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AN OBJECTIVE INDEX FOR THE ASSESSMENT OF THE CONTAMINATION OF SURFACE AND GROUND WATERS BY ACID MINE DRAINAGE

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Summary

Temporal and spatial comparisons of acid mine drainage (AMD) contaminated waters are difficult due to the complex physico-chemical nature of the pollutant. An objective index has been developed and evaluated for assessment of such waters. The acid mine drainage index (AMDI) is calculated using a modified arithmetic weighted index using seven parameters most indicative of AMD contamination. These are pH sulphate, iron, zinc, aluminium copper and cadmium. Weighting was used to express the relative indicator value of each parameter. The pH and sulphate were considered to be of greatest indicator value as they were unaffected by sorption processes, while sulphate was also unaffected by natural neutralization processes. The AMDI as proposed is designed to detect and quantify contamination from AMD and to help categorize samples, quantify impact to receiving waters and to monitor recovery. The AMDI is fully evaluated and discussed.

Introduction

Acid mine drainage (AMD) is a major environmental problem throughout the world, adversely affecting both surface and ground waters. It is caused by the oxidation and hydrolysis of metal sulphides (in particular pyrite) in water permeable strata, or in mined spoil dumped on the surface. This results in the formation of several soluble hydrous iron sulphates, the production of acidity and the subsequent leaching of metals (Nordstrom, 1982). It is principally associated with the mining of sulphide ores, the most commonly associated minerals being sulphur, copper, zinc, silver, gold, lead and uranium. AMD is a complex pollutant characterised in surface and ground waters by elevated concentrations of iron and sulphate, a low pH, and elevated concentrations of a wide variety of metals depending on the host rock geology. The impact of AMD on rivers and lakes is also complex due to the multi-factor nature of the impacts (Kelly, 1988).

Avoca mines in County Wicklow, Ireland, are currently being studied in order to characterise AMD generation and the impact of AMD on the environment. At Avoca the important mineral sulphides are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and sphalerite (ZnS). The area has been extensively mined underground and in more recent times by open cast techniques for both sulphur and copper. This has resulted in large quantities of spoil being deposited on the surface. AMD is produced by chemical and biological action within the surface spoil, as well as in the underground workings which are partially flooded.

There is considerable difficulty in comparing temporal and spatial variation of AMD waste waters, and impacted surface and grounds waters, using individual chemical and physical parameters. This is because slight variations in environmental conditions can cause significant differences in individual parameter flux rates (e.g. adsorption, co-precipitation etc.). Therefore during the extensive studies at Avoca mines a need arose for an assessment technique to comparatively quantify sources of AMD and to identify whether physico-chemical recovery was occurring within the river.

Subjective decisions regarding the physico-chemical quality of AMD and AMD contaminated waters are generally made as *valued judgements* by experts from a wide variety of disciplines, based upon incident ranges in the concentration of specific parameters. This makes comparison of water quality both spatially and temporally difficult. Water quality indices were originally devised by Horton (1965) as a theoretical replacement to purely subjective methods of water quality classification. They have now become a widely adopted method of classifying overall water quality (Brown *et al.*, 1970; Harkins, 1974; House and Ellis, 1987; Joung *et al., 1979*; Scottish development Department, 1976). This paper reports on the development and evaluation of an objective index for the assessment of the contamination in surface and ground waters by AMD.

Methodology

The Acid Mine Drainage Index (AMDI)

The Scottish Development Department (SDD) (1976) evaluated six different water quality indices (WQIs) for monitoring of surface waters by the River Purification Boards in Scotland. The original water quality index had been based on an arithmetic formulation with the index derived simply by summing up the individual products of water quality rating and corresponding weights (equation 1).

Arithmetic weighted index

$$WQI = \sum_{i=1}^{n} q_i w_i \qquad (1)$$

Where WQI is the water quality index being a number from 0 to 100 on a continuous scale, n is the number of parameters, q_i the water quality of the i th parameter, and w_i the weighting attributed to the i th parameter.

The problem with this approach is that it lacks sensitivity in the effect that a single bad parameter value will have on the WQI. In consequence the SDD compared a number of modifications of this index . Two other indices were also found to be useful WQIs. The modified arithmetic weighted index is the square of the arithmetic weighted index divided by 100 (equation 2), while the geometric weighted index is determined by multiplying by each water quality rating raised to the power of its weighting (equation 3).

Modified arithmetic weighted index

$$\mathrm{WQI} = 1/100 \; {\sum_{i=1}^{n} q_i w_i}^{\,2} \tag{2}$$

The equation above (2) has been modified to prevent eclipsing. This occurs when one or more parameters indicate high contamination but the overall index does not reflect this fact so underestimating the degree of contamination (Ott, 1978).

From the SDD study the modified arithmetic index (2) was adopted for the estimation of water quality in Scottish rivers using ten weighted parameters. These were dissolved oxygen, biochemical oxygen demand, faecal coliforms, pH, conductivity, total oxidized nitrogen, orthophosphate, suspended solids and temperature. The geometric weighted index (3) was adequate but if one or more of the parameters scored zero then the WQI became zero irrespective of the other parameter scores. This index also took considerably longer to calculate compared to the others. For these reasons it was not adopted for routine use.

Geometric weighted index

$$\mathrm{WQI} = \prod_{i=1}^{n} q_i^{w_i} \tag{3}$$

The Acid Mine Drainage Index (AMDI) is calculated using the modified arithmetic weighted index (2). Seven parameters were selected and their respective weightings (w_i) are given in Table 1. The parameters selected were those most indicative of AMD contamination (i.e. low pH, high sulphate and associated cations). Weighting was used to express the relative indicator value of each parameter which was a function of its concentration in highly contaminated water compared to uncontaminated water, and detection limits of the analytical procedures used. The pH and sulphate were considered to be of highest indicator value as they were unaffected by sorption processes, while sulphate was also unaffected by neutralization.

Table 1. Parameters and weightings used in the calculation of the AMDI

i	Parameter	Unit	Weighting w_i
1	pH		0.20
2	Sulphate	mg/l	0.25
3	Iron	mg/l	0.15
4	Zinc	mg/l	0.12
5	Aluminium	mg/l	0.10
6	Copper	mg/l	0.08
7	Cadmium	µg/l	0.10
Total weighting			1.00

A weighted water quality rating table (Table 2) is used to calculate the water quality score for each of the seven variables from which the AMDI is calculated using equation 4 below.

$$\text{AMDI} = \frac{[\sum \text{water quality scores}]^2}{100} \qquad (4)$$

In order to make the index as robust as possible then a correction factor was used if parameters were not measured for technical reasons. The correction factor for missing parameters is [1/ (new total /100)]. For example if aluminium analysis was unavailable then the correction factor would be (1/0.90). So the calculation of AMDI would be:

$$\text{AMDI} = \frac{[\sum \text{water quality scores} \ \text{x} \ (1/0.90)]^2}{100} \qquad (5)$$

Study site:

