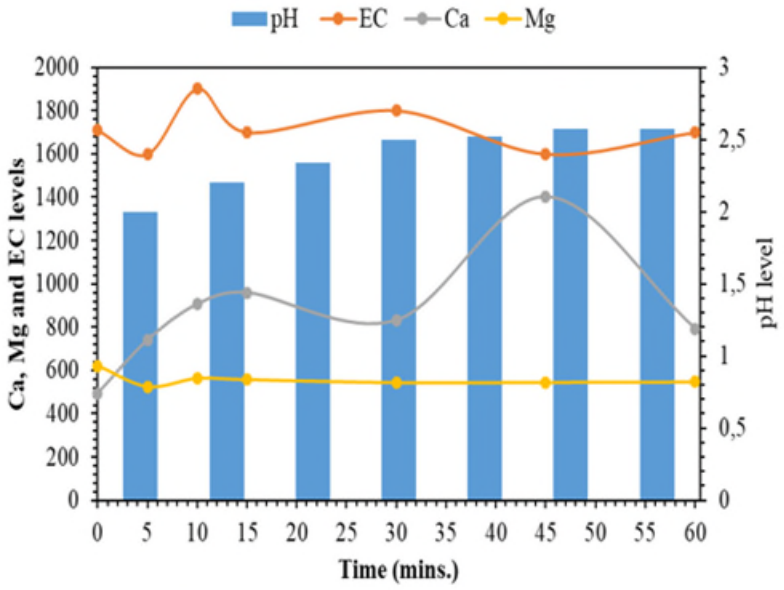


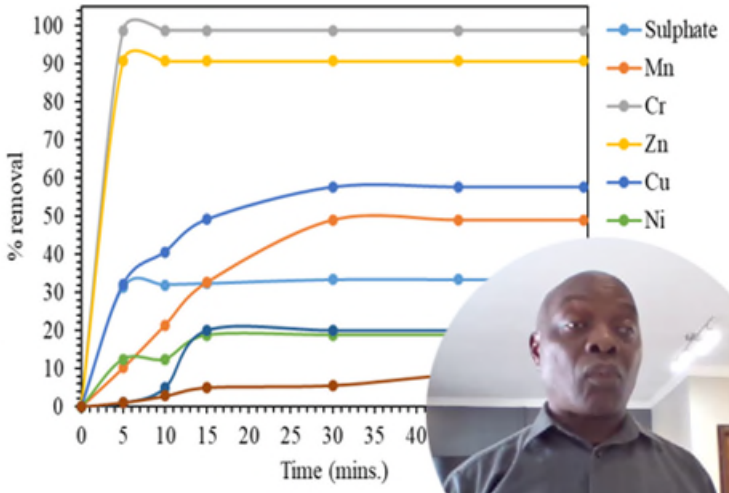
- The removal efficiency rapid up to 45 minute.



