TYNAGH MINE

Background information

Mine Name: Tynagh

Mine District: Tynagh

Alternative Names:

Elements of Interest:
Pb, As, Hg, Cu, Sb, Zn

Project Prefix: TYN-

County:	**Townland:**	**Grid Reference:**
Galway	Derryfrench; Garraunnameetagh	E174935, N213024

Site Description and Environmental Setting

Tynagh mine is located 1.5km north of Tynagh village near Loughrea in East Galway. Lead, zinc and barite were mined between 1965 and 1980. The site is surrounded by rolling farmland that is mainly used as cattle pasture. Individual houses, including farmhouses, and small clusters of houses are common along the roads in the vicinity of the site. Several new houses have been built close to the site in recent years.

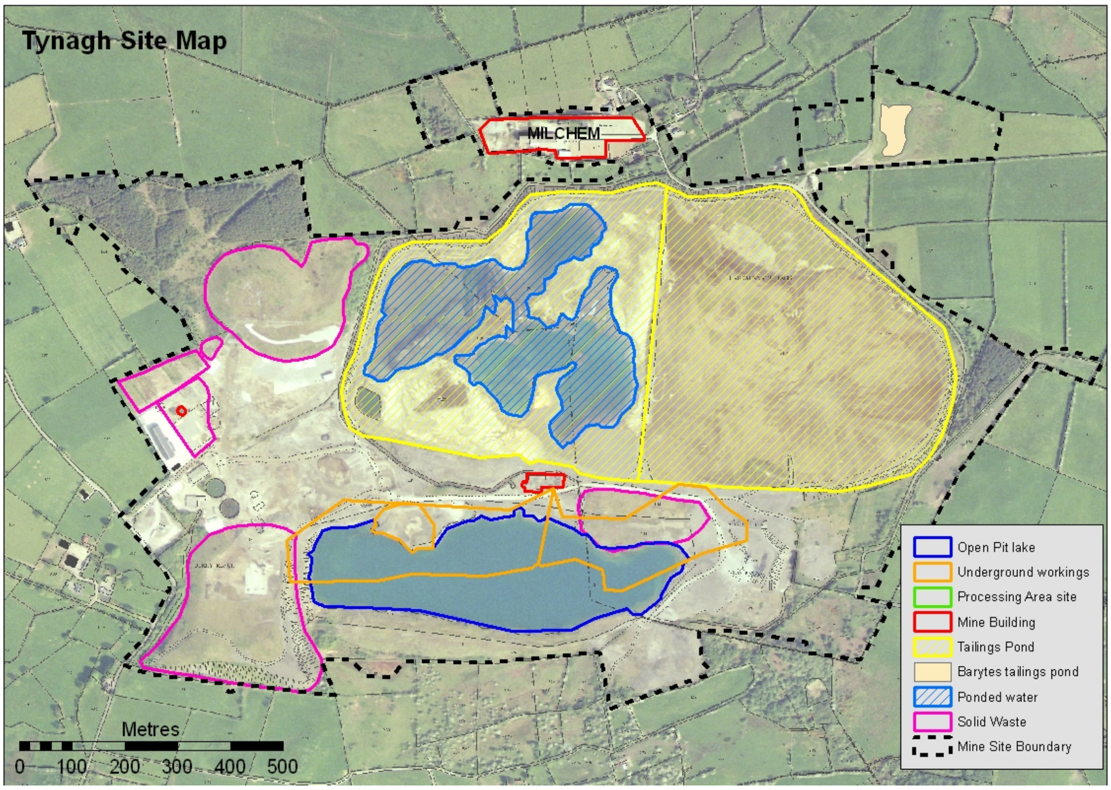

Fig. 1 Tynagh Mine Site, Main Features

The mine site covers approximately 115 ha and consists of several distinct areas: the open pit, the processing site, tailings pond (TMF) and the Milchem barite processing plant (Fig. 1). The site is now privately owned and two parts of it have been sold to industries in the last decade. A gas-fired power station was constructed in 2004-2006 and a galvanizing company now occupies part of the area of the former processing plant. After closure, considerable work was done to stabilize the site: heaps were contoured, buildings were reduced in size and the original shafts were closed and capped with concrete. However, most of the site has not undergone significant remediation. The open pit lake is filled with water. The tailings pond and spoil heaps are partially vegetated but largely barren. The Milchem site is now an equestrian centre, which was not included in the HMS-IRC project.

Geology and Mineralization

The Tynagh deposit is hosted by Lower Carboniferous Waulsortian Limestone. The base of the Waulsortian is in fault contact with an Old Red Sandstone inlier that lies to the south. The North Tynagh Fault is an east-west-trending normal fault that dips north. Movement on this fault took place during the late Carboniferous Variscan deformation.

Mineralization occurs mainly in the Waulsortian Limestone, with approximately 10% occurring in the overlying Lower Limestone and Calp. There are three main ore bodies, two primary and one secondary. Primary ore minerals include galena (PbS), sphalerite (ZnS), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4), tennanite (CuO), barite ($BaSO_4$) and arsenopyrite (FeAsS). Silver was associated with galena and the Cu sulphides. Cu sulphosalts contain both Ag and Hg. Cd was associated with sphalerite in a Cd:Zn ratio of 1:200. The secondary orebody occurred in a karstic sinkhole, 600m long and 50m wide. The mineralization was formed by the weathering of the primary ore. The secondary minerals included cerussite ($PbCO_3$), smithsonite ($ZnCO_3$), azurite ($Cu((OH)_2(CO_3))$), malachite ($Cu((OH)_2(CO_3))$, hemimorphite ($Zn_4((OH)_2(Si_2O_7).H_20)$ and dundasite ($PbAl_2((OH_2)_2(CO_3)_2.H_20)$.