As wide a range as possible of surface and ground waters on the mine site were examined, these included springs, leachate streams (adits), surface runoff, temporary and permanent ponds and lakes. The impact on the receiving water into which the mines drained (the River Avoca) was assessed by regular monitoring of an upstream unpolluted site and a number of sites downstream of the mines. Downstream samples were taken outside the mixing zone. The mixing zone was examined separately as were the various minor contaminated streams that also enter the river below the mine zone. In all 42 separate sites were monitored although not

Table 2. Water quality index for acid mine drainage and contaminated surface and ground waters

Score	pH	Sulphate (mg/l)	Iron (mg/l)	Zinc (mg/l)	Aluminium (mg/l)	Copper (mg/l)	Cadmium (μg/l)
25		<10					
24		10-14					
23		15-29					
22		30-49					
21		50-99					
20	≥6.5	100-199					
19	6.2-6.4	200-299					
18	5.9-6.1	300-399					
17	5.6-5.8	400-499					
16	5.2-5.5	500-599					
15	4.9-5.1	600-799	<0.05				
14	4.5-4.8	800-999	0.05-0.99				
13	4.1-4.4	1000-1499	1.00-4.99				
12	3.9-4.0	1500-1999	5.00-9.99	<0.05			
11	3.7-3.8	2000-3999	10-24	0.05-0.49			
10	3.5-3.6	4000-5999	25-49	0.5-0.9	<1.0		<10
9	3.3-3.4	6000-7999	50-99	1.0-4.9	1.0-4.9		10-24
8	3.1-3.2	8000-9999	100-149	5.0-9.9	5.0-9.9	<0.05	25-49
7	2.9-3.0	10000-11999	150-199	10-24	10-24	0.05-0.99	50-99
6	2.7-2.8	12000-13999	200-249	25-49	25-49	1.0-4.9	100-249
5	2.5-2.6	14000-15999	250-499	50-74	50-99	5.0-9.9	250-499
4	2.3-2.4	16000-17999	500-749	75-99	100-299	10-24	500-749
3	2.1-2.2	18000-19999	750-999	100-249	300-799	25-49	750-999
2	1.8-2.0	20000-21999	1000-1999	250-499	800-1199	50-99	1000-1499
1	1.5-1.7	22000-24999	2000-2999	500-749	1200-1999	100-249	1500-1999
0	≤1.4	≥25000	≥3000	≥750	≥2000	≥250	≥2000

all were sampled regularly. For example, a number of sites dried up during the summer, or were only present during or immediately after heavy rainfall. Sample sites were categorized into a number of similar groups based on source classification. These are: 1. springs and seepage from spoil; 2. Surface runoff; 3. Leachate streams (adits); 4. River mixing zone; 5. Contaminated river; 7. Contaminated streams containing AMD; 8. Uncontaminated river; 9. Lake in Cronebane pit. The mines discharge into the River Avoca just downstream of the White Bridge, and samples were taken immediately after complete mixing at 2.5 km (site 5.1) then at 6 km below the White Bridge (5.2). A major tributary with the same discharge rate as the River Avoca enters the river at 7.25 km. The next sample sites (5.3 and 5.4) are 10.5 and 12.25 km downstream of the White Bridge respectively. The final site is located 13.75 km downstream of the White Bridge (site 5.5), just 1.25 km from where the river finally enters the sea at the port of Arklow

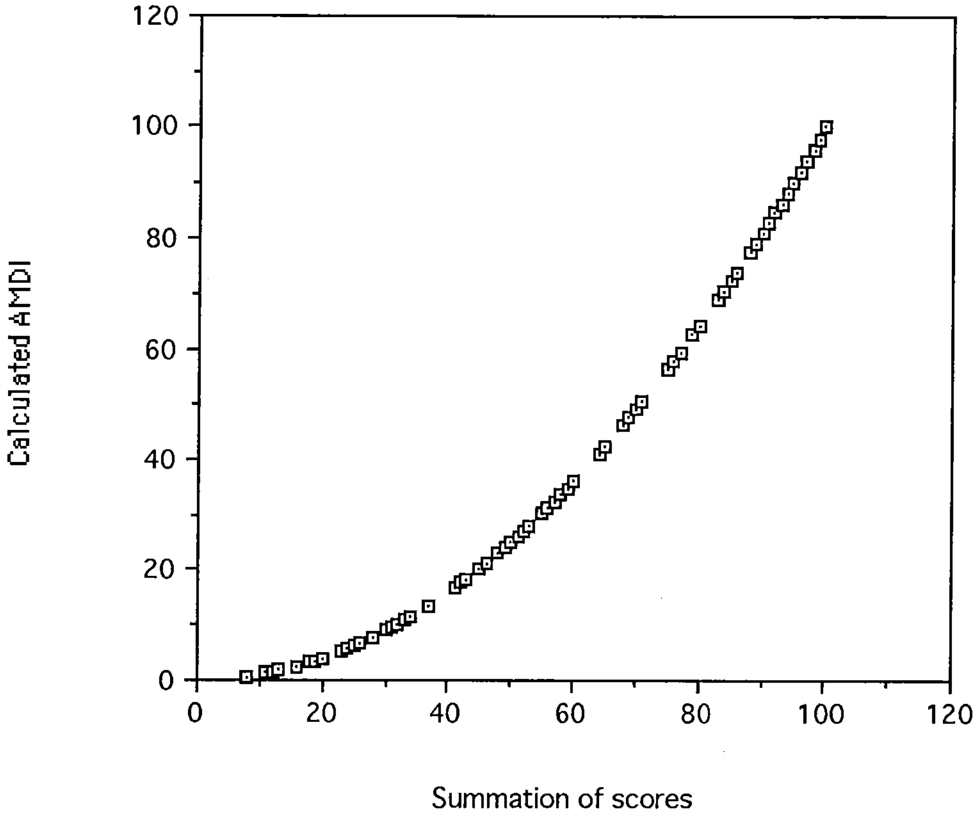
Water quality analysis:

Water samples were filtered as collected in the field through a cellulose nitrate filter paper (pore size 0.45 μm). Two sub-samples were taken, one being acidified for subsequent metal analysis and another for sulphate, conductivity and pH analysis. Samples were stored at 4^{o}C. Conductivity and pH measurements were carried out within 24 hours of sample collection using a WTW® LF196 conductivity meter and a Jenaway® 3015 pH meter. Metals were analysed using atomic adsorption spectrophotometry (AAS) and sulphate analysis was carried out by ion chromatography using a Dionex® 2020. Standard methods were used throughout (APHA, 1989).

Results and discussion

The $\sum$ water quality scores (i.e. the arithmetic weighted index) is in itself a measure of the combined effects of the selected parameters making up the acid mine drainage (AMD). However, problems arise in discriminating between sites where the degree of contamination is very low (e.g. impacted rivers and lakes). In contrast, low $\sum$ water quality scores all indicate strongly contaminated water. Therefore by using the modified version (2) of the arithmetic weighted index (1), the index value becomes more sensitive at higher $\sum$ water quality scores ensuring a higher discriminatory power. This is illustrated in Fig. 1, where a $\sum$ water quality score of 10 has an AMDI value of 1, 30 an AMDI value of 9, 50 an AMDI value of 25, 90 an AMDI value of 81, and 95 an AMDI value of 90.

