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Remediation of Acid Mine Drainage by using Tailings Decant Water as a Neutralization Agent in Sarcheshmeh Copper Mine

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Abstract: This study presents the results of a study on Acid Mine Drainage (AMD) resources and its remediation in Sarcheshmeh open pit mine, one of the world largest porphyry copper deposits in the southeastern of Iran. Water quality samples were taken from water resources around the Sarcheshmeh mine and from tailing decant water pond. Sarcheshmeh waste dumps are the most important AMD generating sources. Also, Sarcheshmeh tailings decant water acts as a neutralization agent for treating AMD and reduce AMD's metals. Due to the mixing of the tailing decant water with the AMD that reached Sarcheshmeh tailings decant pond by Shur River, Cu, Fe, Mn and Zn concentration reduce around to 99.9, 99.3, 95.9 and 88.92% respect to Shur rive, the source of heavy metals. The reduction ratio for metals is Cu>Fe>Ni>Mn>Zn>Pb>CD>Mg.

Key words: Acid mine drainage, decant water, Sarcheshmeh copper mine, waste dump

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INTRODUCTION

One of the earth's most abundant natural resources is water which is a resource that could be at risk by the activities of some industries. It is important that the overwhelming majority of the earth's water exists in forms that render it almost unusable directly for man's needs, either because of salinity, or its physical nature (ice) or location in the ground. Usable fresh water in lakes and rivers, upon which we mostly rely, comprises no more than 0.0161% of the earth's total water. It is this small fraction of the water resources of the world that are most immediately prejudiced by mining and many other human activities (Pamukcu and Simsir, 2008). While there have been improvements in mining methods, practices and technologies in recent years, significant environmental risks, such as acid min drainage (AMD), still remain. The pH of normal uncontaminated water is between pH 6-pH 8, whilst the pH of AMD water ranges between pH 2-4. This may affect both surface streams as well as groundwater resulting in pollution and degradation of the surrounding natural watercourses. The AMD is thus detrimental to the environment in that it can destroy aquatic life and contaminate water supplies. The AMD is considered to be a major problem on mines throughout the world and Sarcheshmeh, the main focus of this study, is no exception.

In the last few decades, many treatment technologies have been developed to remediate AMD. Applying Fenton process (Mahiroglu *et al*., 2009), studying roles of algae and fungi as a technology for passive remediation of AMD (Das *et al*., 2009), application of alkaline products directly into the mine discharge (Zurbuch, 1984, 1996) or incorporation of them into

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soil via trenches or as mine overburden (Hedin *et al*., 1994; Ziemkiewicz *et al*., 1994, 1997; Whitehead *et al*., 2005a, b) are of popular remediation techniques. However, these techniques made various problems due to the formation of metal precipitates and the armoring of the alkaline products (Cravotta, 2003; Hedin *et al*., 1994; Johnson and Hallberg, 2005). Six continuously fed anaerobic bioreactors employing organic and alkaline waste materials were operated by McCauley *et al*. (2009) to investigate relationships between metal and sulfate removal from AMD. Injection of lime-rich grout into abandoned underground coal mines is a popular technique that provides a permanent solution to control AMD (Bulusu *et al*., 2007; Siriwardane *et al*., 2003; Taerakul *et al*., 2004). However, Demers *et al*. (2009) investigated the use of activated silica sol, an inorganic silicate polymer used in municipal water treatment, as a flocculant in the treatment of AMD to improve long term stability of sludge. The AMD mitigation on the Sarcheshmeh is the main focus of this study. The main aim of this study is to identify and investigate a variety of long-term water methods relevant to acid mine water mitigation in relation to Sarcheshmeh copper mine.

Sarcheshmeh porphyry copper mine is located in the Central Iranian Volcanic belt (Fig. 1). This belt with northwest-southeast direction extends as the same direction as Zagros (Derakhshani and Farhoudi, 2005). The eruption of this belt started in the Cretaceous and in the Eocene it got to its highest activity (Derakhshani and Mehrabi, 2009a). Most of the region that we are studying is consisted of volcanic-alluvial parts of Eocene time (Derakhshani and Abdolzadeh, 2009a, b). From the middle Oligocene to Miocene, the injection of diorite to granodiorite bodies creates the porphyry copper of the zone and most