Results… Cont'd

Effect of contact time using metakaolinite clay



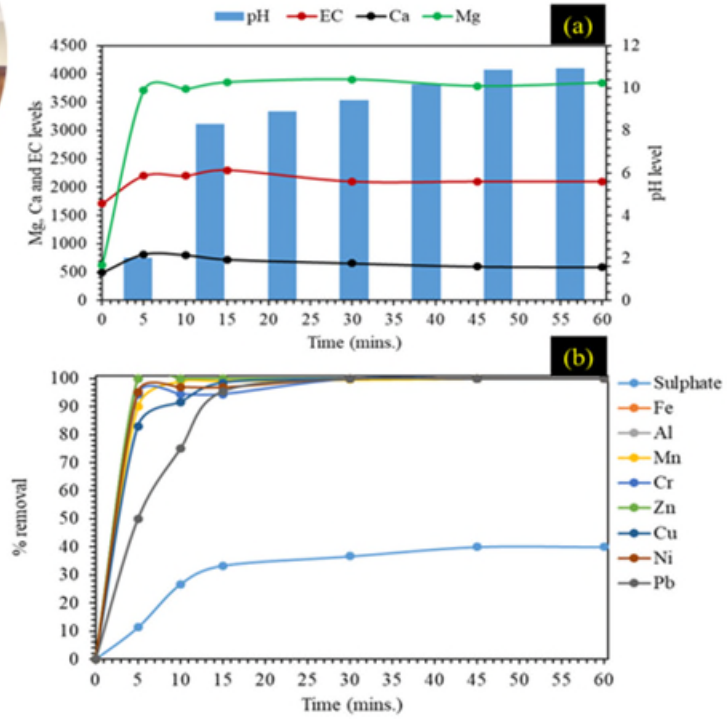


- 45 minutes sufficient for the treatment of real AMD.

Results… Cont'd

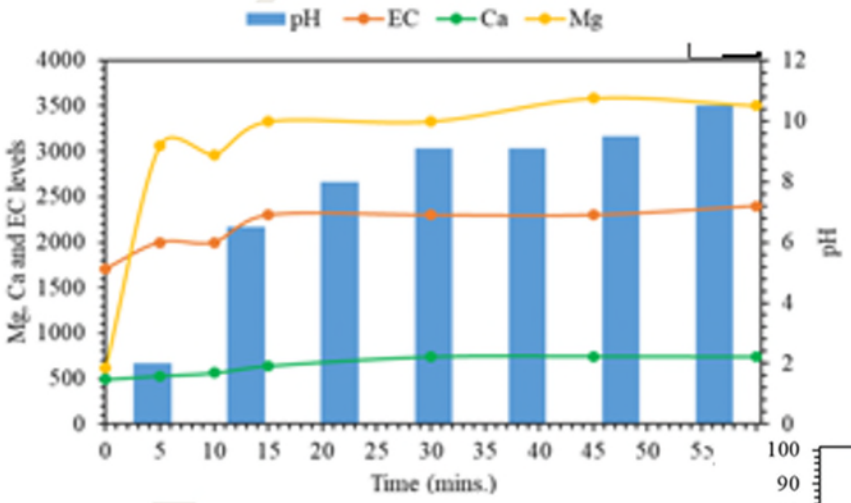
Effect of contact time using MgO

- The removal efficiencies rapid up to 30 minutes.
- 45 minutes sufficient for the treatment of real AMD with MgO.
- There were ≥99.5% removal for Fe, Al, Mn, Cr, Zn, Cu, Ni, and Pb except for sulphate that attained ≥40% removal efficacy.