Fig. 1 Summation of scores plotted against calculated AMDI. This is a comparison of the arithmetic weighted index against the modified arithmetic weighted index.



The mean AMDI for all the major AMD sources and impacted waters are given in Table 3, with a summary of mean water quality for each group in Table 4. The AMDI and water quality of the major individual sites studied are considered in Tables 5 and 6 respectively.

Group 1 contains samples taken from a number of different springs emanating from spoil heaps, and also from ponds into which they discharge. Two key springs were studied (sites 1.1, 1.3) which had a mean AMDI (and range) of 6.2 (3.6-9.0) and 3.1 (0.6-11.6) respectively, while the ponds into which they discharged (sites 1.2, 1.4) have significantly ($p<0.001$) lower mean AMDI values of 4.9 (4.0-5.8) and 1.7 (1.2-2.6) respectively. So the AMDI for springs emanating from spoil heaps is expected to be within the range of 0-10, with receiving ponds having a lower range. The mean value for all the sites included in group 1 is higher than expected due to the inclusion of site 1.6 in the group, which is interflow entering the river. The interflow had a mean AMDI of 23.1 and a range of 20.3-25.0. This results in a large standard deviation for the group as a whole, while the AMDI for individual sites are generally very much narrower indicating a low variation in contaminant level even though discharge rates may be variable.

Table 3. AMDI variability of major categories of mine and receiving waters.

Category	Mean	Median	SD	Minimum	Maximum	n
1	9.6	5.8	8.7	0.6	27.0	35
2	27.1	26.0	15.9	1.4	56.3	27
3	25.1	27.0	7.3	9.0	34.8	59
4	65.2	67.3	11.3	50.4	75.7	4
5	88.0	90.3	6.3	68.9	98.0	88
7	60.8	58.5	18.6	28.1	92.2	10
8	96.9	98.0	2.9	88.4	100.0	28
9	35.7	35.4	4.1	31.4	42.3	8

Table 4. Mean water characteristics of major categories of mine and receiving waters.

Category	pH	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Cd (μg/l)	Al (mg/l)	SO_4 (mg/l)	AMDI	n
1	2.7	255	961	191	903	759	9959	9.6	35-44
2	2.7	51	546	32	125	167	3351	27.1	27-40
3	3.5	72	189	10.5	252	168	2162	25.1	59-69
4	4.7	18	39	2.2	73	8.0	375	65.2	4-8
5	6.7	0.45	0.80	0.03	0.35	0.52	24	88.0	88-113
7	4.9	5.5	13.9	2.1	5.8	14	507	60.8	10-12
8	6.8	0.05	0.14	0.01	4.7	0.25	6.5	96.9	28-38
9	2.9	13.5	31.7	10.5	43	34	501	35.7	8-9

Group 2 included all those waters classified as surface runoff. These range from highly contaminated water from spoil heaps (AMDI<10) to surface runoff diluted from water from non-contaminated areas of the site. For this reason the strength of surface runoff as measured by the AMDI is quite variable as can be seen at sites 2.1 and 2.32, with dilution being a major factor in both cases. As a general guide, the AMDI of surface water ranges from 0-35 (Table 7).

Table 5. AMDI variability of major individual sites of mine and receiving waters studied.

Category	Mean	Median	SD	Minimum	Maximum	n
Springs and seepage from spoil						
1.1	6.2	6.8	1.9	3.6	9.0	9
1.3	3.1	2.1	3.5	0.6	11.6	8
1.6	23.1	24.0	2.5	20.3	25.0	3
Surface runoff						
2.1	19.0	21.4	14.6	1.4	33.6	6
2.32	10.3	10.2	5.6	3.6	17.6	5
Leachate streams						
3.1	25.1	25.0	1.6	21.1	27.0	25
3.22	31.0	31.4	2.6	26.0	34.8	23
3.3	10.8	10.9	0.9	9.0	11.6	10
River mixing zone						
4.1	54.0	52.0	33.7	25.0	87.1	4
Contaminated river						
5.1	84.0	84.0	5.7	70.6	92.2	28
5.2	87.0	86.0	5.6	77.0	96.0	14
5.3	91.3	92.2	2.4	86.5	96.0	20
5.4	93.4	93.1	2.5	88.4	98.0	14
5.5	93.8	94.1	3.0	90.3	98.0	7
5.9	79.7	81.0	6.2	68.9	84.6	5
Contaminated streams						
7.8	87.0	91.3	8.3	77.4	92.2	3
Uncontaminated river						
8.1	96.9	98.0	2.9	88.4	100	28
Lake in Cronebane pit						
9.0	35.7	35.4	4.1	31.4	42.3	8

Group 3 includes the three main adit streams, the Deep Adit (site 3.1), Ballymurtagh Adit (3.22) and the Shallow Adit (3.3). The water from the adits is diluted by uncontaminated groundwater, with the Shallow Adit the least affected being at the highest elevation within the mine. The strength of the water discharged from the Shallow Adit remained remarkably constant with an AMDI of 10.8 (SD 0.9). This adit discharge eventually re-enters the mine workings to reappear in the Deep Adit. The mines at Avoca are drained by two large adits into the River Avoca which transects the site. The west side is drained by the Ballymurtagh Adit while the Deep Adit drains the east side. They had a mean AMDI (and range) of 31.0 (26.0-34.8) and 25.1 (21.2-27.0) respectively. While individual parameter values varied significantly, as did the discharge rates, the AMDI values remained fairly constant with standard deviations (SD) of 2.6 and 1.6 respectively. The AMDI was able to show that the two main adits were significantly different ($p<0.001$) in terms of degree of contamination by AMD, which was not clear from the individual chemical parameters. As a group, adits can be classed into two sub-groups. The main adits fall within the range of 20-35, while the Shallow Adit is more similar to group 1 waters. Infact the Shallow Adit is fed directly by such discharges as it located immediately below a large elevated spoil heap known as Mount Platt.

Table 6. Mean water characteristics of major individual sites of mine and receiving waters studied.

Category	pH	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Cd (μg/l)	Al (mg/l)	SO_4 (mg/l)	AMDI	n
1.1	2.5	433	975	165	1028	621	7723	6.2	9-11
1.3	2.6	381	1479	439	1774	1820	17883	3.1	8-9
1.6	2.9	48	38	14	63	256	3349	23.1	3
2.1	2.6	67	1507	53	197	406	8394	19.0	6-7
2.32	2.3	180	1316	81	213	259	6977	10.3	5-6
3.1	3.6	73	120	4.0	255	122	1599	25.1	25-30
3.22	3.8	30	150	1.8	46	76	1723	31.0	23-26
3.3	2.7	161	449	46	712	480	4796	10.8	10-12
4.1	4.7	33	63	4.0	145	40	572	54.0	4
5.1	5.9	0.67	1.5	0.05	0.79	0.83	25	84.0	28-38
5.2	6.0	0.50	0.6	0.02	0.70	0.20	25	87.0	14-15
5.3	6.4	0.34	0.26	0.004	0.00	0.15	23	91.3	20-24
5.4	8.5	0.17	0.21	0.005	0.00	0.31	21	93.4	14-15
5.5	8.2	0.16	0.19	0.007	0.00	0.33	23	93.8	7-15
5.9	5.4	0.93	1.93	0.18	0.00	1.9	30	79.7	5-6
7.8	6.7	0.58	2.15	0.05	0.00	1.53	41	84.8	3-4
8.1	6.8	0.05	0.14	0.01	4.7	0.25	6.4	96.9	28-38
9.0	2.9	14	32	10.5	43	34	502	35.7	8-9

Group 4 includes all the river mixing zone and so will include areas of clean river water, adit discharge as well as partially and completely mixed waters. For that reason there is a wide variation in AMDI with values recorded from 25.0 to 87.1.