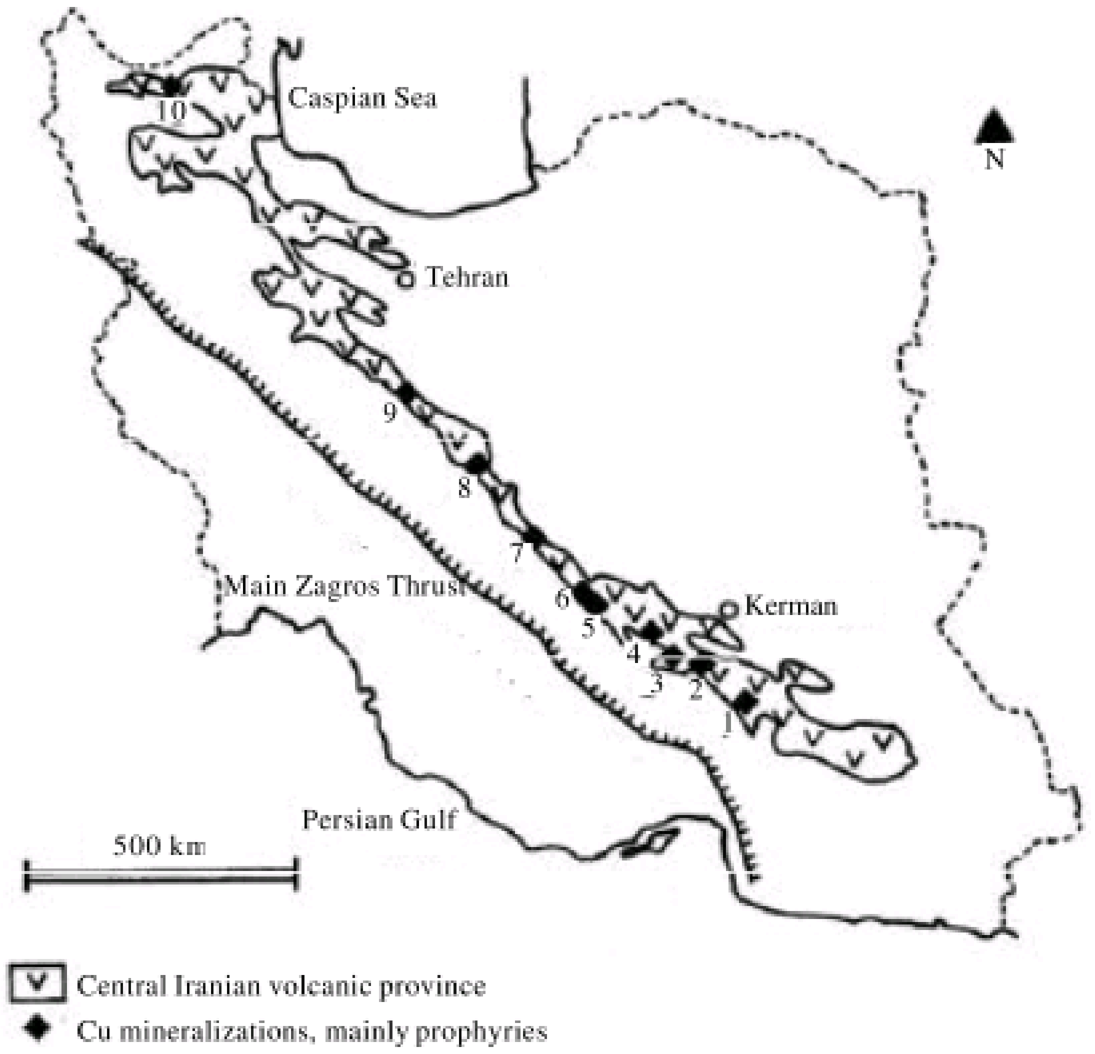

Fig. 1: A sketch map showing the position of the Central Iranian volcanic belt and some porphyry-type copper mineralization of Kerman and Yazd region relative to the main Zagros Thrust. 1: Bahraseman, 2: Takht, 3: Kuh Panj, 4: Sarcheshmeh, 5: Meiduk, 6: Gowde Kolvary, 7: Darrehzereshg, 8: South of Ardestan, 9: Sharifabad, 10: Sungun (after Shahabpour and Doorandish, 2008)

of related occurrences. Also, in many areas extensive layers have covered these intrusive bodies in guise of little diorites and stock. After that dykes and stocks of diorite-quartz diorite in upper Miocene had been implementing to plutonium cycle in the area (Derakhshani and Abdolzadeh, 2009b).

The Sarcheshmeh tailings dam is located on the Shur River, 20 km far from the Sarcheshmeh copper mine. The Sarcheshmeh tailings are discharged into the tailings dam reservoir. The Shur River starts from the Sarcheshmeh mine and discharges into the

