

Remediation Options for Contaminated Canal Sediments

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ABSTRACT A 7 km stretch of a canal in South Wales was affected by a pollution incident due to a major minewater discharge. The incident resulted in the blanketing of the canal bed with an orange-yellow (rust coloured) layer that adversely affected the aquatic life of the canal and the regeneration of the area. This paper presents the research work undertaken to assess the effect of the incident on the sediments of the canal and to identify the potential factors that would affect the remediation/final disposal options available for the sediments.

INTRODUCTION

A 7 km stretch of a canal in South Wales was affected by a pollution incident due to a major minewater discharge. Peak contaminant loading of 400 mg.Fe/L at flow of 36 L/sec has been recorded during that incident (Ranson, 1999). The incident resulted in the blanketing of the canal bed with an orange-yellow (rust coloured) layer that adversely affected the aquatic life of the canal and the regeneration of the area. A mine water treatment project, which opened in 2002, has resolved the problem of the contamination of the mine water discharged to the canal.

The canal company had proposed to fully restore the polluted sections of the canal to overcome the environmental and regeneration consequences of the pollution incident. They propose to achieve the restoration by completely dredging the canal

and removing the contaminated dredged sediments to landfill (Dig and Dump strategy). The Canal Company had based their strategy on very limited characterisation data. Cardiff University's Geoenvironmental Research Centre (GRC) was approached to undertake a research programme to further characterise the sediments including its leachability, assess the viability of alternative remediation strategies including soil washing/separation process, examine the dewatering potential of the sediments and comments of the potential beneficial use of sediments. This paper presents the research work undertaken to assess the effect of the incident on the sediments of the canal and to identify the potential factors that would affect the remediation/final disposal options available for the sediments

SITE AND SAMPLING

The affected 7 km section of the Canal runs north-east to south-west and starts at about 400m upstream the constructed minewater treatment plant. This Canal section is confined within a narrow valley corridor that is also occupied by a river and three roads (Figure 1).

Five locations were selected along the canal for sampling as shown in Figure 1. For each location a bulk sediment sample of about 20kg was obtained from the top 400mm layer of the canal bed. In location (S5) an 80cm core of undisturbed sample was obtained for vertical characterisation of the sediments. Canal water samples and river water sample at the overflow discharge point to the river at (S1) were also collected.

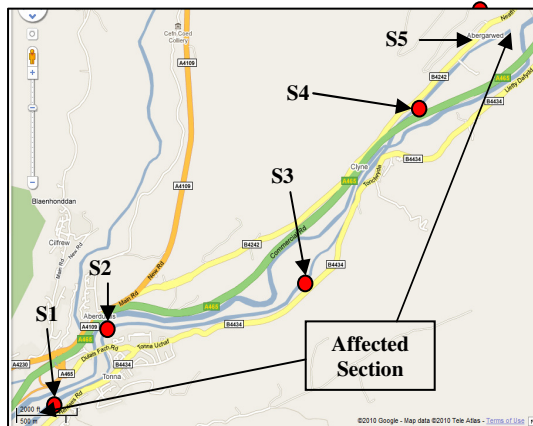


Fig. 1 Site and sampling locations

RESULTS AND DISCUSSION

1. Geotechnical Characterisation

Moisture content vary horizontally between 56% (S4) and 245% (S1) and vertically between 27% (bottom layers) to 683% (top 5 cm) indicating difficulties in transporting the sediments if dig and dump is to be used without dewatering.

Particles size analysis results presented in Table 1 indicates that the sediments are predominantly well-graded sandy silt or clay (S1, S4 and S5) to silty sand (S2 and S3). Results show that

sediments consist of an average of about 34% fines 40% sand and 26% fine-medium gravel. Results also show a great variability in the fractions content between the different locations along the canal. This suggests that if soil washing/separation is to be considered 66% of the sediment can be recovered as sand and gravel.