Group 5 is the most interesting group as it examines the recovery of the river downstream of the mines starting at site 5.1 immediately below the mixing zone. Group 8 contains just one site (8.1) which is the uncontaminated river measured upstream of the mines. The AMDI varies from 88.4-100, indicating very clean water although due to other inputs there is a wide variation in quality, especially at high river discharge rates. The mean AMDI is 96.9 with a standard deviation of 2.9. Downstream recovery is seen with mean AMDI values of 84.0, 87.0, 91.3, 93.4 and finally 93.8 close to the estuary. Another site included in this group is site 5.9 which is an uncontaminated section of the river affected by bankside interflow from the mine. Here the effect of the AMD is clearly seen by a reduction in AMDI to 79.7 (SD 6.2).

Group 7 included small tributaries of the river outside the immediate mining area which were also contaminated by AMD. The degree of contamination varied enormously from highly impacted sites (AMDI<30) to minimal impact (AMDI >90). The mean AMDI for the group is 60.8, although the wide variation (SD 18.6) is a measure of the degree of contamination and available dilution to cope with it. For this reason it is not surprising that the AMDI of this group is significantly different to all the other groups except group 4 (the mixing zone in the river).

Group 9 also only contained a single site (9.1). This is a large lake fed by surface runoff at the base of the Cronebane Pit, a large open cast mine. The lake has a mean AMDI of 35.7 and a range of 31.4-42.3. The lake is affected by dilution by rainfall and is similar to diluted surface runoff. The AMDI of the lake is not significantly different to surface runoff (group 2), the main adits (group 3) or the mixing zone in the river (group 4).

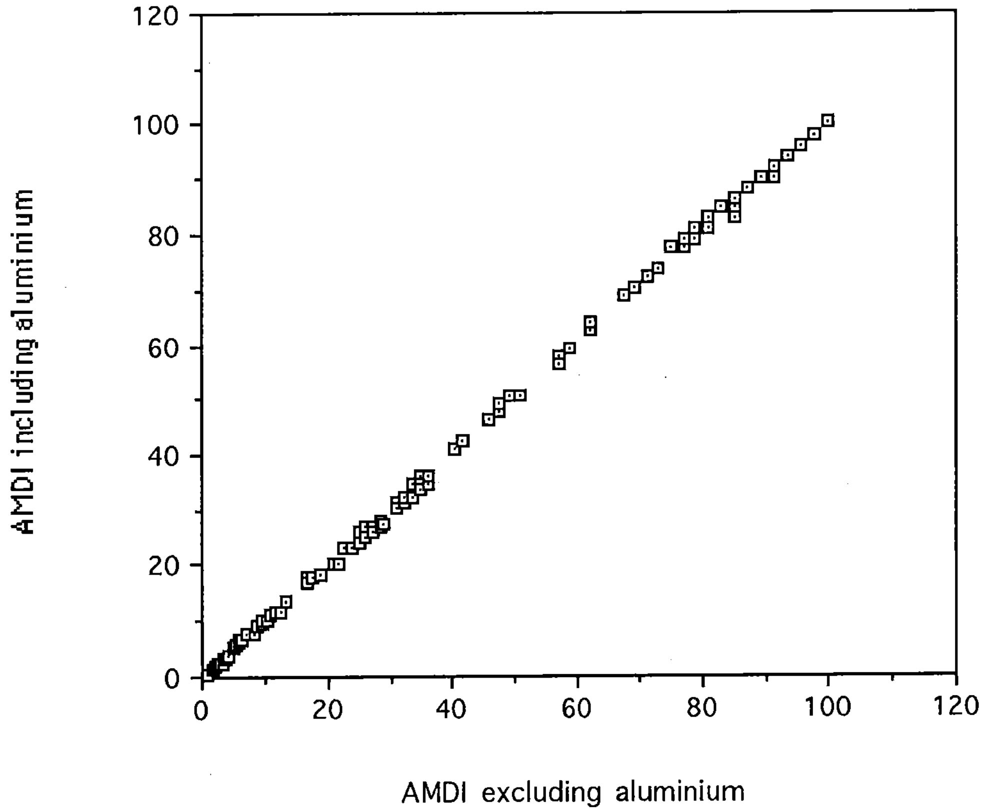
All the groups are significantly different to each other with the exceptions outlined above, indicating that the AMDI is useful in discriminating between types of AMD affected waters. Individual sites show a much lower degree of variability in AMDI (Table 5) than the groups, with significant differences discernible between all sites including the main adits and the contaminated and uncontaminated river sites. Full results are given in appendix I.

Table 7. Classification of contaminated and uncontaminated waters by AMDI.

AMDI	Type of water
0-20	Raw AMD with little or no dilution, mainly seepage from spoil collecting in surface ponds.
0-15	Surface runoff directly from spoil.
15-35	Surface runoff after prolonged rainfall or due to excessive dilution by water from uncontaminated areas.
20-35	Adit discharge. AMD subject to dilution from groundwater. Also interflow entering river at bankside and all water collected within flooded area of mine.
25-90	Mixing zone of river. AMDI dependent on degree of mixing. Also contaminated surface streams and tributaries not within mining area.
70-98	Impacted river downstream of the mines including recovery zone.
90-100	Surface and groundwater uncontaminated by AMD.

A direct comparison was made between the AMDI calculated using all the weighted parameters and with the AMDI excluding one parameter which was compensated for by using the correction factor (equation 5). Aluminium was selected as unlike the other metals analysed, it required different gases for analysis by AAS. Figure 2 shows an excellent correlation between the AMDI and the AMDI-Al (index calculated without aluminium) ($r^2 = 1.000$, $n = 259$). There was no significant difference ($p>0.05$) between the AMDI and the AMDI-Al for all sites examined. This is reflected by the regression equation (AMDI= 0.985 AMDI-Al + 0.58) which shows that the correction factor works well.

Fig. 2 Comparison between AMDI calculated with and without aluminium.



Conclusions

The AMDI is a useful method to quantitatively assess the relative strength and impact of acid mine drainage. It is able to discriminate between actual sources and types of AMD, in categorising AMD and assessing the degree of impact on surface waters, especially recovery within lotic systems.