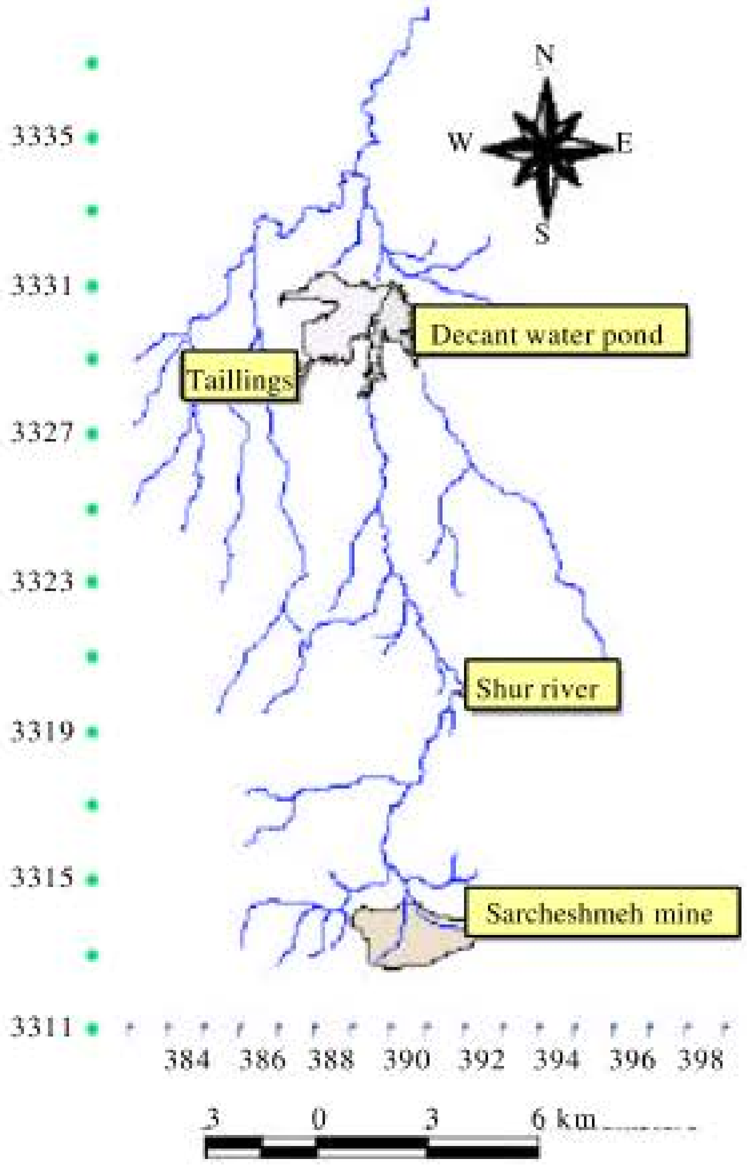

Fig. 2: Shur River, Sarcheshmeh mine and tailings dam relationship

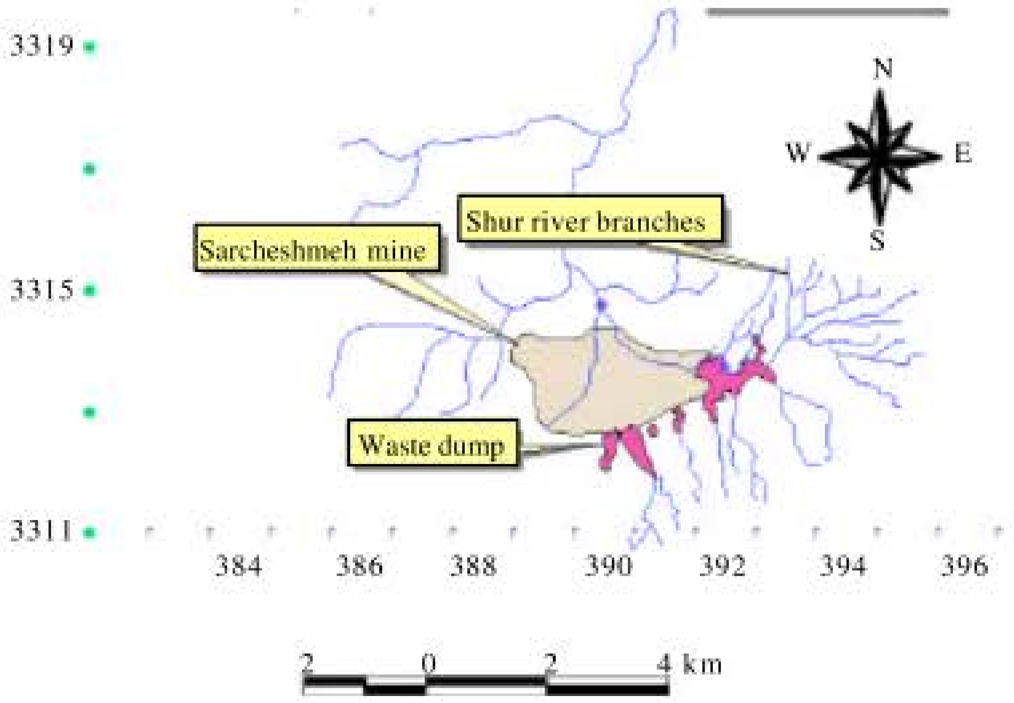

Fig. 3: The Sarcheshmeh mine wastes accumulated in the Shur River branches

Sarcheshmeh tailings decant water pond. The decant water discharges into the decant water pond too. The AMD and the decant water have been mixed in the decant water pond (Fig. 2). Also, the Sarcheshmeh mine's wastes are accumulated on the Shur River branches (Fig. 3). Therefore, the Shur River runoff was accumulated behind the waste dumps. It flows beneath the waste dump and reached the Shur rive channel. The water accumulation behind the waste dumps and it flows beneath them, causes the water, air and sulfuric minerals contact. The surface waters drainage in the Sarcheshmeh mine have a higher pH and lower concentration of trace metals compared with some other porphyry copper deposits (Shahabpour and Doorandish, 2008). The problem of acid mine drainage (AMD) has been present since mining activity began 35 years ago.

MATERIALS AND METHODS

This study is concentrated on remediation of AMD by using tailings decant water as a neutralization agent in Sarcheshmeh copper mine, Iran. The AMD causes environmental pollution in the industrial countries which have mining industries. The AMD prevention in its sources is a favorite alternative, but it is not possible in many locations. In this situation, the AMD should be collected and treated (Johnson and Hallberg, 2005).