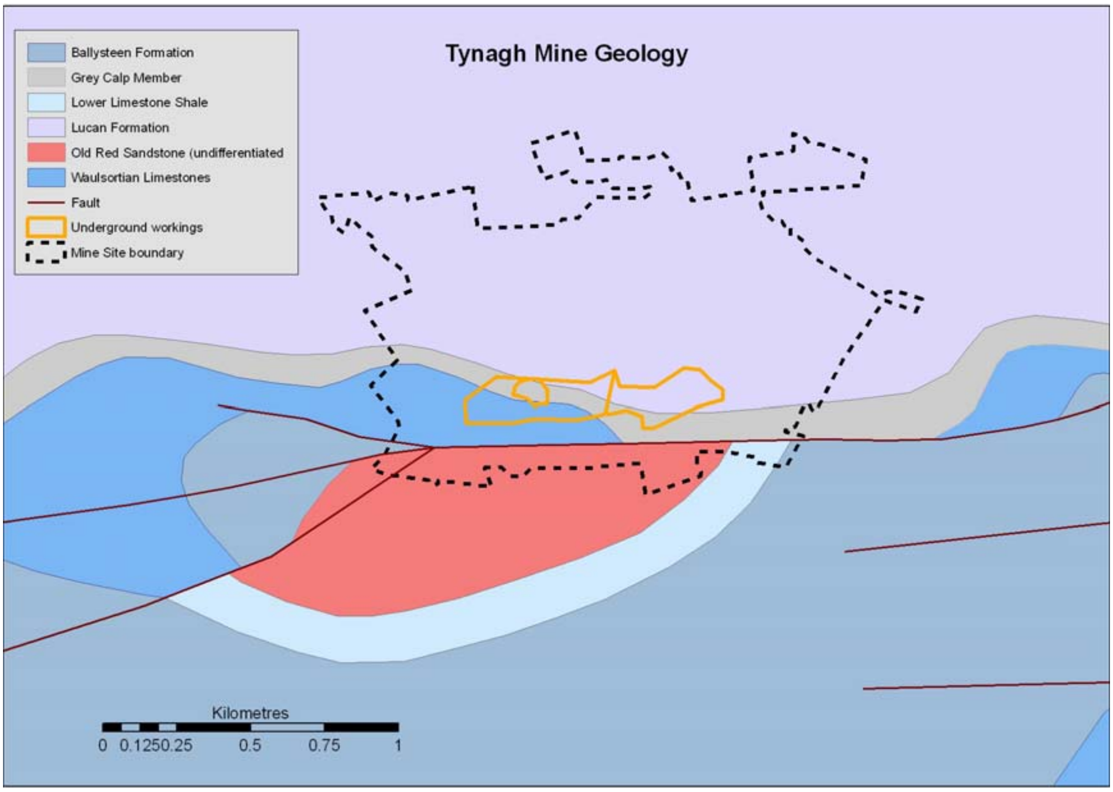

Fig. 2 Geology of area around Tynagh Mine

Mining History and Production

The "Old Tynagh Mine" is referred to initially in the Annals of the Four Masters (1632) and subsequently in the 19th century memoir of the Geological Survey of Ireland (Kinahan 1863). In the 1950s the Geological Survey of Ireland carried out field surveys on the site of the old mine, 2km east of the current mine site. Subsequently, the area attracted the interest of Irish Base Metals and a soil survey in 1960 defined an anomaly on the site of the open pit, with Pb > 1000 mg/kg and Zn between 5000 and 8000 mg/kg (Hutchings, 1979). Diamond drilling began in 1961 and eventually defined three ore bodies, a secondary ore body overlying a primary orebody with the third lying along the fault to the east. Open cast mining of the secondary orebody commenced in 1965 and continued until 1974 when underground mining began on the primary orebody. The underground workings were developed via a portal excavated in the base of the open pit. From there both men and material were transported underground using a conveyer system.

The ore was processed on site, transported to Galway and then shipped abroad for smelting. Primary crushing was done underground. After grinding in the mill on the processing area on the surface, the fine material underwent thickening and froth floatation. From 1965 to 1980 approximately 8 million tonnes of ore were produced. Initial reserves for the primary ore were estimated to be 5.8 million tonnes of approximately 4% Pb, 4% Zn, 0.6% Cu and 56 g/t Ag (Hutchings 1979). . The richer secondary ore had initial reserves of 4 million tonnes of up to 9.9% Pb, 7.4% Zn, 1.3% Cu and 100 g/t Ag. Barite was a major component of the gangue and Ba was recovered from the tailings in a separate processing plant operated by Milchem. Total output of Ba was around 400,000 tonnes.

Extraction of Pb and Zn from the secondary ore was less efficient than extraction from the primary ore. As a consequence, the tailings produced during processing of the secondary ore are relatively rich in metals. This is reflected in high Pb and Zn concentrations measured in the western cell of the tailings pond during the HMS-IRC project (see below and Tailings Pond site report).