Although the present index has been devised solely to indicate the relative contamination of surface and ground waters by AMD, it could easily be modified to alter the emphasis of the index. For example to solely assess the recovery of rivers, to measure toxicity to migratory fish, or total toxicity by calibrating the index against a standard toxicity procedure such as Microtox®. Its use in toxicity studies would allow inhibition to be related to different combinations of the physico-chemical parameters measured.

The advantage of the index is that it takes all the physico-chemical parameters into account, giving an estimation of the level of contamination. While some loss of information is inevitable, the benefit of the AMDI is an overall gain in comprehension, especially for non-specialists. Its real strength is in the comparison of impacted sites and sources of AMD both spatially and temporally. For example, it is sensitive enough to show that the two main adits draining the Avoca mines are significantly different, although the individual variability of parameters is wide. The Ballymurtagh adit was shown to be consistently less polluting and less variable in terms of contamination over time, even though the discharge rate was very variable. The AMDI was particularly useful in measuring the impact of AMD in the Avoca River, indicating a slow but significant recovery downstream which was not discernible using either conventional chemical or biological assessment procedures. In routine surveillance, the AMDI has prove useful in quality control by identifying mistakes in computation and analysis, when values fall outside the expected ranges.

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Appendix: I (a). Mean, median, number of samples (no.), standard deviation (sd), minimum and maximum for all the main groups of samples.

Group 1

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.65	2.65	44	0.29	2.1	3.3
Zn mg/l	255	180	44	273	16	1526
Fe mg/l	961	937	44	794	33	2384
Cu mg/l	191	147	44	180	4.5	590
Cd μg/l	903	710	44	754	30	2480
Al mg/l	759	514	43	731	57	2211
As μg/l	218	65	42	399	0	1641
SO4 mg/l	9959	8460	35	7044	1280	24668
Conductivity μS	6896	6580	43	3967	1750	15700
AMDI-Al	9.9	5.4	35	9.0	0.80	28.4
AMDI	9.6	5.8	35	8.7	0.6	27.0
AMDI mixed	9.6	5.8	35	8.7	0.6	27.0

Group 2

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.7	2.7	40	0.38	2.1	3.6
Zn mg/l	51	14	40	96	0.06	509
Fe mg/l	546	157	40	1188	0.75	5447
Cu mg/l	32	13	40	44	1	197
Cd μg/l	125	55	40	143	0	560
Al mg/l	167	59	37	298	5.5	1429
As μg/l	382	18	37	1253	0	7030
SO4 mg/l	3351	975	30	6321	159	26050
Conductivity μS	2936	1900	40	3179	360	13900
AMDI-Al	28.3	28.5	30	15.9	1.5	57.1
AMDI	27.1	26.0	27	15.9	1.4	56.3
AMDI mix	28.7	28.6	30	16.0	1.4	56.3

Group 3

Parameter	Mean	Median	No.	sd	Min	Max
pH	3.5	3.6	69	0.40	2.6	4
Zn mg/l	72	70	68	49	25	215
Fe mg/l	189	131	69	133	90	731
Cu mg/l	10.5	2.3	69	17	1.0	70
Cd μg/l	252	220	69	246	0	910
Al mg/l	168	114	67	152	65	618
As μg/l	36	19	67	50	5	177
SO4 mg/l	2162	1630	61	1270	1094	6330
Conductivity μS	2631	2180	69	1022	1760	5220
AMDI-Al	26.0	27.3	61	7.43	9	36
AMDI	25.1	27.0	59	7.3	9	34.8
AMDI mix	25.1	26.0	61	7.2	9	34.8

Group 4

Parameter	Mean	Median	No.	sd	Min	Max
pH	4.7	4.9	8	1.0	3.4	6.1
Zn mg/l	18	2.4	8	30	0.14	70
Fe mg/l	39	9.3	8	55	0.06	127
Cu mg/l	2.2	0.41	8	3.5	0.04	8.1
Cd μg/l	73	0	8	134	0	290
Al mg/l	8.0	5.5	4	7.9	1.8	19.2
As μg/l	1.5	1	4	1.9	0	4
SO4 mg/l	375	153	8	453	24	1104
Conductivity μS	635	240	8	750	70	1800
AMDI-Al	59.4	66.8	8	23.9	25	87.1
AMDI	65.2	67.3	4	11.3	50.4	75.7
AMDI mix	59.6	67.3	8	24.0	25	87.1

Group 5

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.7	6.3	113	1.3	4.3	10
Zn mg/l	0.45	0.38	113	0.41	0.01	2.7
Fe mg/l	0.80	0.37	113	1.38	0	8.6
Cu mg/l	0.03	0.01	113	0.06	0	0.33
Cd μg/l	0.35	0	113	2.97	0	30
Al mg/l	0.52	0.30	104	0.91	0.001	5.96
As μg/l	0.05	0	104	0.40	0	4
SO4 mg/l	24	23	96	12	5	80
Conductivity μS	182	118	111	369	59	3750
AMDI-Al	86.6	89.2	96	6.7	67.6	97.8
AMDI	88	90.3	88	6.3	68.9	98
AMDI mix	87.6	89.7	96	6.4	68.9	98

Group 7

Parameter	Mean	Median	No.	sd	Min	Max
pH	4.9	4.4	12	1.4	3.5	6.7
Zn mg/l	5.5	3.4	12	8.0	0.10	29
Fe mg/l	13.9	0.56	12	42	0	146
Cu mg/l	2.1	0.50	12	3.1	0.01	9.4
Cd μg/l	5.8	0	12	17	0	60
Al mg/l	14	5.6	11	23	0.09	80.9
As μg/l	2.2	0	11	5.8	0	19
SO4 mg/l	507	240	11	697	26	2000
Conductivity μS	735	350	12	846	130	2620
AMDI-Al	63.1	58.8	11	19.5	28.4	91.3
AMDI	60.8	58.5	10	18.6	28.1	92.2
AMDI mix	63.6	59.3	11	19.9	28.1	92.2

Group 8

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.8	6.8	38	0.41	5.5	7.4
Zn mg/l	0.05	0.04	38	0.06	0	0.27
Fe mg/l	0.14	0.1	38	0.19	0	0.86
Cu mg/l	0.01	0	38	0.05	0	0.30
Cd μg/l	4.7	0	38	24	0	150
Al mg/l	0.25	0.16	31	0.33	0.001	1.77
As μg/l	0.03	0	31	0.18	0	1
SO4 mg/l	6.4	6	35	2.7	3	19
Conductivity μS	76	74	37	27	42	220
AMDI-Al	97.1	97.8	35	3.02	87.1	100
AMDI	96.9	98.0	28	2.9	88.4	100
AMDI mix	96.3	98	35	2.9	88.4	100

Group 9

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.9	2.9	9	0.04	2.9	3
Zn mg/l	13.5	13.7	9	5.0	7.4	21
Fe mg/l	31.7	20	9	26	8.1	88
Cu mg/l	10.5	9.4	9	3.9	5.4	17
Cd μg/l	43	40	9	25	10	80
Al mg/l	34	29	9	13	18	52
As μg/l	4.3	3	9	4.6	0	16
SO4 mg/l	501	525	8	161	239	740
Conductivity μS	1052	1040	9	212	700	1450
AMDI-Al	35.4	35.4	8	3.8	30.9	41.5
AMDI	35.7	35.4	8	4.1	31.4	42.3
AMDI mix	35.7	35.4	8	4.1	31.4	42.3

Appendix: I (b). Mean, median, number of samples (no.), standard deviation (sd), minimum and maximum for samples from each site.