Neutralization is the most common method for AMD remediation. A typical system would include adding an alkaline agent, aerating and remove precipitated material (Singh and Rawat, 1985). There are several methods for AMD prevention that could be applied singly or together depending on economic factors and location (Coulton *et al*., 2003). The AMD neutralization principal lies in the insolubility of heavy metals in alkalinity conditions. Some metals such as Fe, Zn and Cu are precipitated by controlling pH to a typical set point of 9.5. Other metals such as Ni and Cd require a higher pH, in the range of 10.5 to 11 (Aube and Zinck, 2003).

The AMD treatment methods could be divided to abiotic and biological system. Both abiotic and biological system include active (i.e., require continuous inputs of resources to sustain the process) and passive (i.e., require relatively little resource input once in operation) methods (Johnson and Hallberg, 2005). Recent approaches use passive treatment systems for treating AMD. These systems are relatively inexpensive to build and require minimum maintenance during their lifetime compared to active, mechanical treatment (DeNicola and Stapleton, 2002). Active treatment is generally adopted for those waters that are difficult to treat passively, or where other considerations, such as land availability, prevent the use of passive treatment (Coulton *et al*., 2003). The active treatment systems produce high volume iron-rich sludge (Johnson and Hallberg, 2005).

The AMD treatment by passive systems has received much attention lately (Ziemkiewicz *et al*., 2003). These systems could be classified according to different criteria such as: aerobic or anaerobic, complexity and requirements for maintenance and dominant chemical or biological processes occurring during treatment (Neculita *et al*., 2007). Limestone-based systems are another system for AMD treating (Ziemkiewicz *et al*., 1997). Limestone is the most inexpensive material for acid neutralization, but due to armoring of limestone it isn't typically recommended for highly acidic, Fe-rich waters. Armoring of limestone is a common cause of failure in limestone-based drainage treatment system (Hammarstrom *et al*., 2003).

RESULTS

In order to AMD management, the AMD sources must be recognized. Water quality samples were taken around the Sarcheshmeh mine to investigate the AMD generation. The

Table 1: Dump No.11 upstream data, UD (ppm)

Statistical analysis	pH	Cu	Fe	Mn	Zn
Min	4.10	3.34	0.00	18.45	4.78
Max	5.70	145.14	0.25	124.56	29.16
Average	4.47	63.22	0.08	61.40	15.91
SD	0.39	37.44	0.06	32.23	7.50

Table 2: Dump No.11 downstream data, DD (ppm)

Statistical analysis	pH	Cu	Fe	Mn	Zn
Min	3.25	60.00	0.04	27.38	9.45
Max	4.18	180.00	0.78	95.00	31.30
Average	3.77	118.12	0.30	66.55	21.61
SD	0.18	34.10	0.17	19.73	6.02

Table 3: Sarcheshmeh drainage water wells data (ppm)

Statistical analysis	pH	Cu	Fe	Mn	Zn
DW01					
Average	7.31	0.04	0.19	0.21	0.03
Min	7.09	0.00	0.00	0.00	0.00
Max	7.49	0.08	0.43	0.90	0.10
SD	0.12	0.03	0.14	0.31	0.03
DW02					
Average	6.15	0.02	2.18	0.97	0.23
Min	5.95	0.00	0.83	0.80	0.12
Max	6.29	0.06	4.70	1.27	0.42
STDEV	0.18	0.03	2.19	0.26	0.16
DW03					
Average	6.94	0.14	0.52	0.55	0.09
Min	6.71	0.00	0.05	0.09	0.02
Max	7.25	0.75	2.13	0.78	0.29
SD	0.17	0.26	0.74	0.26	0.10

Table 4: Shur River data, SR (ppm)

Statistical analysis	pH	Cu	Fe	Mn	Zn
Min	3.84	0.00	0.00	2.56	0.43
Max	6.75	69.82	11.50	49.69	15.37
Average	5.46	10.84	2.72	12.88	4.43
SD	0.78	18.52	2.89	10.01	3.60

water quality samples were taken from discharge wells in the mine pit, the Shur River runoff (upstream and downstream of the waste dumps), the decant water pond and from Shur River runoff (Fig. 4).

Table 1 shows the Shur River runoff data, accumulated in the upstream of the waste dump No.11 (UD). Also, Table 2 shows the Shur River runoff data, accumulated in the downstream of the waste dump No. 11 (DD). Comparison the up and downstream dump No. 11 data show that the metal concentrations increase in the dump downstream. Cu, Fe, Mn and Zn concentration increased 87.8, 295.5, 8.4 and 35.8%, respectively.

For water level control in the mine area, there are 11 wells in Sarcheshmeh mine pit. Their total capacity is 120 L sec^{-1}. the extracted water discharged into Shur River. Table 3 shows quality data measure in three wells.

The Shur River quality is measured in SR point. The Shur River discharge in the SR is 150 L sec^{-1}. Table 4 shows the quality data in the SR. According to Table 1 to 4, SR acidity is lower than UD and DD. This is due to water well discharge into Shur River. With pH increasing in the SR, metal concentration reduced relative to UD and DD too. The Cu, Mn and Zn concentration in SR reduce 90.8, 80.6 and 79.5%, respectively relative to DD.