TABLE 1 Summary of PSD results

Particle	S1 %	S2 %	S3 %	S4 %	S5 %	Mean %
Gravel	14	53	36	18	8	26
Sand	49	32	45	37	36	40
Fines	37	15	19	45	56	34

2 Chemical Characterisation

Results for bulk and that of its fraction are presented in Table 2 together with CLEA soil guidance values (SGV) (Defra/Environment Agency, 2002) and ICRL values (ICRCL, 1987). Results show that concentration of heavy metals such as As, Ni, Cu and Zn are exceeding the threshold vales of guidelines for certain potential uses. Values of the sulphides in the bulk are higher than the ICRL threshold values. This suggest that the sediment is slightly to moderately contaminated with As, Cu, Ni, Zn and sulphide and cannot be used as it is as a fill in residential areas, allotments, parks, playing fields and open spaces. However the sediment can be used as a fill for industrial/commercial area.

It is worth mentioning that the sand portions used in these tests are the by-products of the wet sieving analysis. This will allow comment to be made on the viability of the soil washing process with water only in separating the contaminants from the coarse sized particles. Results of fines and sand fractions confirm that most of the contaminants are associated with the fines fraction of the sediments. However, some contaminant concentrations for the washed sand are still higher than the threshold values at some locations. This is not completely unexpected given the high concentration of iron and sulphides

in the sediments which might encapsulate the heavy metals and make them less mobile when washed with water only (Zheng et al, 2001). On the basis of the above results, it can be concluded that soil washing with water only may not produce a clean coarse fraction and a contaminated fines fraction.

TABLE 2 Chemical characterisation results

		As ppm	Cu ppm	Ni ppm	Zn ppm	Sulphide ppm
S1	Bulk	45	254	372	576	
	Sand	27	95	149	159	
	Fines	43	320	322	437	
S3	Bulk	51	294	469	620	
	Sand	25	171	189	212	
	Fines	54	296	340	812	
S5	Bulk	52	181	367	464	6492
	Sand	24	74	140	162	2.4
	Fines	59	190	384	596	28.1
CLEA SGV	Res	20		50		
	Com	500		5000		
ICRCL		10-40	130	70	300	1000

Pore water chemical analysis is vital in deciding the type of treatment required, if any, for the dewatered water if solid-liquid separation (dewatering) process is to be employed. Results for surface water indicates that heavy metals concentration of the river and canal surface water are below EQS value for List 2 dangerous substances. Results for Pore water bulk and core samples show similar trend as that of the surface water except for the S5 sample which shows a slightly higher level of As than the EQS value. The results suggest that if mechanical dewatering is to be used as a size reduction measure, most of the output water (pore water) may need no treatment before discharge in the canal or the nearby river.

3. Mineralogical Characterisation

Sediment's mineralogical composition were assessed using X-Ray Diffraction (XRD) method. Results show that the Canal sediments main constituents are quartz, pyrite, carbonate and clay

(kaolinite, illite, chlorite, montmorillonite) minerals. However, the relative contents of each mineral vary along the canal and with depth. The distribution of clay minerals in the sediment is kaolinite>illite>chlorite□montmorillonite. The results also indicate that sediment at S1 contains the highest amount of quartz and pyrite, and the lowest amount of montmorillonite whereas sediments at S5 contain the lowest amount of quartz and highest content of clay minerals. For the vertical variation samples there is no clear trends for the quartz and pyrite content, but the content of clay minerals increases with depth.

4. Leachability Tests

Leachability test are required to classify the material for disposal (Environment Agency, 2001). It is also required in assessing the sediment for potential beneficial uses. To cover all the possible scenarios of disposing and reusing the sediments the leachability was assessed for three cases; Sediment as it is (fresh), Dewatered sediment (centrifuged) and dried sediment. Leaching test was carried out according to National Rivers Authority test method mentioned in R&D Note 301 (Lewin et al, 1994). Results are presented in Table 3 together with the EQS values and the threshold values of Table 1 of the "guidance on the disposal of contaminated soil".