Site 1.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.47	2.5	11	0.06	2.4	2.6
Zn mg/l	433	294	11	429	153	1526
Fe mg/l	975	1040	11	458	96	1626
Cu mg/l	165	145	11	52	98	252
Cd µg/l	1028	970	11	380	550	1670
Al mg/l	621	553	11	221	298	1030
As µg/l	156	101	11	112	35	387
SO4 mg/l	7723	7903	9	2582	4230	11400
Conductivity µS	6883	6580	10	1723	4320	9340
AMDI-Al	6.04	6.5	9	1.9	3.6	9
AMDI	6.2	6.8	9	1.9	3.6	9
AMDI mix	6.2	6.8	9	1.9	3.6	9

Site 1.2

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.5	2.5	3	0.1	2.4	2.6
Zn mg/l	212	230	3	80	124	282
Fe mg/l	1081	1137	3	490	565	1540
Cu mg/l	146	151	3	71	73	215
Cd µg/l	973	1020	3	502	450	1450
Al mg/l	563	575	3	293	264	849
As µg/l	384	360	3	284	113	680
SO4 mg/l	9080	9080	2	2234	7500	10660
Conductivity µS	6197	5640	3	2091	4440	8510
AMDI-Al	4.7	4.7	2	0.99	4	5.4
AMDI	4.9	4.9	2	1.2	4	5.8
AMDI mix	4.9	4.9	2	1.2	4	5.8

Site 1.3

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.64	2.70	9	0.11	2.50	2.80
Zn mg/l	381	427	9	105	162	516
Fe mg/l	1479	1973	9	898	45	2384
Cu mg/l	439	491	9	117	191	590
Cd µg/l	1774	1970	9	508	810	2480
Al mg/l	1820	2031	8	460	810	2211
As µg/l	74	63	7	33	37	127
SO4 mg/l	17883	18150	8	5056	7594	24668
Conductivity µS	11483	12180	9	2719	5850	15700
AMDI-Al	3.6	2.5	8	3.7	0.8	12.6
AMDI	3.1	2.1	8	3.5	0.6	11.6
AMDI mix	3.1	2.1	8	3.5	0.6	11.6

Site 1.4

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.7	2.7	3	0	2.7	2.7
Zn mg/l	436	458	3	66	362	488
Fe mg/l	2019	2100	3	183	1809	2147
Cu mg/l	468	492	3	60	399	512
Cd µg/l	2047	2140	3	291	1720	2280
Al mg/l	2023	2090	3	183	1817	2163
As µg/l	44	44	3	6.5	37	50
SO4 mg/l	19032	18600	3	2619	16656	21840
Conductivity µS	12100	12400	3	1375	10600	13300
AMDI-Al	2.0	1.8	3	0.7	1.5	2.8
AMDI	1.7	1.4	3	0.7	1.2	2.6
AMDI mix	1.7	1.4	3	0.7	1.2	2.6

Site 1.6

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.9	2.9	3	0.06	2.9	3
Zn mg/l	48	47	3	13	36	61
Fe mg/l	38	36	3	6.8	33	46
Cu mg/l	14	13	3	4.5	9.8	19
Cd µg/l	63	60	3	35	30	100
Al mg/l	256	235	3	100	168	365
As µg/l	0	0	3	0	0	0
SO4 mg/l	3349	3183	3	752	2694	4170
Conductivity µS	3750	3470	3	913	3010	4770
AMDI-Al	24.3	25	3	2.2	21.8	26.1
AMDI	23.1	24.0	3	2.5	20.3	25
AMDI mix	23.1	24.0	3	2.5	20.3	25

Site 1.7

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.97	2.80	3	0.29	2.80	3.30
Zn mg/l	61	61	3	1.0	60	62
Fe mg/l	172	183	3	19	150	184
Cu mg/l	13	15	3	7.5	4.5	19
Cd μg/l	233	230	3	5.8	230	240
Al mg/l	96	106	3	18	76	107
As μg/l	34	26	3	33	6	71
SO4 mg/l	1310	1310	1		1310	1310
Conductivity μS	2027	2080	3	254	1750	2250
AMDI-Al	26.1	26.1	1		26.1	26.1
AMDI	26.0	26.0	1		26.0	26.0
AMDI mix	26.0	26.0	1		26.0	26.0

Site 1.8

Parameter	Mean	Median	No.	sd	Min	Max
pH	3	2.95	4	0.14	2.90	3.20
Zn mg/l	64	62	4	6.9	58	73
Fe mg/l	186	182	4	13	175	205
Cu mg/l	16	19	4	7.6	4.5	21
Cd μg/l	230	215	4	34	210	280
Al mg/l	98	99	4	19	73	119
As μg/l	40	42	4	21	12	64
SO4 mg/l	1599	1590	3	324	1280	1927
Conductivity μS	2158	2180	4	278	1800	2470
AMDI-Al	21.5	20.8	3	3.2	18.8	25
AMDI	21.2	20.3	3	3.4	18.5	25
AMDI mix	21.2	20.3	3	3.4	18.5	25

Site 1.9

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.20	2.10	5	0.17	2.10	2.50
Zn mg/l	77	83	5	39	16	126
Fe mg/l	1425	1629	5	767	129	2178
Cu mg/l	118	148	5	59	14	151
Cd μg/l	214	260	5	82	70	260
Al mg/l	340	407	5	160	57	437
As μg/l	1066	1421	5	668	13	1641
SO4 mg/l	12979	12980	3	256	12722	13234
Conductivity μS	7294	8640	5	2949	2060	9050
AMDI-Al	5.2	5.4	3	0.29	4.9	5.4
AMDI	5.6	5.8	3	0.27	5.29	5.76
AMDI mix	5.6	5.8	3	0.27	5.29	5.76

Site 2.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.59	2.6	7	0.27	2.10	2.70
Zn mg/l	67	33	7	72	7.7	179
Fe mg/l	1507	249	7	2295	56	5447
Cu mg/l	53	18	7	63	9.7	146
Cd μg/l	197	110	7	224	10	560
Al mg/l	406	59	7	603	30	1429
As μg/l	1481	40	7	2719	2	7030
SO4 mg/l	8394	1375	6	11561	670	26050
Conductivity μS	5133	2280	7	5541	1360	13900
AMDI-Al	18.8	21	6	14.4	1.5	33.4
AMDI	19.0	21.4	6	14.6	1.4	33.6
AMDI mix	19.0	21.4	6	14.6	1.4	33.6