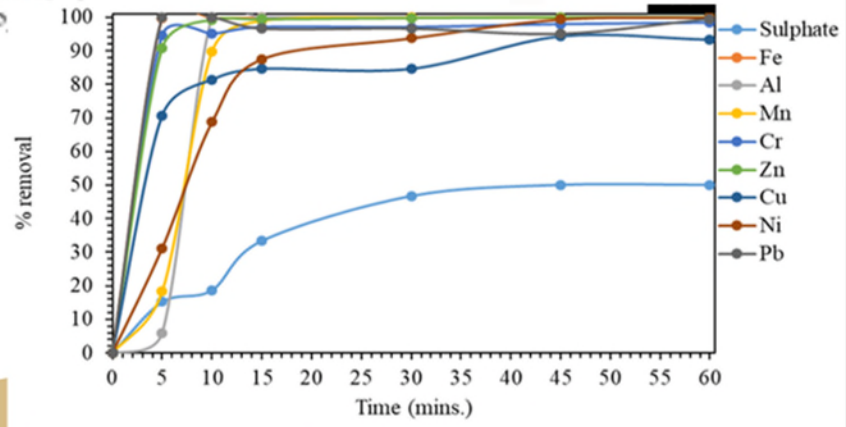


Results… Cont'd

Effect of contact time using composite

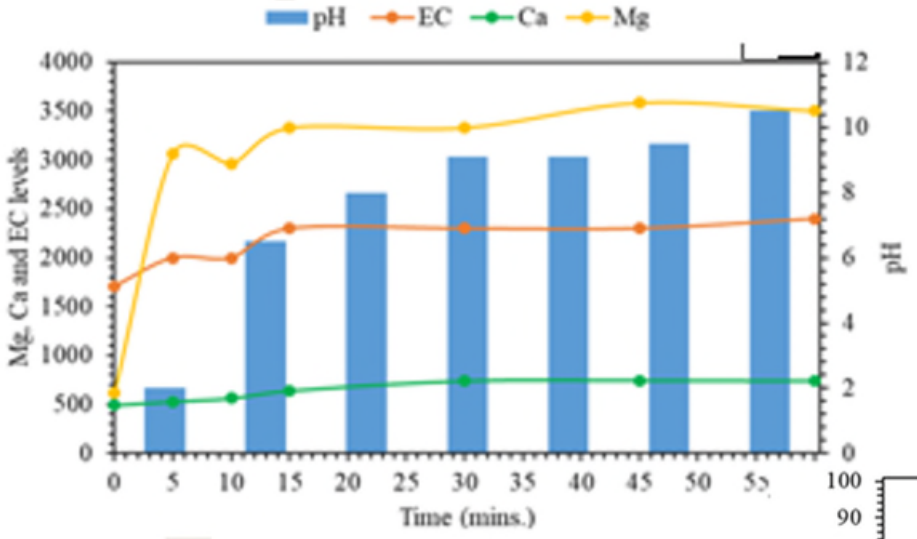


- The removal efficiency rapid up to 45 minute.

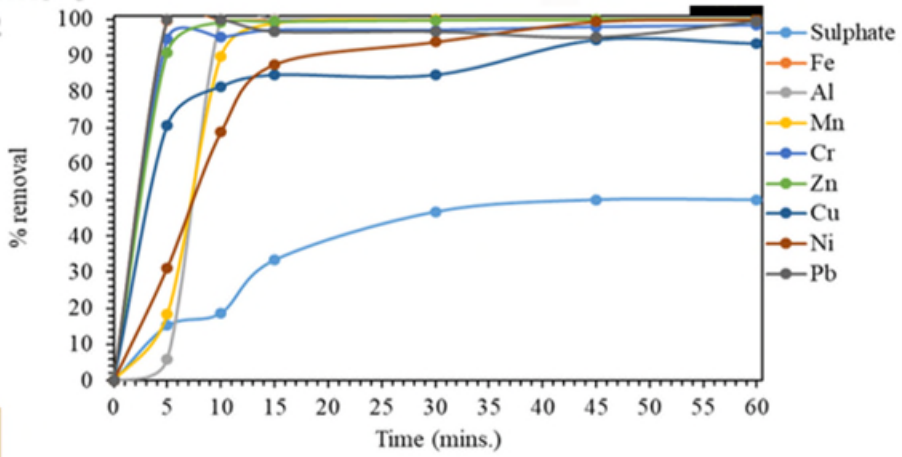


Results… Cont'd

Effect of contact time using composite



- 45 minutes - sufficient for the treatment of real AMD with composite.



Results… Cont'd

Treatment of real AMD under optimum conditions using MgO, metakaolinite and composite

			Metakaolinite		MgO		Composite	
Element	**Units**	**Real AMD**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**
Sulphate	mg/L	15000	10150	32,3	9000	40	7500	50
Fe	mg/L	1800	1650	8,3	0,1	100	1	100
Al	mg/L	500	750	-	0,1	100	0,1	100
Mn	mg/L	98	60	38,8	0,1	99,9	0	100
Cr	mg/L	0,09	0	100	0	99,9	0	100
Zn	mg/L	120	10	91,7	0	100	0	100
Cu	mg/L	0,59	0,2	74,6	0	99,8	0	100
Ni	mg/L	1,6	1	37,5	0	99,9	0	100
Pb	mg/L	0,2	0,1	65	0	100	0	100
pH	pH	2	2,8	-	10,9	-	10,5	-
EC	mS/ cm	1709	1700	0,5	2100	-	2100	-
Ca	mg/L	495	757	-	598	-	721	-
Mg	mg/L	622	536	13,8	3783	-	3727	-

