A GEOCHEMICAL SURVEY OF OPENCAST MINE WATER IN THE UNITED KINGDOM.

S. M. Reed[1] and R. N. Singh[2]

1 British Coal
Opencast Executive
United Kingdom

2 Department of Mining Engineering
University Park
Nottingham
NG7 2RD
United Kingdom

ABSTRACT

The paper presents an investigation into the quality of opencast mine waters in the six opencast mining regions of Great Britain, largely in England and Wales. A description of the research programme is presented together with the methods for sampling and analysis. The work has been performed with a view to assessing post-mining water pollution problems associated with opencast restoration.

INTRODUCTION

Opencast coal mining in Great Britain is administered by British Coal in six geographical regions, namely; Scotland, North-East, North-West, Central-East, Central-West and South West. These regions are shown in figure 1. This paper examines the water qualities from both current and restored opencast mine sites. For convenience the work has been subdivided into investigations in each of the above geographical regions.

Initial investigations commenced with the circulation of a questionnaire to each opencast region. The aim of the survey was to obtain some initial background information on which to base future study. The first priority was to determine how many sites undergo regular and full water analysis programmes. Information was requested on the following subjects:

a). Details of recent water samples from current working sites, with details of sampling point, e.g. sump, lagoons, discharge points.

b). Were any mines suffering from acid drainages, (however slight), and what were the forms of water treatment existing at each mine.

c). Were there any reported issues of water from restored areas or tips on mine sites which were either working or restored.

d). Were there sites with piezometers installed in backfill which could be sampled for quality.

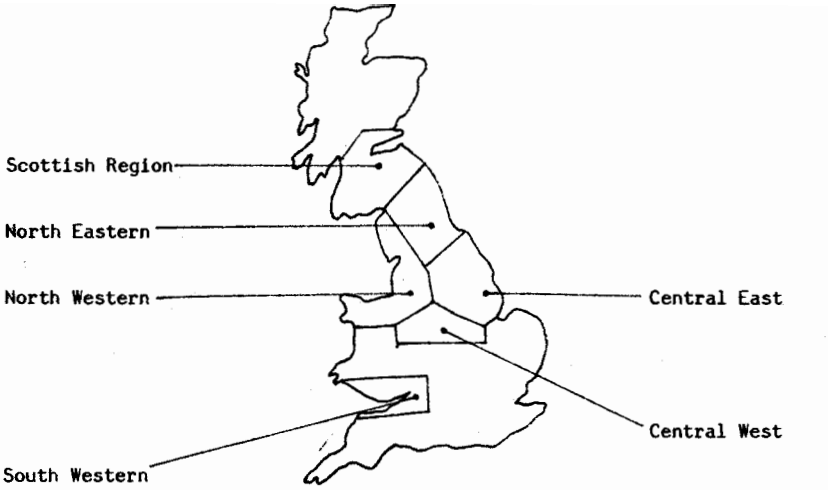

Figure 1. The Opencast Regions of Great Britain

On the basis of these replies, an overall picture of the groundwater geochemistry in British surface coal mining could develop.

Review work, (Reed 1986, Reed and Singh 1986), has indicated that pH, iron, sulphates and chlorides are the main pollutants which may emerge from a backfill mass, or from old deep mine workings. Of importance was to realise that acid and ferruginous waters are bacterially catalysed and the reaction can only be self-supporting at pH values below 4.5. By simple observation of the pH of inflowing waters into the pit was it possible to observe whether an acid forming reaction had initiated. In some of mines visited, the highwalls were stained red by the deposition of ferric hydroxide, thus indicating that a portion of the hydrogeology of the mine was creating acid water which was becoming diluted in the overall pit environment. The recovery of the water table was also considered from the point of view of the likelihood of emergent springs. A few restored opencast mines which had produced surface springs flowing out of the backfill were also tested for water quality. Some opencast sites currently working are to be used to restore deep mined colliery spoil. Colliery spoil material tends to have a much higher pyritic (iron and sulphur) content than opencast spoils and consequently have a far greater pollution potential.