Site 2.2

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.52	2.6	5	0.16	2.3	2.7
Zn mg/l	43	48	5	34	11	94
Fe mg/l	222	189	5	232	14	616
Cu mg/l	30	26	5	25	12	72
Cd μg/l	170	210	5	144	20	370
Al mg/l	145	143	5	125	41	350
As μg/l	34	10	5	41	5	99
SO4 mg/l	1688	1770	4	796	810	2403
Conductivity μS	3118	3100	5	1457	1670	5470
AMDI-Al	23.2	21.4	4	6.9	17.8	32.1
AMDI	23.4	21.8	4	7.2	17.6	32.5
AMDI mix	23.4	21.8	4	7.2	17.6	32.5

Site 2.31

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.7	2.8	3	0.26	2.4	2.9
Zn mg/l	15	9.3	3	13	5.4	30
Fe mg/l	128	40	3	162	28	315
Cu mg/l	17	6.1	3	19	5.1	39
Cd μg/l	43	20	3	59	0	110
Al mg/l	50	22	3	50	22	108
As μg/l	14	9	3	15	2	30
SO4 mg/l	511	511	2	154	402	620
Conductivity μS	1857	1310	3	1337	880	3380
AMDI-Al	37.4	37.4	2	3.8	34.7	40.1
AMDI	38.48	38.48	2	3.5	36	41
AMDI mix	38.48	38.48	2	3.5	36	41

Site 2.32

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.25	2.25	6	0.16	2.1	2.4
Zn mg/l	180	94	6	194	29	509
Fe mg/l	1316	846	6	1272	312	3763
Cu mg/l	81	61	6	63	22	197
Cd µg/l	213	180	6	96	150	400
Al mg/l	259	201	6	194	66	623
As µg/l	462	370	6	386	93	1134
SO4 mg/l	6977	4800	5	5918	1566	16840
Conductivity µS	5785	4920	6	3032	2530	11360
AMDI-Al	9.7	9.7	5	5.6	3.2	16.9
AMDI	10.3	10.2	5	5.6	3.6	17.6
AMDI mix	10.3	10.2	5	5.6	3.6	17.6

Site 2.5

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.98	3.0	4	0.13	2.8	3.1
Zn mg/l	6.3	4.2	4	7.4	0.06	17
Fe mg/l	27	22	4	26	5.7	59
Cu mg/l	5.6	4.9	4	3.0	3.2	9.4
Cd µg/l	63	25	4	95	0	200
Al mg/l	26	18	3	22	8	51
As µg/l	6	4	3	7.2	0	14
SO4 mg/l	345	200	3	251	200	634
Conductivity µS	788	665	4	303	590	1230
AMDI-Al	43	49	3	10.5	30.9	49
AMDI	40.3	40.3	2	14.3	30.3	50.4
AMDI mix	43.2	49	3	11.3	30.3	50.4

Site 2.6

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.8	2.8	3	0	2.8	2.8
Zn mg/l	12	11	3	2.6	10	15
Fe mg/l	106	57	3	87	55	206
Cu mg/l	9.9	6.4	3	6.2	6.2	17
Cd µg/l	87	20	3	124	10	230
Al mg/l	45	45	2	34	21	70
As µg/l	35	35	2	37	9	61
SO4 mg/l	590	590	2	14	580	600
Conductivity µS	1450	1150	3	528	1140	2060
AMDI-Al	33	33	2	1.8	32	35
AMDI	36	36	1		36	36
AMDI mix	34	34	2	2.8	32	36

Site 2.9

Parameter	Mean	Median	No.	sd	Min	Max
pH	3.0	3.0	3.0	0	3	3
Zn mg/l	2.9	2.5	3	0.7	2.4	3.7
Fe mg/l	30	15	3	26	14	60
Cu mg/l	3.4	3	3	0.7	2.9	4.2
Cd μg/l	0	0	3	0	0	0
Al mg/l	11	11	2	3.2	9.1	14
As μg/l	4.5	4.5	2	6.4	0	9
SO4 mg/l	250	250	2	0	250	250
Conductivity μS	770	740	3	61	730	840
AMDI-Al	47.5	47.5	2	0	47.5	47.5
AMDI	49	49	1	-	49	49
AMDI mix	48.3	48.3	2	1.1	47.5	49

Site 3.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	3.55	3.55	30	0.14	3.3	3.8
Zn mg/l	73	72	29	6.7	67	103
Fe mg/l	120	114	30	27	90	248
Cu mg/l	4.0	3.4	30	2.4	1.0	8.2
Cd μg/l	255	240	30	71	190	590
Al mg/l	122	119	28	10	110	143
As μg/l	7.0	7	28	0.96	5	9
SO4 mg/l	1599	1598	27	98	1220	1810
Conductivity μS	1949	1965	30	85	1760	2090
AMDI-Al	26.4	26.1	27	1.7	23.9	29
AMDI	25.1	25	25	1.6	21.2	27.0
AMDI mix	25.1	25	27	1.6	21.2	27.0

Site 3.22

Parameter	Mean	Median	No.	sd	Min	Max
pH	3.81	3.8	26	0.17	3.4	4.0
Zn mg/l	30	29	26	4.4	25	40
Fe mg/l	150	139	26	39	91	223
Cu mg/l	1.8	1.6	26	0.3	1.3	2.4
Cd μg/l	46	60	26	25	0	80
Al mg/l	76	76	26	8.2	65	91
As μg/l	20	20	26	2.3	16	25
SO4 mg/l	1723	1670	23	194	1439	2230
Conductivity μS	2475	2335	26	341	2100	3310
AMDI-Al	31.7	32.1	23	3.0	26.1	36
AMDI	31	31.4	23	2.6	26.0	34.8
AMDI mix	31	31.4	23	2.6	26.0	34.8

Site 3.3

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.73	2.70	12	0.07	2.6	2.8
Zn mg/l	161	150	12	36	90	215
Fe mg/l	449	407	12	114	319	731
Cu mg/l	46	45	12	9.2	36	70
Cd μg/l	712	705	12	158	500	910
Al mg/l	480	490	12	76	369	618
As μg/l	138	140	12	29	78	177
SO4 mg/l	4796	5191	10	1161	2780	6330
Conductivity μS	4707	4713	12	361	3970	5220
AMDI-Al	11	11.1	10	1.02	9	11.9
AMDI	10.8	10.9	10	0.90	9	11.6
AMDI mix	10.8	10.9	10	0.90	9	11.6

Site 4.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	4.7	4.6	4	1.5	3.4	6.1
Zn mg/l	33	32	4	38	0.14	70
Fe mg/l	63	62	4	72	0.06	127
Cu mg/l	4.0	3.9	4	4.6	0.04	8.10
Cd μg/l	145	145	4	167	0	290
Al mg/l	-	-	-	-	-	-
As μg/l	-	-	-	-	-	-
SO4 mg/l	572	581	4	582	24	1104
Conductivity μS	928	920	4	990	70	1800
AMDI-Al	54.0	52	4	33.7	25	87.1
AMDI	-	-	-	-	-	-
AMDI mix	54.0	52	4	33.7	25	87.1