Geochemistry

The detailed geochemistry of mine waste at Tynagh is described for each site in separate reports. However, data for stream sediments and surface water are considered here in the context of the mine and the surrounding area. An overview of solid waste geochemistry is also provided in order to allow consideration of variation across the site as a whole.

1. Surface Water

Surface water sampling was carried out in both winter (January 2007) and summer (June 2007) seasons at a total of 22 sites. Table 2 summarizes the data for June 2007. The pH (7.3 – 8.3) and EC (0.64 – 0.72 mS/cm) of surface water upstream of the mine are typical of surface water in areas underlain by limestone. Downstream, pH remains much the same but EC shows a notable increase in tandem with metal concentrations. Highest EC values are found in the Barnacullia stream along the northern boundary of the TMF (Fig. 1). A discharge from the TMF, with EC = 1.68 mS/cm, contributes to this but stream water upstream of the discharge also has high EC (1.2 mS/cm), reflecting contributions from other mine sources along its length. These sources may include other, unseen discharges from the TMF or from mine waste leachate.

Table 1 Tynagh surface water samples, June 2007

	pH	EC mS/cm	Pb µg/l	Zn µg/l	Cu µg/l	As µg/l	Cd µg/l	Ni µg/l
Upstream								
n	3	3	3	3	3	3	3	3
Minimum	7.3	0.64	2	57	29	0.5	0.5	7
Maximum	8.3	0.72	3	499	36	1	0.5	11
Median	8.2	0.68	2	97	35	1	0.5	10
Mean	7.9	0.68	2.3	218	33	0.8	0.5	9.3
Downstream								
n	9	9	9	9	9	9	9	9
Minimum	7.4	0.73	2	238	32	0.5	0.5	13
Maximum	8.4	1.23	4	4136	51	2	17	65
Median	8.1	0.83	3	1249	40	1	6	32
Mean	8.0	0.95	2.8	1867	41	1.3	7.3	33.9

Zn contents are notably elevated in the samples along the Barnacullia stream, with maximum Zn concentrations of around 4000 mg/kg. Cd concentrations in the stream reach 17 µg/l and Ni 65 µg/l. These elevated metal concentrations persist down stream for at least 700m below the confluence with the Castletown river (Fig. 3). Pb concentrations are not significantly elevated downstream, reflecting the relatively low solubility of Pb under alkaline conditions.

Surface water on and discharges from the TMF have higher metal contents, higher EC and slightly lower pH than stream waters (Table 2). Zn, Cu, Cd, Ni and Pb all have elevated concentrations in these waters. The pH is near-neutral or alkaline; median alkalinity for mine water samples was 138 mg/l $CaCO_3$. Mine water is buffered to high pH and alkalinity by the high limestone ($CaCO_3$) content of the waste. As a consequence, there is no risk of AMD at Tynagh. The discharge on the north side of the TMF has the highest concentrations of Zn, Cd and Ni. The highest concentrations of Cu and Pb are found in the ponded water on the surface of the western cell of the TMF. The data in Table 2 are for the summer sampling period as more sites were sampled in summer than winter. However, one discharge (TYN-W013), located on the southeastern end of the spoil heap at the west end of the open pit lake, was active only in winter. Data for this sample are included in Table 2 for comparison. This discharge it is the most metal-rich mine water sampled. Of particular interest are the very high levels of Cd, Zn and Ni. This discharge was identified by the EPA (EPA 2003) in its investigation as being of particular concern as the discharge flows across nearby farmland.

Table 2 Tynagh TMF Discharge and Surface Water Chemistry, June 2007

	pH	EC mS/cm	Pb µg/l	Zn µg/l	Cu µg/l	As µg/l	Cd µg/l	Ni µg/l
n	5	5	5	5	5	5	5	
Minimum	6.7	0.79	2	550	39	0.5	0.5	15
Maximum	8.0	1.86	40	4753	72	2	13	156
Median	7.7	1.31	3	1472	41	1	3	37
Mean	7.5	1.32	10.8	1951	47	1.2	4.7	56
TYN-W013	7.4	2.1	14	34560	35	0.5	350	403

Fig. 3 shows the distribution of Zn in surface water for June 2007 with the discharge at the southeastern end of SP05 (TYN-W013) included for comparison, although it is a winter sample. The pattern of elevated metal concentrations in streams close to the site is clear.