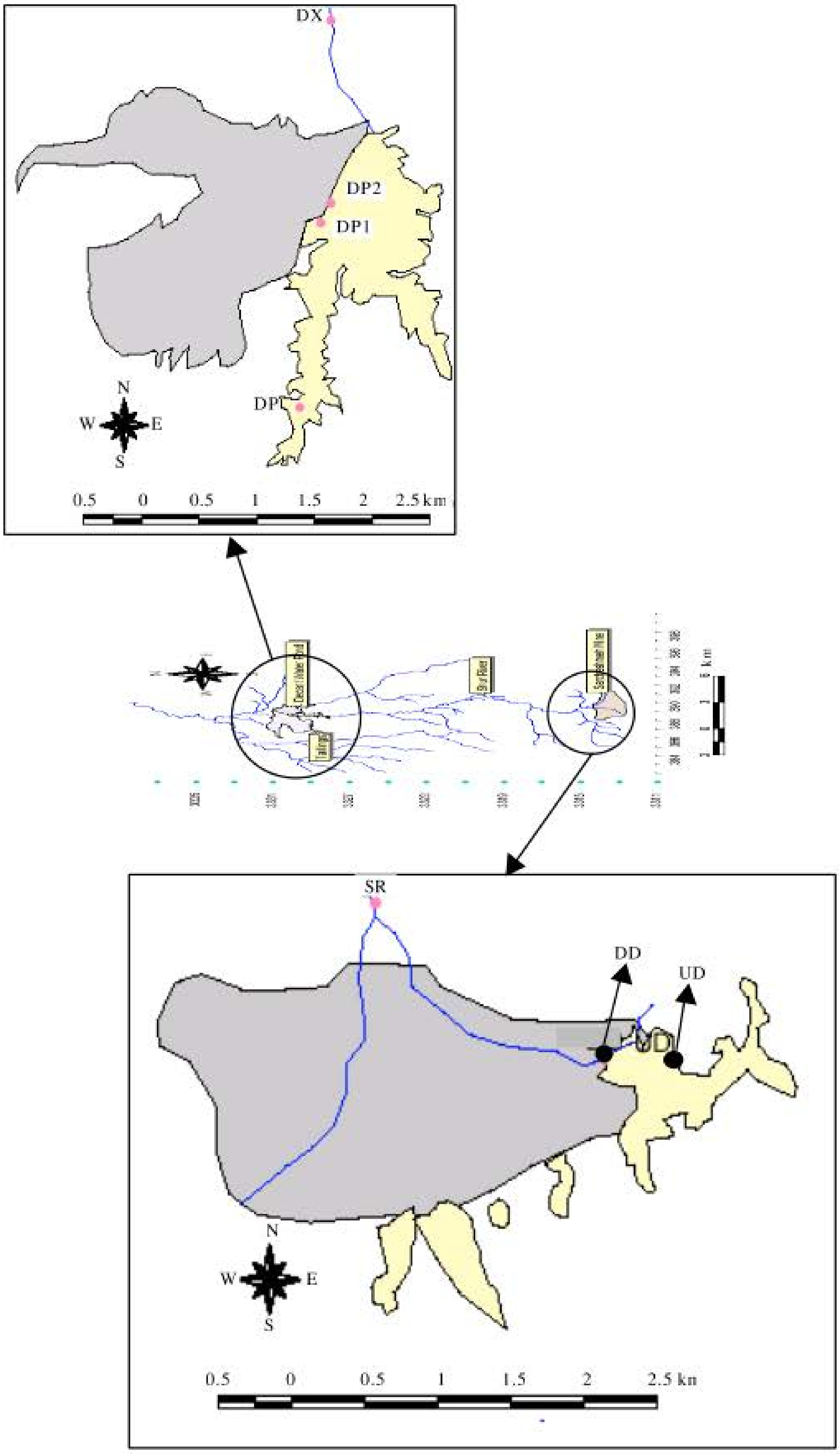

Fig. 4: Sampling point near the Sarcheshmeh mine and the decant water pond

Table 5: Sarcheshmeh decant water data, TA (ppm)

Statistical analysis	pH	P.Alk	M.Alk
Average	11.55	421.22	496.43
Minimum	7.50	21.00	27.00
Maximum	12.30	1070.00	3300.00
SD	0.95	265.02	450.41

Table 6: Sarcheshmeh decant water pond data, DP1 (ppm)

Variables	Count	Mean	SD	Minimum	Maximum
TSS	69	6.52	5.22	1.00	28.00
Cu	69	0.15	0.70	0.01	4.91
Fe	69	0.05	0.17	0.01	1.18
Ni	69	0.04	0.07	0.01	0.46
Pb	69	0.10	0.08	0.01	0.38
Zn	69	0.71	1.38	0.01	5.21
Mg	69	17.31	5.69	5.83	32.28
Mn	69	0.82	1.59	0.01	9.75
Co	69	0.03	0.03	0.01	0.19
Cd	69	0.01	0.01	0.01	0.04
Mo	69	1.20	0.48	0.27	2.91
pH	69	7.67	0.75	4.90	11.50

Table 7: Sarcheshmeh decant water pond data, DP2 (ppm)