The results presented in Table 3 show that the concentrations of heavy metals in the leachate of the dewatered sample are slightly higher than those of the fresh sample (as it is). This can be explained by considering the higher amount of contaminated solids in the dewatered sample. The results also show a reduced concentrations of As and Zn and an increased concentrations of Ni and Cu in the leachate of dried sample compare to both the fresh and dewatered sample. Heavy metals concentrations in the leachate of all samples are below the EQS values. This suggest that leachate from the sediments will pose no threat to the controlled surface water if it is disposed in a landfill or used beneficially. Table 3 also shows that As level in the leachate of all the samples and the Ni and Cu level in the leachate of

the dried samples are higher than the threshold values specified in the disposal guidance. This may suggest that the sediment cannot be considered as inert for disposal classification.

TABLE 3 Concentration of HMs in the leachate

Sample	As	Cu	Ni	Zn	Fe
	ppb	ppb	ppb	ppb	ppb
S5 - As it is	38.1	13.4	39.6	16.4	<6.2
S5 - Dewatered	44.6	18.6	46.2	34.9	<6.2
S5 - Dried	11.5	65.8	103.9	19.8	<6.2
EQS Values	50	100	200	500	1000
Disposal Guidance	10	20	50	500	100

4. Dewaterability Tests

Dewatering is required to help in the handling of the sediment during transportation to landfill. Mechanical dewatering may reduce the amount of the material to be transported to landfill and hence reduce its environmental impact. Chemical dewatering may cause slight increase in the volume and weight of the final product, but it has the added advantage of stabilising, reducing odour and for some additives pasturing the material to be dewatered.

Chemical Dewaterability

Chemical dewatering or “conditioning” is the process of adding certain materials to reduce the water content of a slurry or sludge. Portland cement, hydrated lime and quick lime are selected as the additives in these tests due to its cost effectiveness and local availability. For each additive two mixes were tried; 4% and 8% by weight of the wet sediment. The moisture content was monitored with time as a measure of effectiveness. Measured amount of additive was mixed with a 1kg sample of the sediment in an open top plastic container. Samples for moisture content measurement were taken from the container at pre-specified time intervals. Results, which show the moisture content - time relation for the 8% mixes are presented in Figure 2.

The results indicates that for the same mix proportion, the addition of quick lime is more

effective in reducing the moisture content of the mixture than both the hydrated lime and the Portland cement by about 6% and 12% for the addition of 4% and 8% respectively. The differences increase with time for up-to 3 hours after mixing. Quick lime behaviour can be attributed to the reaction of the lime with water and the high heat produced during this reaction that may have helped further reducing the moisture content by evaporation. On the basis of the above results it can be concluded that quick lime out-perform the cement and hydrated lime in dewatering the sediment and therefore it would be the recommended choice if chemical dewatering is to be considered.

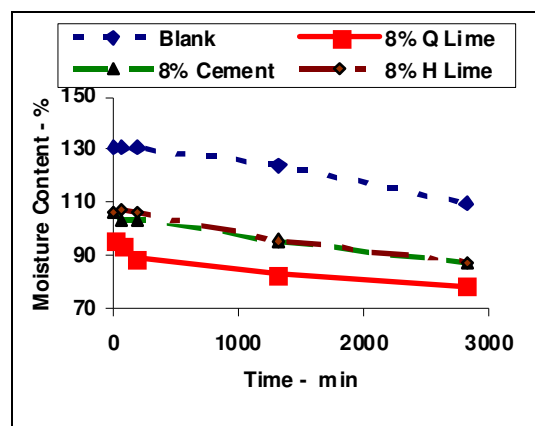


Fig. 2 Moisture content – time relation

Mechanical Dewaterability

Sediment Characteristics such as Specific Resistance to Filtration (SRF), sediments solid content and moisture quality and content, strongly influence the sediments drainage rate. Its determination is prerequisite for the rational selection of the most cost-effective volume reduction process (Cristensen, 1983). The SRF is the main parameter to characterise the mechanical dewaterability of any sludge or slurry. SRF provides an empirical measure of the resistance applied by the solid material to the release of water (Karpuzcu et al 1996).