METHOD OF SAMPLING AND ANALYSIS

All mine waters collected were analysed by flame atomic absorption spectrophotometry, UV-visible spectrophotometry and conventional chemical techniques, (titrations etc). The use of more expensive equipment being restricted by the available budget. A summary of the techniques used is presented in table 1.

Standard methods of water treatment were used, e.g. HCl acidification for the preservation of iron oxidation states. Where possible pH values were measured in the field.

Table 1. Summary of Methods for Determining Major Ion Concentrations

Ion		Classification	Summary
Sodium	Na^+	Flame Photometric	
Potassium	K^+	Flame Photometric	Direct comparison against Standard.
Calcium	Ca^{2+}	Flame Photometric	
Magnesium	Mg^{2+}	Titrimetric	Titrate for Total Hardness and correct for Calcium.
Iron	Fe^{2+} and Fe^{3+}	Spectophotometric	Reaction with O-Phenanthroline. Absorbance measured at 510 nm.
Manganese	Mn^{2+}	Spectrophotometric	Reaction with Ammonium Persulphate. Absorbance measured at 525 nm.
Aluminium	Al^{3+}	Spectrophotometric	Reaction with Eriochrome Cyanine R. Absorbance taken at 535 nm.
Sulphate	SO_4^{2-}	Gravimetric	Precipitation of Barium Sulphate.
Chloride	Cl^-	Titrimetric	Silver Nitrate titration.
Total Nitrogen	NO_T	Spectrophotometric	Absorbance measured at 220 nm. Corrected for interference at 275 nm.

BRITISH LEGISLATION REGARDING WATER POLLUTION

British legislation regarding the pollution of natural waters by mining effluents has become increasingly stringent over the past few years.

Since 1951, all the groundwater pumped off a surface mine has been required to comply with various River Pollution Acts passed in that year. The most recent legislation has been the Control of Pollution Act 1974, C.O.P.A., (H.M.S.O. 1974), designed to bring the law in line with E.E.C. directives on water pollution relevant to fish and drinking water abstraction. Pumping off surface mine sites requires a discharge consent obtained from either the River Board or Local Authority. A typical example for a Scottish opencast mine is presented in table 2. Significantly, the 1974 Act makes no exemptions to the period of abandonment of a mine.

Recent discharge consents have included limits for heavy metals such as Zinc, Cadmium and Lead, specifying maximum concentrations. The surface coal mining industry in the United Kingdom has however no record of heavy metal pollution in water discharges.

All consents restrict suspended solids concentrations to between 20 - 200 mg/l dependent on the site in question. Storm exceptions may be granted. pH values must maintained in the range 5 - 9. Oil, total iron and volume of discharge are also controlled.

Typical Discharge Consent Condition - Scottish Opencast Mine. (Norton 1983).

- Outlets to be used for discharge of Trade Effluent only.
- Temperature of Discharge must not exceed 30 C.
- Discharge must not contain more than 30 mg/l Suspended Solids.
- Discharge must not contain more than 5 mg/l Total Iron.
- pH to be maintained between 5 and 9.
- The effluent shall not contain any visible signs of oil or grease or any matter to such an extent to cause the receiving water to be poisonous or injurious to fish, fish spawn or the food of fish.

REGIONAL OBSERVATIONS OF MINE WATER QUALITY

Scottish Region

Opencast mine waters in the Scottish region are typified by low pH and high dissolved iron contents forming a potential environmental hazard. Problems arise from ironstone bands interbedded with the excavated strata. These are weathered either on the surface of the exposed slope or in the backfill as broken rock. The problem of acid waters is widespread in the region which has resulted in the need t construct lime neutralisation plants on mine sites. Careful control is required in the Region to avoid the public image of surface mining in the region becoming severely tarnished. In particular in attitudes to consents for proposed opencast mine sites.

To illustrate the type of problems which have been encountered in the region, surface springs which have emerged from underneath tip material have been recorded as having pH values of 2.8 and dissolved iron contents of 8,000 - 30,000 ppm, (Norton 1983).