Results… Cont'd

Treatment of real AMD under optimum conditions using MgO, metakaolinite and composite

			Metakaolinite		MgO		Composite	
Element	**Units**	**Real AMD**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**
Sulphate	mg/L	15000	10150	32,3	9000	40	7500	50
Fe	mg/L	1800	1650	8,3	0,1	100	1	100
Al	mg/L	500	750	-	0,1	100	0,1	100
Mn	mg/L	98	60	38,8	0,1	99,9	0	100
Cr	mg/L	0,09	0	100	0	99,9	0	100
Zn	mg/L	120	10	91,7	0	100	0	100
Cu	mg/L	0,59	0,2	74,6	0	99,8	0	100
Ni	mg/L	1,6	1	37,5	0	99,9	0	100
Pb	mg/L	0,2	0,1	65	0	100	0	100
pH	pH	2	2,8	-	10,9	-	10,5	-
EC	mS/ cm	1709	1700	0,5	2100	-	2100	-
Ca	mg/L	495	757	-	598	-	721	-
Mg	mg/L	622	536	13,8	3783	-	3727	-

Results… Cont'd

Treatment of real AMD under optimum conditions using MgO, metakaolinite and composite

			Metakaolinite		MgO		Composite	
Element	**Units**	**Real AMD**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**
Sulphate	mg/L	15000	10150	32,3	9000	40	7500	50
Fe	mg/L	1800	1650	8,3	0,1	100	1	100
Al	mg/L	500	750	-	0,1	100	0,1	100
Mn	mg/L	98	60	38,8	0,1	99,9	0	100
Cr	mg/L	0,09	0	100	0	99,9	0	100
Zn	mg/L	120	10	91,7	0	100	0	100
Cu	mg/L	0,59	0,2	74,6	0	99,8	0	100
Ni	mg/L	1,6	1	37,5	0	99,9	0	100
Pb	mg/L	0,2	0,1	65	0	100	0	100
pH	pH	2	2,8	-	10,9	-	10,5	-
EC	mS/ cm	1709	1700	0,5	2100	-	2100	-
Ca	mg/L	495	757	-	598	-	721	-
Mg	mg/L	622	536	13,8	3783	-	3727	-

Results… Cont'd

Treatment of real AMD under optimum conditions using MgO, metakaolinite and composite

			Metakaolinite		MgO		Composite	
Element	**Units**	**Real AMD**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**	**Treated AMD**	**% removal**
Sulphate	mg/L	15000	10150	32,3	9000	40	7500	50
Fe	mg/L	1800	1650	8,3	0,1	100	1	100
Al	mg/L	500	750	-	0,1	100	0,1	100
Mn	mg/L	98	60	38,8	0,1	99,9	0	100
Cr	mg/L	0,09	0	100	0	99,9	0	100
Zn	mg/L	120	10	91,7	0	100	0	100
Cu	mg/L	0,59	0,2	74,6	0	99,8	0	100
Ni	mg/L	1,6	1	37,5	0	99,9	0	100
Pb	mg/L	0,2	0,1	65	0	100	0	100
pH	pH	2	2,8	-	10,9	-	10,5	-
EC	mS/ cm	1709	1700	0,5	2100	-	2100	-
Ca	mg/L	495	757	-	598	-	721	-
Mg	mg/L	622	536	13,8	3783	-	3727	-

Conclusion

1. The levels of inorganic contaminants in metalliferous effluents were reduced after applying the metakaolinite, MgO and their composite.
2. The treatment efficiency order = composite ≥ MgO ≥ metakaolinite.

Acknowledgement

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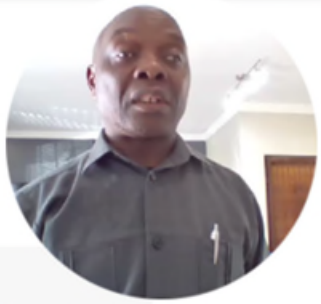

02

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Thank you!