Variables	Count	Mean	SD	Minimum	Maximum
TSS	69	6.87	7.39	1.00	53.00
Cu	69	0.09	0.64	0.01	5.34
Fe	69	0.03	0.10	0.01	0.81
Ni	69	0.03	0.05	0.01	0.41
Pb	69	0.10	0.07	0.01	0.35
Zn	69	0.58	1.13	0.01	4.32
Mg	69	16.70	5.87	4.17	31.20
Mn	69	0.73	1.42	0.01	10.71
Co	69	0.03	0.02	0.01	0.22
Cd	69	0.01	0.00	0.01	0.05
Mo	69	1.20	0.58	0.17	3.20
pH	69	7.55	0.60	5.30	8.80

Table 8: Sarcheshmeh decant water pond data, DP (ppm)

Elements	Count	Maximum	Minimum	Mean	SD
Cu	69	10.18	0.01	0.289688	1.473281
Fe	69	1.30	0.01	0.053750	0.168697
Ni	69	0.62	0.01	0.043906	0.117319
Pb	69	0.35	0.01	0.097188	0.077326
Zn	69	6.14	0.01	0.653438	1.286866
Mg	69	35.84	6.60	17.334690	6.031948
Mn	69	11.23	0.02	0.897031	2.250966
Co	69	0.28	0.01	0.031406	0.047871
Cd	69	0.06	0.01	0.012344	0.010038
Mo	69	3.20	0.18	1.199841	0.566450
As	69	0.80	0.80	0.800000	8.95E-16
pH	69	9.50	4.90	7.596667	0.707099

Table 5 shows the decant water quality data. Base on the quality data, pH of decant water is more than 10. The Shur River discharged into the decant water pond. The Shur River acidity would be reduce due to mixing with the decant water. The decant water pond quality samples were collected in three point (DP1, DP2 and DP). Quality samples from the decant pond outflow were collected in DX (Fig. 4). Table 6 shows the quality data in the DP1. Also Table 7 and 8 show the quality data in the DP2 and DP, respectively.

Figure 5a-d show the different element concentration in the decant pond. Element concentration reduce toward the decant pond flow direction. This is due to mixing the Shur River flow and the decant water.