Henton, (1981), reports a number of acidic emanations from restored mine sites within the Scottish Region, including the emergence of acidic water on grazing land, the flooding of church foundations by polluting waters, and recovery of acid waters to surface in a market garden. Pollution of a watercourse supplying a papermill resulted in the discontinuation of the production of high quality photocopying paper.

North-East Region

Two restored opencast mines in the region have formed streams, one emerging out of the fill, and one emerging out of the solid ground adjacent to the mine site.

The quality of the water emerging out of the fill is not of sufficient standard for use owing primarily to chloride and sulphate contents. The pH of the sample is adequate at 6.6 and the iron content is negligible. The sample has also appeared to have remained unchanged in chemical composition over time.

The second stream which contains a small concentration of iron emerges from the ground outside the site boundary and is discharging into a water course. The dilution is however so great that there is practically no environmental effect. The hydrology of the site does appear to have been slightly altered in that a stream which previously existed in the same area has dried up to be replaced by this new outflow.

Many sites in the North-East are excavating old deep mine workings. In the Northern area of Northumberland especially, these workings tend to drain the opencast fills as they are directly linked to a deep mine colliery pump. This obviously is temporarily reducing recovery rates and levels in a number of restored opencast sites in the area despite a standard restoration policy of applying clay seals to excavated underground workings. The pumping is expected to terminate in c.10 years time and further recovery will be initiated over the entire area. This may be of importance if streams re-establish out of backfill, (although the fill is not unduly pyritic) or from the induced collapse settlement of unsaturated fills.

Table 3 details some average water quality data measured in the Region.

Table 3
Typical Mine Water Sample, North-East Region.
all mg/l except pH
Full Analysis Example.

pH.....	7.9
Total Hardness as $CaCO_3$.	472
Total Alkalinity.... as $CaCO_3$.	184
Sodium.....	24
Potassium.....	-
Calcium.....	120
Iron Total.....	0
Aluminium.....	0
Manganese.....	0.1
Chloride.....	37
Sulphate.....	273
Oxidised Nitrogen...	0

Summary of Sites Investigated, (5 mines, 8 seams)

pH = 5.8 - 7.9 Total Iron = 0 - 3.4 mg/l

North-West Region

As for most Regions no water treatment facilities save lagoons are required in the North-West region. Samples of water obtained from sites however do indicate that the region suffers slightly from waters of poorer quality. This is a trend which has been observed over a few years, when in 1981 the compliance with water discharge consent conditions, (governing the quality of the discharged water), for the North-west was 59% compared with 66% for Scotland and a nationwide average of 75%, (Norton 1983). Samples taken on several sites showed low pH values and high iron contents with other dissolved metal salts showing high concentrations as well. Whilst the region has no where near the problems of Scotland some environmental problems may occur if voids are considered for the disposal of colliery spoil materials. It should be noted that the overall discharge of the mines examined were within the consent limits owing to dilution effects within the mine site. Examples of analysis are presented in Table 4.

Table 4
Typical Mine Water Samples, North-West Region.
all mg/l except pH

	Site 1	Site 2	Site 3	Site 4	
				Seam A	Seam B
pH.....	6.5	6.6	7.3	7.9	7.4
Sodium.....	12	166	41	8	55
Potassium.....	8	18	16	4	7
Calcium.....	130	263	145	83	95
Iron Total.....	5	0	12	0	11
Manganese.....	0.7	1	0.5	0.3	0.4
Chloride.....	25	56	88	23	32
Sulphate.....	125	110	130	238	134
Oxidised Nitrogen...	1	1	1.5	0	0.5

Central East/West Regions

All sites in these regions discharge water of satisfactory nature. One site in the Central East region did however have relatively high aluminium contents with aluminium hydroxide being deposited in a local water course. One site had water inflows arising from three seams, one of which was high in iron contamination. The iron deposits on the walls of the mine indicated that acid water was present although it was much diluted in the general pit environment. The general nature of the overburden was however lacking in pyritic material and consequently an post-mining acid water problem extremely doubtful.