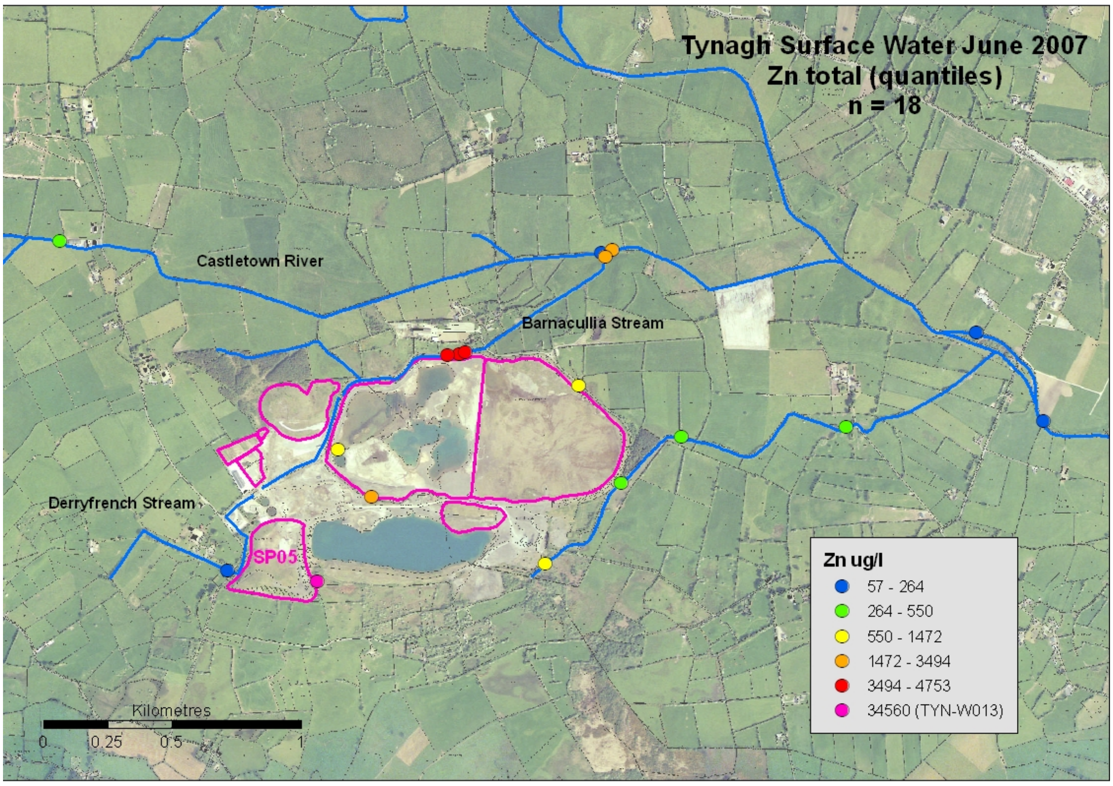

Fig. 3 Tynagh Surface Water Zn concentrations

2. Groundwater

Tynagh mine sits on a locally important aquifer. GSI's aquifer vulnerability compilation categorizes the aquifer's vulnerability as "high to low", indicating that the bedrock is not generally exposed. Extensive groundwater sampling was not carried out for Tynagh as part of the HMS-IRC project. Leachate tests were carried out on composite samples for most waste piles (see individual site reports). Water from one well located in a farmyard to the northwest of the mine site had elevated levels of Zn (> 100 µg/l) in both summer and winter samples. A preliminary groundwater study (Henry 2008), carried out on behalf of concerned residents in the area, examined four wells around the site, three to the east and one to the west. Samples from the wells east of the mine showed As concentrations ≤ 299 µg/l, Ni ≤ 35 µg/l and Pb ≤ 20 µg/l. These concentrations of As and Ni exceed the current drinking water standards (European Communities 2007) of 10 µg/l and 20 µg/l, respectively.

3. Stream Sediments

Stream sediment samples were taken at 11 sites upstream, adjacent to and downstream of the Tynagh mine (Table 3). Three upstream samples were taken (1, 2 & 10, Table 3 and Fig. 4). Samples 1 & 2 have Pb ≤ 45 mg/kg and Zn ≤ 116 mg/kg; by comparison the concentrations of Pb and Zn in sample 10 from Derryfrench are much higher (222 and 590 mg/kg, respectively). The Derryfrench site is located very close to a large spoil heap (SP05) and may have been exposed to contamination. In addition, soil samples in this area, taken during the EPA investigation in 2003, have relatively high Pb (up to 490 mg/kg) and Zn (up to 770 mg/kg) concentrations (EPA 2003).

Table 3 Stream sediment samples around Tynagh mine site

SAMPLE	Map Number	Easting	Northing	Location
TYN-07-SS001	1	173511	213882	u/s of mine site
TYN-07-SS002	2	175615	213833	u/s confluence w Barnacullia stream
TYN-07-SS003	3	175662	213844	d/s confluence w Barnacullia stream
TYN-07-SS004	4	175636	213821	Barnacullia stream u/s confluence
TYN-07-SS005	5	177329	213177	old mill 2.8 km d/s mine
TYN-07-SS006	6	177080	213522	old mill 2.3 km d/s of mine
TYN-07-SS007	7	176566	213148	East-side TMFdischarge 1 km d/s mine
TYN-07-SS010	10	174175	212593	u/s mine site, Derryfrench
TYN-07-SS013	13	175927	213115	east-side TMF discharge 320m d/s mine
TYN-07-SS014	14	175020	213434	Barnacullia stream u/s TMF discharge
TYN-07-SS015	15	175114	213452	Barnacullia stream d/s TMF discharge