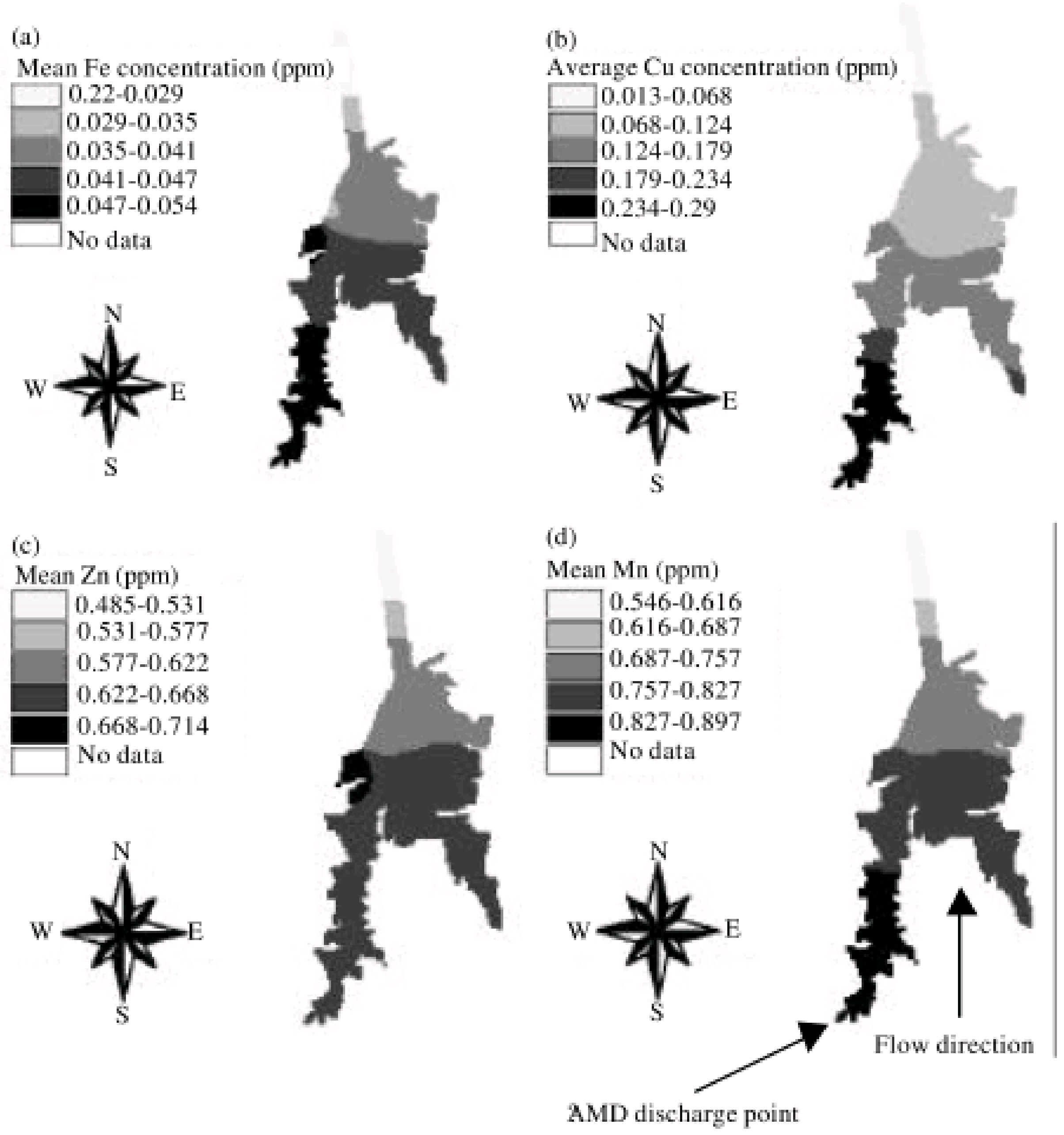

Fig. 5: Some heavy metals concentration in the decant water pond. (a) Fe, (b) Cu, (c) Zn and (d) Mn

Table 9: Decant water pond outflow data, DX (ppm)

Variable	Count	Mean	SD	Minimum	Maximum
Cu	67	0.01	0.02	0.01	0.14
Fe	67	0.02	0.03	0.01	0.25
Ni	67	0.02	0.02	0.01	0.08
Pb	67	0.08	0.06	0.01	0.21
Zn	67	0.49	1.08	0.01	4.72
Mg	67	15.86	5.27	5.20	27.80
Mn	67	0.53	0.73	0.01	3.53
Co	67	0.02	0.01	0.01	0.09
Cd	67	0.01	0.00	0.01	0.02
Mo	67	1.14	0.57	0.22	3.20
pH	65	7.63	0.54	5.30	9.50

Table 9 shows the decant pond outflow (DX) statistical parameters. pH increase in the decant point outflow (DX) relative to the source of pollution (SR). Also, the heavy metal concentration reduce in the decant pond outflow. Cu, Fe, Mn and Zn averages ratio reduction in the decant pond outflow were 99.9, 99.3, 95.9 and 88.92% relative to SR. So findings of this study correlate with the aim of the project. This study shows that the most important resource of AMD in Sarcheshmeh Copper mine is waste dumps where flow of water beneath them could increase water acidity and also heavy metals concentration. On the other hand, combination of AMD with the water which is separated from sediments could decrease acidity and dissolved heavy metals.

DISCUSSION

There are very little published works on remediation of acid mine drainage of Sarcheshmeh porphyry copper mine in Southern part of Central Iranian Volcanic Belt and to the best of our knowledge this is the first study of its kind that concentrates on the remediation of AMD by using tailings decant water as a neutralization agent in Sarcheshmeh copper mine. The results of this study strongly agree with the findings of Shahabpour and Doorandish (2008). Base on our results, waste dumps are the most important pollution source in the Sarcheshmeh mine. The Shur River acidity increases after accumulation and flows beneath the waste dumps. Therefore, its heavy metals concentration increases due to pH degradation.

Mixing of AMD and decant water, neutralize the acidity of water and is effective in decreasing of dissolved heavy metals. Previous studies used external materials to neutralize and remediate AMD, but the present research used internal materials, which are available in mining process, to remediate AMD. This method doesn’t need any external material respect to the active methods. So, this method has not any problems like high cost of neutralization materials, high volume of settled sludge and requirements to a storage which the active methods have. Maintenance is not required in this method respect to the active method. Also the efficiency of this method will not decrease during the time. In fact this method could be considered as passive methods with no need to maintenance and no need to external materials but using of available internal materials for remediating of AMD.

CONCLUSION

After mixing of the Shur River runoff with the decant water in the decant water pond, its pH increase and its heavy metals concentration decrease. Using the decant water as a neutralization agent doesn't need to an additional reservoir to disposal the created sludge. It doesn’t need additional expenses. It doesn’t need any maintenance during its life . It doesn’t need any resources as neutralization agent.

Also, this method has some disadvantages as follow:

- The Shur River flows from the Sarcheshmeh mine to the decant water pond. It may has some environmental impacts during its flow from the mine to the decant water pond
- This method couldn't work during the mine closure time. Because the decant water as a neutralization agent would be disappeared at that time

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REFERENCES

Aube, B. and J. Zinck, 2003. Lime treatment of acid mine drainage in Canada. Proceedings of the Brazil-Canada Seminar on Mine Rehabilitation, Dec. 1-3, Florianópolis, Brazil, pp: 1-12.

Bulusu, S., A.H. Aydilek and N. Rustagi, 2007. CCB-based encapsulation of pyrite for remediation of acid mine drainage. J. Hazardous Mater., 143: 609-619.

Coulton, R., C. Bullen and C. Hallett, 2003. The design and optimization of active mine water treatment plants. Land Contam Reclam, 11: 273-279.

Cravotta, C.A., 2003. Size and performance of anoxic limestone drains to neutralize acidic mine drainage. J. Environ. Quality, 32: 1277-1289.

Das, B.K., A. Roy, M. Koschorreck, S.M. Mandal, K. Wendt-Potthoff and J. Bhattacharya, 2009. Occurrence and role of algae and fungi in acid mine drainage environment with special reference to metals and sulfate immobilization. Water Res., 43: 883-894.