Table 5 details some example analyses.

Table 5
Typical Mine Water Samples, Central Regions.
all mg/l except pH

	Central East Site			Central West Site	
	*Seam A	Seam B	Run-off	Seam A	Seam B
pH.....	8.3	7.2	8.1	7.5	7.5
Total Hardness as $CaCO_3$.	350	750	680	540	560
Sodium.....	707	359	23	856	115
Potassium.....	27	19	17	22	23
Calcium.....	114	205	145	173	165
Iron Total.....	0.3	15	0	2	0.7
Chloride.....	4000	3850	220	3230	370
Sulphate.....	422	232	440	130	550
Oxidised Nitrogen...	2	1	3	1	2

South West Region

The geotechnical settings of opencast mine sites in the South Wales region are such that many sites form parts of hillsides or may be adjacent to restored colliery spoil heaps. No water pollution has been so far recorded from opencast sites although recently a water treatment plant with lime neutralisation facilities has been constructed at a new site. It has proved almost impossible to trace water flow through sites owing to the extremely complicated hydrology and hydrogeology of the area. Analyses are presented in Table 6.

Table 6
Typical Mine Water Samples, South West Region.
all mg/l except pH

	Site 1	Site 2		Site 3		
		Seam A	Seam B	Seam A	Seam B	Seam C
pH.....	8.4	6.2	8.2	7.5	5.9	6.8
Total Hardness as $CaCO_3$.	680	2000	920	1200	1480	840
Sodium.....	28	8	13	51	77	104
Potassium.....	7	10	16	19	5	5
Calcium.....	115	172	155	140	195	112
Iron Total.....	2.6	1.8	1.4	4.5	2.9	3.1
Manganese.....	1.4	0.8	1	0.1	0.2	0.2
Chloride.....	64	44	50	52	40	40
Sulphate.....	182	230	215	225	142	150
Oxidised Nitrogen...	1	1	1	0	0	0.5

CONCLUSIONS

The paper has presented a survey carried out in all the regions of opencast mining in the United Kingdom into the qualities of water flowing into the mines.

The following conclusions can be drawn.

a). The Scottish Region would appear to be the only area at present suffering from an acidic and ferruginous mine water problem. pH values are very low with corresponding high dissolved iron concentrations providing a serious environmental hazard. This problem is at present controlled by on-site lime neutralisation plants to increase the pH of mine water and to precipitate dissolved iron salts.

b). The overall water qualities from mines in other Regions conducted in the survey appear to be satisfactory. Future water treatment may be required in South Wales where the strata does contain a degree of pyrite. A water treatment plant has been constructed on one site, although only as a precautionary measure.

c). There is a general lack of information regarding concentrations of trace/ heavy metals in mine water, e.g. (Zn, Cd, Pb). Recent discharge consents have stipulated limits on these metal concentrations. Whilst during the course of this survey it has been indicated that such heavy metals are absent from opencast mine waters, standard measures must be taken to determine concentrations for each individual site.

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REFERENCES.

HENTON, M.P. (1981), The problem of water table rebound after mining activity and its effect on ground and surface water quality. Proc. Int. Symp. Quality of Groundwater, Noordwijkerhout, Netherlands, 1981, pp 111-116.

H.M.S.O. (1974), The Control of Pollution Act 1974. Her Majesty's Stationary Office, 1974.

NORTON, P. J. (1983), A Study of Groundwater Control in British Surface Mining. Unpublished Ph.D Thesis, University of Nottingham, 1983. pp460.

REED, S. M. (1986). Groundwater Recovery Problems associated with Opencast Mine Backfills. Ph.D Thesis, University of Nottingham.

REED, S. M. and SINGH, R. N. (1986). Groundwater Recovery Problems associated with Opencast Mine Backfills. International Journal of Mine Water, Vol 5. No. 3. September 1986, pp47-74.