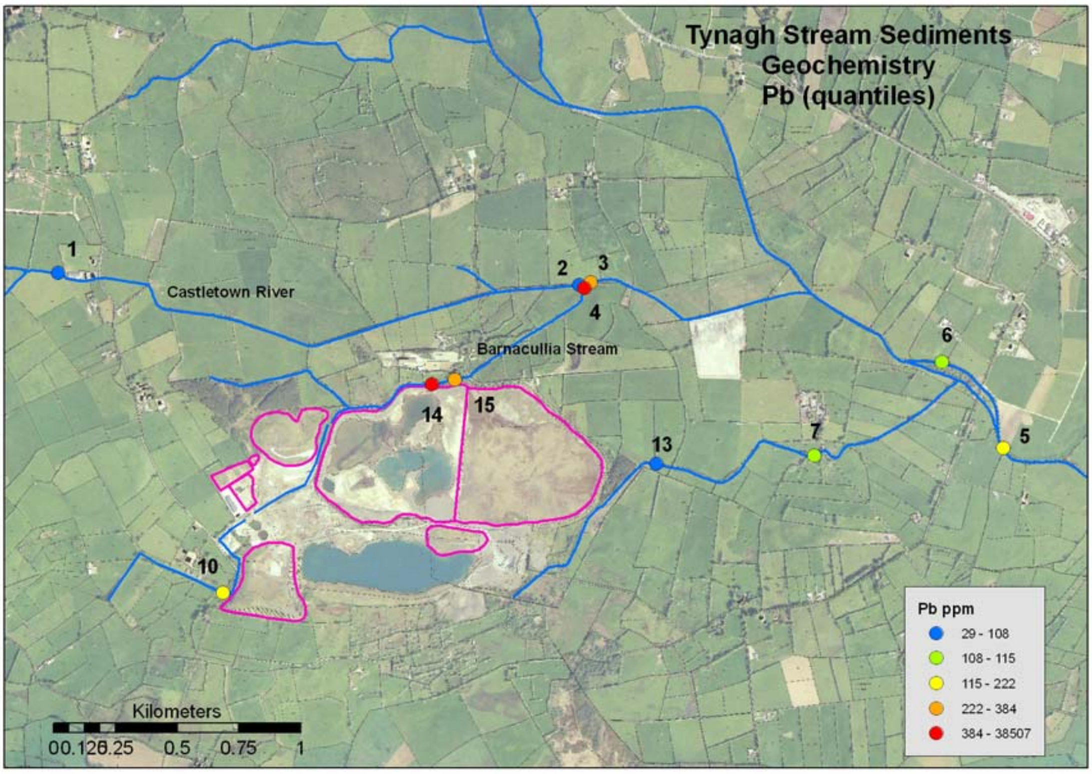

Fig. 4 Tynagh Stream Sediment sampling points

Very high concentrations of Pb and Zn are found in stream sediments in the Barnacullia stream, immediately beside the TMF. One sample (site 14 on Fig. 4) had 3.8% Pb and 3.4% Zn although the texture of this sample suggests it is significantly contaminated by tailings. Further downstream, values drop significantly and below the confluence of the Barnacullia stream and the Castletown river (site 3) Pb concentration was 342 mg/kg and Zn 4259 mg/kg. Nevertheless, elevated concentrations of Pb (148 mg/kg) and Zn (1551 mg/kg) were detected in samples taken almost 3km downstream of the site (site 5, Fig. 4). A summary of stream sediment chemistry is given in Table 4.

Table 4 Tynagh Stream Sediment samples, summary statistics

mg/kg	Pb	Zn	Cu	Cd	As
n	11	11	11	11	11
Minimum	29	113	0.0	0.0	0.0
Maximum	38507	33913	4532	285	1183
Median	149	1551	41	0.0	18
Mean	3880	5472	485	40	136

Data from the HMS-IRC study are in general agreement with those of the EPA investigation (EPA 2003). The concentration of Pb in stream sediments in the Barnacullia stream is greatly in excess of 1000 mg/kg, which is considered to be the upper acceptable limit to which livestock can be exposed (EPA 2004).

4. Solid Waste

Solid waste analyses were carried out at Tynagh by *in situ* XRF analyses. Check samples were returned to the lab for preparation prior to in-house analysis by XRF and subsequent analysis by MA-ES in an external laboratory. The Tynagh mine site was subdivided into four sub-sites for reporting purposes and a detailed review of solid waste analyses on each sub-site is provided in separate site reports. The four subsites (Fig. 5) were (1) the processing area site (42 analyses), (2) the tailings pond (60 analyses), (3) the open pit area, incorporating two spoil heaps (SP04 and SP05) (21 analyses) and (4) a single spoil heap, SP06, to the west of the tailings pond (10 analyses).

Tables 5 and 6 summarize the data for the 133 *in-situ* XRF analyses completed on the four sub-sites at Tynagh. Median values for each sub-site are included for comparison. Significant concentrations of Pb, Zn and Ba, in particular, remain in most of the waste analysed, as well as localized high concentrations of As, Cu, Ni, Cd, Cr and even Hg. Fig. 5 – 7 show the distribution of Pb, Zn and Ba across the site and obvious difference are apparent between the different waste heaps. These differences reflect the nature of the waste. Thus the tailings pond has high Ba because barite was not recovered in the processing plant but concentrated in the tailings. The relatively low levels of Zn in the tailings pond attest to its efficient extraction during processing. The high concentrations of Pb appear to reflect the difficulties encountered in adequately processing the secondary (oxide) ore. Spoil heaps generally have variable and often high concentrations of Pb and Zn since they generally consist of "low-grade", i.e. mineralized, waste. The cluster of samples with high Pb and Zn concentrations on the site of the former processing plant delineate a zone where high As, Hg and Cd are also found (see Processing Area site report). This site is in daily use by workers from the adjacent galvanizing plant.