De Nicola, D.M. and M.G. Stapleton, 2002. Impact of acid mine drainage on benthic communities in streams: The relative roles of substratum vs. aqueous effects. Environ. Pollu., 119: 303-315.

Demers, I., J. Finch and E. El-Ammouri, 2009. Use of activated silica sol as a flocculant in the treatment of acid mine drainage to promote sludge stability. Minerals Eng., 22: 506-512.

Derakhshani, R. and G. Farhoudi, 2005. Existence of the oman line in the empty quarter of Saudi Arabia and its continuation in the red sea. J. Applied Sci., 5: 745-752.

Derakhshani, R. and A. Mehrabi, 2009a. Geologically-constrained fuzzy mapping of porphyry copper mineralization potential, Meiduk district, Iran. Trends Applied Sci. Res., 4: 229-240.

Derakhshani, R. and A. Mehrabi, 2009b. Spatial association of copper mineralization and faults/fractures in Southern Part of Central Iranian volcanic belt. Trends Applied Sci. Res., 4: 138-147.

Derakhshani, R. and M. Abdolzadeh, 2009a. Geochemistry, mineralization and alteration zones of darrehzar porphyry copper deposit, Kerman, Iran. J. Applied Sci., 9: 1628-1646.

Derakhshani, R. and M. Abdolzadeh, 2009b. Mass change calculations during hydrothermal alteration/mineralization in the porphyry copper deposit of Darrehzar, Iran. Res. J. Environ. Sci., 3: 41-51.

Hammarstrom, J.M., P.L. Sibrell and H.E. Belkin, 2003. Characterization of limestone reacted with acid-mine drainage in a pulsed limestone bed treatment system at the Friendship Hill National Historical Site, Pennsylvania USA. Applied Geochem., 18: 1705-1721.

Hedin, R.S., G.R. Watzlaf and R.W. Nairn, 1994. Passive treatment of acid mine drainage with limestone. J. Environ. Quality, 23: 1338-1345.

Johnson, D.B. and K.B. Hallberg, 2005. Acid mine drainage remediation options: A review. Sci. Total Environ., 338: 3-14.

Mahiroglu, A., E. Tarlan-Yel and M.F. Sevimli, 2009. Treatment of combined acid mine drainage: Flotation circuit effluents from copper mine via Fentons process. J. Hazardous Mater., 166: 782-787.

McCauley, C.A., A.D. O'Sullivan, M.W. Milke, P.A. Webe and D.A. Trumm, 2009. Sulfate and metal removal in bioreactors treating acid mine drainage dominated with iron and aluminum. Water Res., 43: 961-970.

Neculita, C.M., G.J. Zagury and B. Bussière, 2007. Passive treatment of acid mine drainage in bioreactors using sulfate-reducing bacteria. J. Environ. Quality, 36: 1-16.

Pamukcu, C. and F. Simsir, 2008. Prevention of chemical contamination of groundwater by mine water. J. Southern Afr. Inst. Min. Metallurgy, 108: 155-160.

Shahabpour, J. and M. Doorandish, 2008. Mine drainage water from the sar cheshmeh porphyry copper mine, Kerman, IR Iran. Environ. Monit. Assess., 141: 105-120.

Singh, G. and N.S. Rawat, 1985. Removal of trace elements from acid mine drainage. Mine Water Environ., 4: 17-23.

Siriwardane, H.J., R.S.S. Kannan and P.F. Ziemkiewicz, 2003. Use of waste materials for control of acid mine drainage and subsidence. J. Environ. Eng., 129: 910-915.

Taerakul, P., M. Lamminen, Y. He, H. Walker, S.J. Triana and E. Whitlatch, 2004. Long-term behavior of fixated flue gas desulfurization material grout in mine drainage environments. J. Environ. Eng., 130: 816-823.

Whitehead, P.G., B.J. Cosby and H. Prior, 2005a. The Wheal Jane wetlands model for bioremediation of acid mine drainage. Sci. Total Environ., 338: 125-135.

Whitehead, P.G., G. Hall, C. Neal and H. Prior, 2005b. Chemical behavior of the Wheal Jane bioremediation system. Sci. Total Environ., 338: 41-51.

Ziemkiewicz, P.F., J.G. Skousen and R. Lovett, 1994. Open limestone channels for treating acid mine drainage: A new look at an old idea. Green Lands, 24: 36-41.

Ziemkiewicz, P.F., J.G. Skousen, Brant, D.l. and R.J. Lovett, 1997. Acid mine drainage treatment with armored limestone in open limestone channels. J. Environ. Quality, 26: 1017-1024.

Ziemkiewicz, P.F., J.G. Skousen and J. Simmons, 2003. Long-term performance of passive acid mine drainage treatment systems. Mine Water Environ., 22: 118-129.

Zurbuch, P.E., 1984. Neutralization of acidified streams in West Virginia. Fisheries, 9: 42-47.

Zurbuch, P.E., 1996. Early results from calcium carbonate neutralization of two West Virginia rivers acidified by mine drainage. Proceedings of the 17th West Virginia Surface Mine Drainage Task Force Symposium, Apr. 2-3, Morgantown, WV, pp: L1-L9.