SRF was determined using Buchner Funnel-vacuum filtration unit similar to the one described by (Besra et al., 2000). Results indicates that the SRF for the bulk sediment of S1 and S5 and that of the fines of S5 are in the range of 6.64E+11 to 1.66 E+12. Canal sediment's SRF values represent poor dewatering characteristics since good dewatering characteristics are associated with SRF value of 1E+10 and lower (Karpuzcu et al. 1996).

5. Soil Washing

Soil washing with pH manipulation and/or the addition of biosurfactant was carried out to assess the viability of this technique for the decontamination of the sediments. Three types of additives were investigated in different concentration. These additives are: Hydrochloric Acid (HCl), Sodium Hydroxide (NaOH) and Biosurfactant with and without NaOH. Soil washing tests were carried out on S5 bulk samples using similar procedure as that used by Mulligan et al (2001). The percentage metal removal was determined based on the initial metal content in the sediment and all results are presented as percent metal removal. Distilled water alone was used to account for removal of contaminants by physical mixing.

The results of the soil washing tests are presented in Table 4. The results show that increasing the alkalinity of the solution by adding NaOH of different concentration helped in removing 24-30% of the Arsenic content of the sediments. However, increasing the alkalinity had no effect on removing Copper, Nickel and Zinc. On the other hand, the results suggest that acidic solutions with concentration of more than 1% HCl are effective in removing Nickel (>41%) and Arsenic (>23%) and less effective in removing Copper (<16%) and Zinc (<13%).

Results also show that the addition of biosurfactant only to the washing water, at percentages of up to 2%, has a very little to no effect on the heavy metals removal capability of the solution. Contaminants removal capability of

the soil washing process can be enhanced greatly by the addition of biosurfactant with NaOH. The results indicate that a solution of 1% NaOH and 0.5% biosurfactant has cleaned the sediments from all the Arsenic, 59% of the Nickel and 9% of the Zinc. This is in agreement with the finding of Mulligan et al (2001b). On the basis of the above results it can be concluded that washing water need to be enhanced with the addition of a small percentage of biosurfactant with NaOH if soil washing is to be used to clean the sediment.

TABLE 4 Heavy metals removal of the different solutions

Solution	pH	% Removal			
		As	Cu	Ni	Zn
1.5% NaOH	12.7	30	0	1	0
1% NaOH	12.6	30	0	1	0
0.5% NaOH	12.4	29	0	1	0
0.25% NaOH	12.1	25	2	2	0
1.5% HCl	0.8	26	16	43	12
1% HCl	1.2	23	9	41	8
0.5% HCl	2.0	19	0	35	3
0.25% HCl	5.2	0	0	7	0
0.5% B*		5	0	1	0
1.0% B		6	0	1	0
2.0% B		6	0	1	0
1% NaOH + 0.5%B	12.7	100	0	59	9
1%NaOH + 1.0%B	12.6	93	0	54	8
1% NaOH + 2.0%B	12.4	91	0	46	7

* B = Biosurfactant

CONCLUSIONS

Canal sediments are predominantly well-graded sandy silt or clay to silty sand can be classified as slightly to moderately contaminated with As, Ni, Cu, Zn and sulphide. Most contaminants are associated with the fines fraction of the sediment although at some locations the sand fraction of the sediments may contain contaminants loading higher than some threshold vales. High moisture content of the top layer of the sediments may

cause some difficulties in handling the sediment during transportation if dig and dump is to be used without dewatering. The sediment has poor mechanical dewatering characteristics, as for its chemical dewaterability, Quick lime is more effective in dewatering/conditioning the sediment than Portland cement or Hydrated lime. If soil washing/separation is to be used effectively more than 65% of the sediment can be recovered as an aggregate, however, the only effective additive to the washing water that can improve its ability to remove the different contaminants is a mixture of (0.5%Biosurfactant+1%NaOH).

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