Site 5.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	5.9	5.9	38	0.6	4.6	7.2
Zn mg/l	0.67	0.65	38	0.42	0.16	2.3
Fe mg/l	1.5	1	38	1.9	0	8.6
Cu mg/l	0.05	0.05	38	0.06	0	0.28
Cd μg/l	0.79	0	38	4.9	0	30
Al mg/l	0.83	0.37	32	1.18	0.001	4.3
As μg/l	0.03	0	32	0.18	0	1
SO4 mg/l	25	24	33	9.0	10	50
Conductivity μS	104	110	37	22	59	140
AMDI-Al	82	81	33	5.8	69	91
AMDI	84	84	28	5.7	70.6	92.2
AMDI mix	83.0	82.8	33	5.7	70.6	92.2

Site 5.2

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.0	6	15	0.6	4.9	7.1
Zn mg/l	0.5	0.5	15	0.2	0.13	0.9
Fe mg/l	0.6	0.5	15	0.3	0.2	1
Cu mg/l	0.02	0.01	15	0.03	0	0.07
Cd μg/l	0.7	0	15	2.6	0	10
Al mg/l	0.2	0.2	15	0.1	0.001	0.5
As μg/l	0	0	15	0	0	0
SO4 mg/l	25	25	14	12	9	44
Conductivity μS	112	106	15	29	62	180
AMDI-Al	85	85	14	6.2	75	96
AMDI	87	86	14	5.6	77	96
AMDI mix	87	86	14	5.6	77	96

Site 5.3

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.4	6.5	24	0.3	5.2	7
Zn mg/l	0.34	0.38	24	0.13	0.05	0.55
Fe mg/l	0.26	0.30	24	0.12	0.05	0.43
Cu mg/l	0.004	0	24	0.006	0	0.02
Cd μg/l	0	0	24	0	0	0
Al mg/l	0.15	0.14	21	0.09	0.02	0.34
As μg/l	0	0	21	0	0	0
SO4 mg/l	23	24	23	7.0	6.0	31
Conductivity μS	114	116	23	17	67	149
AMDI-Al	90.4	91.3	23	2.5	85	95.6
AMDI	91.3	92.2	20	2.4	86.5	96.0
AMDI mix	91.2	92.2	23	2.3	86.5	96.0

Site 5.4

Parameter	Mean	Median	No.	sd	Min	Max
pH	8.47	8.5	15	1.22	6.7	10.1
Zn mg/l	0.17	0.17	15	0.10	0.03	0.38
Fe mg/l	0.21	0.24	15	0.13	0	0.37
Cu mg/l	0.005	0	15	0.01	0	0.04
Cd μg/l	0	0	15	0	0	0
Al mg/l	0.30	0.30	15	0.15	0.001	0.51
As μg/l	0	0	15	0	0	0
SO4 mg/l	21	20	14	13	6	59
Conductivity μS	170	144	15	68	75	311
AMDI-Al	92.7	92.4	14	2.7	87.1	97.8
AMDI	93.4	93.1	14	2.5	88.4	98.0
AMDI mix	93.4	93.1	14	2.5	88.4	98.0

Site 5.5

Parameter	Mean	Median	No.	sd	Min	Max
pH	8.21	8.3	15	1.1	6.2	9.5
Zn mg/l	0.16	0.13	15	0.11	0.01	0.34
Fe mg/l	0.19	0.26	15	0.17	0	0.45
Cu mg/l	0.007	0	15	0.01	0	0.05
Cd μg/l	0	0	15	0	0	0
Al mg/l	0.33	0.33	15	0.21	0.001	0.78
As μg/l	0	0	15	0	0	0
SO4 mg/l	23	25	7	15	5	40
Conductivity μS	595	262	15	920	120	3750
AMDI-Al	93.2	93.4	7	3.4	89.2	97.8
AMDI	93.8	94.1	7	3.0	90.3	98.0
AMDI mix	93.8	94.1	7	3.0	90.3	98.0

Site 5.9

Parameter	Mean	Median	No.	sd	Min	Max
pH	5.38	5.55	6	0.80	4.3	6.3
Zn mg/l	0.93	0.65	6	0.93	0.16	2.70
Fe mg/l	1.93	1.09	6	2.13	0.01	4.90
Cu mg/l	0.18	0.16	6	0.10	0.08	0.33
Cd μg/l	0	0	6	0	0	0
Al mg/l	1.9	1.1	6	2.1	0.45	6.0
As μg/l	0.67	0	6	1.6	0	4
SO4 mg/l	30	16	5	30	8	80
Conductivity μS	105	101	6	37	60	158
AMDI-Al	79.1	81	5	6.8	67.6	85
AMDI	79.7	81	5	6.2	68.9	84.6
AMDI mix	79.7	81	5	6.2	68.9	84.6

Site 7.8

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.65	6.65	4	0.06	6.6	6.7
Zn mg/l	0.58	0.16	4	0.88	0.10	1.90
Fe mg/l	2.15	0.44	4	3.50	0.31	7.40
Cu mg/l	0.05	0.02	4	0.06	0.01	0.14
Cd μg/l	0	0	4	0	0	0
Al mg/l	1.53	0.17	3	2.43	0.09	4.34
As μg/l	0	0	3	0	0	0
SO4 mg/l	41	26	3	25	26	70
Conductivity μS	197	190	4	28	170	237
AMDI-Al	86.5	91.3	3	8.3	77	91.3
AMDI	84.8	84.8	2	10.4	77.4	92.2
AMDI mix	87.0	91.3	3	8.3	77.4	92.2

Site 8.1

Parameter	Mean	Median	No.	sd	Min	Max
pH	6.82	6.80	38	0.41	5.5	7.4
Zn mg/l	0.05	0.04	38	0.06	0	0.27
Fe mg/l	0.14	0.10	38	0.19	0	0.86
Cu mg/l	0.01	0	38	0.05	0	0.30
Cd µg/l	4.7	0	38	24	0	150
Al mg/l	0.25	0.16	31	0.33	0.001	1.77
As µg/l	0.03	0	31	0.18	0	1
SO4 mg/l	6.4	6	35	2.7	3	19
Conductivity µS	76	74	37	27	42	220
AMDI-Al	97.1	97.8	35	3.0	87.1	100
AMDI	96.9	98.0	28	2.9	88.4	100
AMDI mix	97.3	98.0	35	2.9	88.4	100

Site 9

Parameter	Mean	Median	No.	sd	Min	Max
pH	2.92	2.90	9	0.04	2.90	3
Zn mg/l	14	14	9	5.0	7.4	21
Fe mg/l	32	20	9	26	8.1	88
Cu mg/l	10.5	9.4	9	3.9	5.4	17
Cd µg/l	43	40	9	25	10	80
Al mg/l	34	29	9	13	18	52
As µg/l	4.3	3	9	4.6	0	16
SO4 mg/l	502	525	8	161	239	740
Conductivity µS	1052	1040	9	212	700	1450
AMDI-Al	35.4	35.4	8	3.8	30.9	41.5
AMDI	35.7	35.4	8	4.1	31.4	42.3
AMDI mix	35.7	35.4	8	4.1	31.4	42.3