Table 5 Summary statistics, *in situ* XRF analyses of solid waste, Tynagh

mg/kg	Pb	Zn	Cu	As	Ni	Cd	Cr	Ba
Whole site:								
n	133	133	133	133	133	133	133	133
Minimum	341	347	45	0.0	0.0	0.0	0.0	0.0
Maximum	913892	334808	256276	86734	2395	1969	639	75032
Median	11496	7819	1122	909	0.0	58	186	12420
Mean	35635	28234	10652	4091	65	130	211	19620

Table 6 Median concentrations, *in-situ* XRF analyses, Tynagh sub-sites

mg/kg	Pb	Zn	Cu	As	Ni	Cd	Cr	Ba
Median								
Process Area	12024	14864	1561	1369	0.0	65	119	4037
Tailings Pond	13100	4468	950	1054	0.0	40	316	23382
Open Pit area	12164	23640	1041	875	0.0	79	162	5542
SP06	4298	12768	525	255	127	22	117	1339

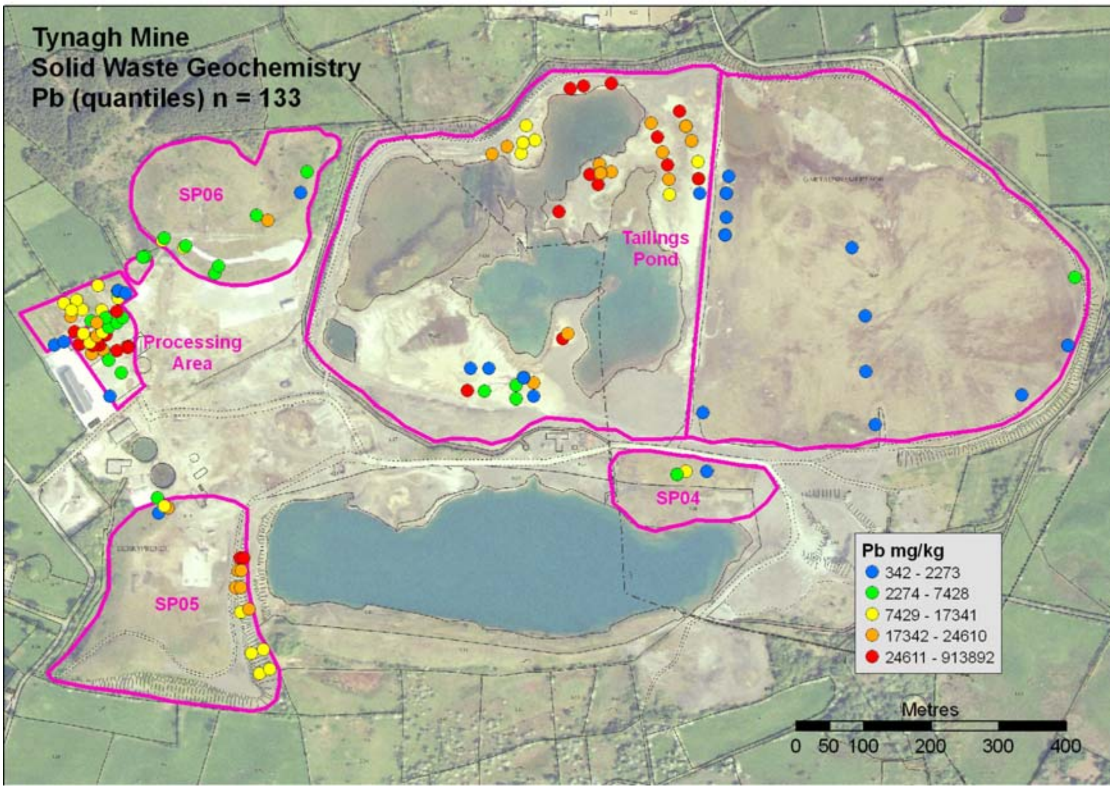

Fig. 5 Pb in solid waste XRF analyses, Tynagh

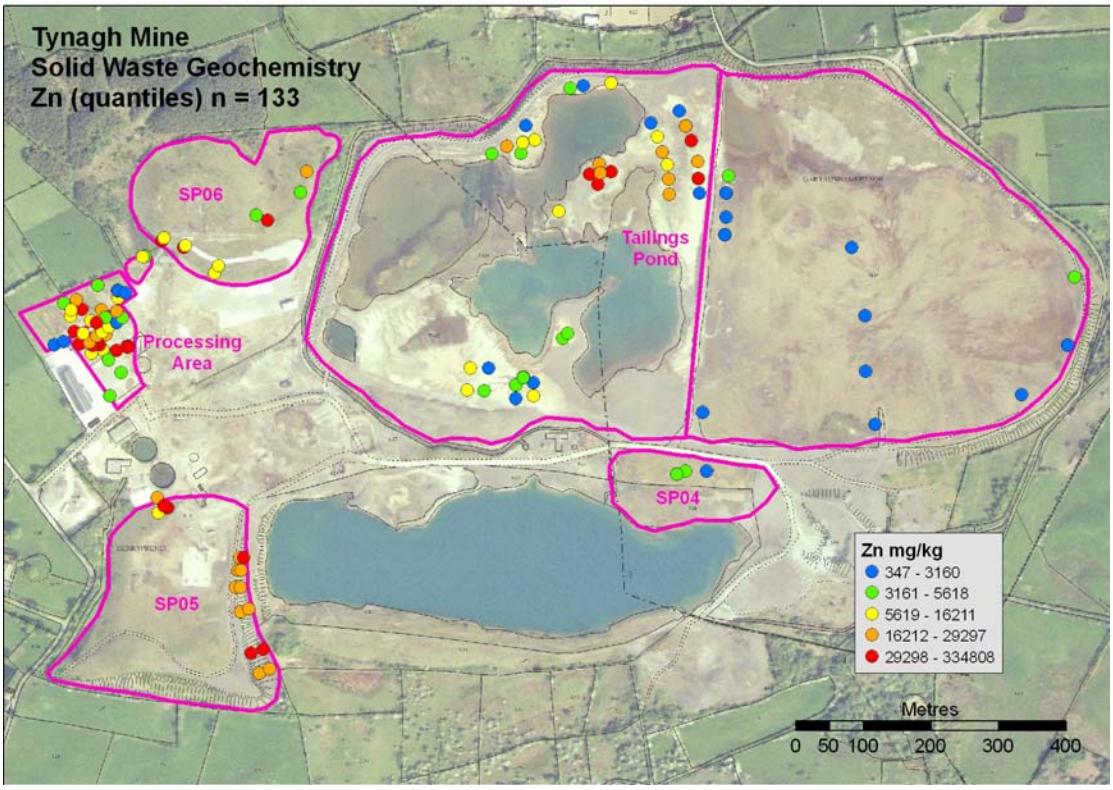

Fig. 6 Zn in solid waste XRF analyses, Tynagh

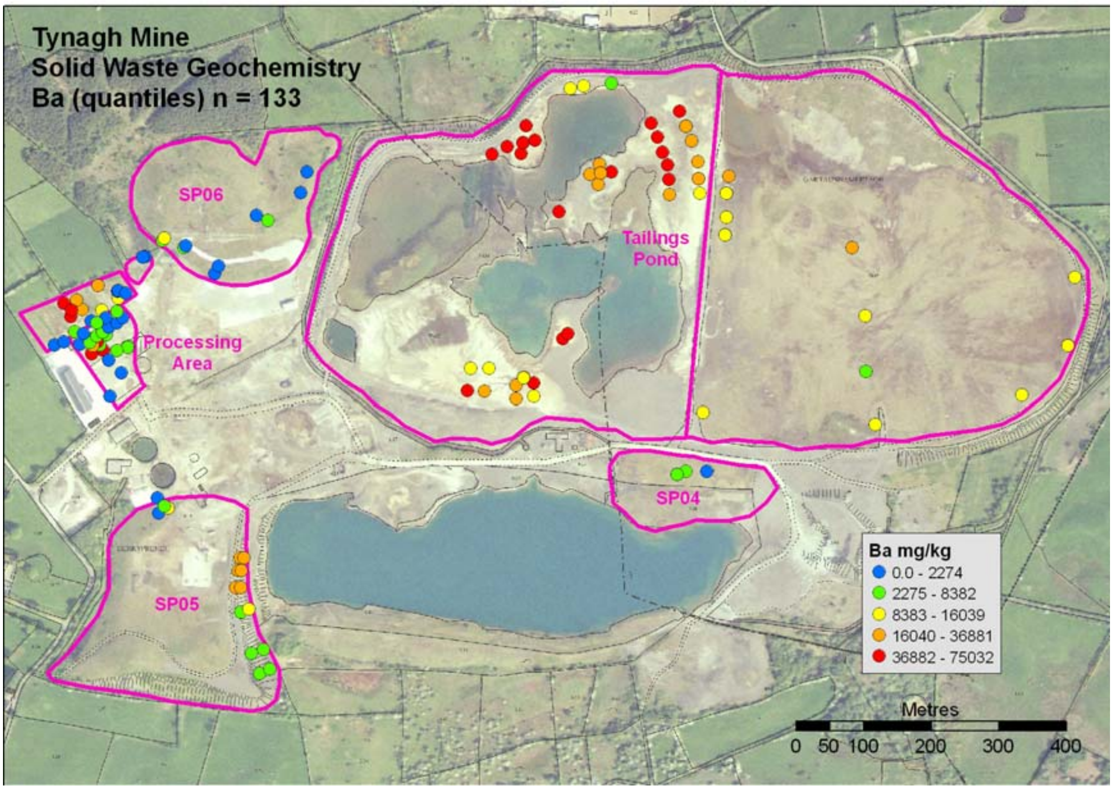

Fig. 7 Ba in solid waste XRF analyses, Tynagh

5. HMS-IRC Site Scores

Table 7 HMS-IRC Site Scores by waste type, Tynagh Mine

Waste	Solid Waste	Water Discharges	Stream Sediments	Totals
1. Hazard Score	**9447**	**152**	**93**	**9692**
2. Pathway Score				
Groundwater	1219.00	17.50		1236.50
Surface Water	1272.86	19.84		1292.70
Air	59.80			59.80
Direct Contact	81.88			81.88
Direct Contact (Livestock)			37.06	37.06
3. Site Score	**2634**	**41**	**37**	**2712**

The total site score for Tynagh mine, after adding the individual site scores for the Processing Area, the TMF site, the Open Pit site and the SP06 site, is 2712 (Table 7), the highest score for any mine site or district in the country, placing it in Class I. Solid waste accounts for just over 97% of this total, with remainder almost equally divided between mine water discharges and stream sediments. The very high contribution by solid waste comes mainly from two sources: the western cell of the TMF (1171) and SP05 (1252) on the Open Pit site. These scores reflect the very large volumes of and the high concentrations of Pb in the waste, as well as the proximity to local streams.

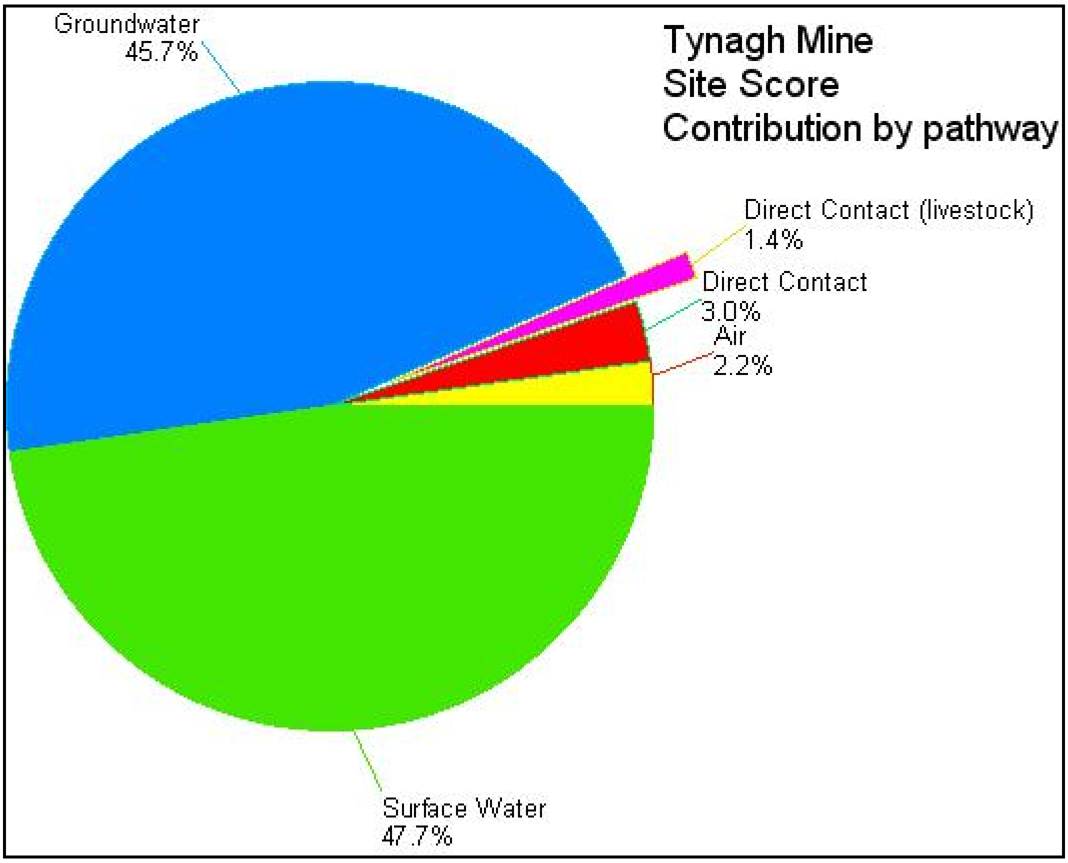

Fig. 8 Site Scores, Tynagh Mine: contribution by pathway

Fig. 8 shows the contribution of individual pathways to the total score for the site. As is generally the case for the HMS-IRC scoring system, the groundwater (45.7%) and surface water (47.7%) pathways are the dominant components of the site score, in this case making essentially equal contributions to the total. Although the contribution of both the direct contact (3.0%) and air (2.2%) pathways seems very small by comparison, the actual scores these percentages represent (82 and 60, respectively) are considerable in themselves. To put them in context, the direct contact pathway score for Tynagh is greater than the entire score for the Allihies District in West Cork (76) or the 7.5 million m^3 of solid waste in the Shelton Abbey tailings pond (64) in the Avoca District, Co. Wicklow. The modest contribution to the total score by stream sediments should not deflect from the fact that the very high concentrations of Pb and other metals in some stream sediments at Tynagh pose a direct risk to the health of animals, chiefly cattle, that use the local streams for watering (EPA 2004). Site scores, and the contributions made by various waste sources and pathways, are a means of classifiying sites on the basis of potential overall risk. Specific risks posed by individual waste sources, regardless of the size of their contribution to the total site score, should not be ignored.

6. Geochemical overview and conclusions

Tynagh Mine contains large volumes of solid mine with high concentrations of Pb and other heavy metals. Part of the site is used by two companies and, in one case, part of the ground is heavily contaminated by Pb, Zn, As, Hg and Cd. Several seepages from spoil and tailings introduce Zn, Cd and Ni to local streams and groundwater although the volume of these discharges is generally low. As a consequence of buffering by carbonate from the limestone that hosted the ore none of these discharges poses a threat of acid mine drainage on or around the site. Leachate testing indicates that the waste at Tynagh has the potential to contaminate groundwater; analysis of water in one well east of the site revealed a high As concentration, indicating that there is contamination of groundwater in the vicinity of the site. Stream sediments are severely contaminated by Pb and other metals close to the site, mainly in the Barnacullia stream on the northern boundary of the tailings pond. High concentrations of mine-related metals have been detected almost 3 km downstream of the site.

References

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