Iron Platform Services Ltd.

June 8th 2012

Mr. Paul Whitehouse
Research Expert Air, Land & Water, Evidence Directorate
Environment Agency
Red Kite House
Howbery Park, Benson Lane
Crowmarsh Gifford
Wallingford OX10 8BD

Dear Mr. Whitehouse

On behalf of the REACH Iron Platform we are herewith submitting comments on the recently published UKTAG EQS proposal for iron. The REACH Iron Platform is a consortium that was formed to address issues related to REACH and other regulatory programmes that would impact the iron and steel industries. The Iron Platform has members from many countries, but in particular has several members whose headquarters or operations are located within the UK, including Tata Steel Europe and Rio Tinto. For further information please see our website at www.iron-consortium.org.

We have filed comments on the public web page, however, the web page was not constructed in such a way as to allow us to submit the results of the extensive toxicity testing that we have done with fish, daphnids and algae. We have embarked on a two year programme to evaluate the influence of water chemistry on the toxicity of total iron in surface waters. To that end we have performed extensive testing with three species under a variety of water chemistries where hardness, pH and dissolved organic carbon were varied. The results of these studies were used to develop models whereby the water chemistry can be used to make a prediction of the toxicity (EC 10) to each species (fathead minnow, waterflea and green alga) under the conditions of different surface water locations.

We believe our data set would be quite helpful in your consideration of an EQS for iron. In that light, we have prepared a report that summarizes the toxicity information and its implication for iron concentrations in UK surface waters. We would be pleased to discuss this further with you and to provide the details of each of the toxicity studies. For further discussions or if you have questions, please contact Dr. William Adams (William.adams@riotinto.com) or me

Yours sincerely,

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Iron Industry comments on the UKTAG EQS proposal for Iron.

Is the report clear in explaining how we have developed the proposed environmental standards and conditions?

The report identifies that due to complexities in the interpretation of much of the historical ecotoxicity data for iron an alternative approach based on direct observations under field conditions has been applied. In general we support the approach taken, but have some concerns about certain aspects of the derived standard. Our concern is that a single value for the EQS is over protective in many waters and under protective for sensitive waters. We have prepared a detailed analysis in support of this view and will share it with the Environment Agency.

Do the proposals:

- *Identify the environmental standards and conditions required to achieve the environmental objectives of the Water Framework Directive?*

We support the proposal to apply the standard as a total iron concentration, given the very low solubility of iron under the majority of typical natural surface water conditions. The extensive laboratory toxicity testing we have performed supports support the conclusion that total iron is a better indicator of toxicity than dissolved iron.

The use of field evidence to derive the proposed standard may provide a more direct link between chemical stressors and ecological quality than standards which are derived entirely from laboratory data. We support the use of this approach in cases where the derived standard is adequately protective of sensitive ecosystems.

- *Use the best information currently available?*

Recent studies performed on behalf of the Iron Industry on the toxicity of iron to freshwater organisms (fish, *Daphnia*, and algae) have indicated that there is an important effect of local water chemistry on the potential for iron to cause adverse effects on freshwater organisms.

These studies suggest that whilst invertebrates may be the most sensitive organisms under the majority of conditions, they may not be the most sensitive under all conditions. In particular these studies indicate that the most sensitive conditions for iron are likely to exist where pH, hardness (or calcium concentrations), and dissolved organic carbon (DOC) concentrations are all low. Under these conditions fish may be more sensitive than invertebrates. Consideration of this recent information in the derivation of the EQS proposal would be likely to improve the ecological relevance of the proposed standard.

- *Are there any other issues in relation to UKTAG's approach to developing UK environmental standards and conditions that you wish to comment on?*

We note that significant levels of compliance failures are expected for the proposed quality standard for iron. Given the observations of co-variation between dissolved iron concentrations and DOC in UK surface waters (Peters et al. 2011 BECT 86:591) it is possible that some areas with high iron exposures may not pose a risk to aquatic ecosystems. Conversely, it is possible that fish communities in some sensitive areas may not be adequately protected by the current proposal.

A preliminary assessment of a selection of sites included in the indicative compliance assessment for iron suggests that if the effect of local water chemistry on the adverse effects of iron to aquatic organisms were taken into account there would be relatively few, if any, compliance failures (based on the predicted EC10 value for the most sensitive trophic level). A summary report of this analysis can be provided to UKTAG by the Iron Industry. Conversely, a preliminary assessment of several locations where the sensitivity of aquatic organisms to iron is likely to be maximised suggests that the proposed EQS for iron of 0.73 mg l^{-1} may not be adequately protective of fish communities where pH, DOC, and calcium concentrations are all low (the most sensitive conditions for iron). These combinations of conditions are likely to occur in areas such as the Lake District, Snowdonia, and Cornwall, although they may not necessarily coincide with elevated iron exposures.

Development of models to predict the adverse effects of iron on aquatic organisms as a function of local water chemistry, and application for iron compliance assessment in England.

1 Summary of testing conducted

Chronic iron toxicity tests were conducted with an alga (*Pseudokirchneriella subcapitata*), a cladoceran (*Ceriodaphnia dubia*), and the fathead minnow (*Pimephales promelas*). For each species, several toxicity tests were conducted with varying levels of dissolved organic carbon (DOC), hardness, and pH (Table 1.1).

Table 1.1 Ranges of DOC, hardness, and pH tested in the iron toxicity studies

Test Organism	Range of DOC Tested (mg/L)	Range of Hardness Tested (mg/L as $CaCO_3$)	Range of pH Tested
P. subcapitata	0.3-9.9	26-255	6.3-8.0
C. dubia	0.3-4	11-252	6.3-8.0
P. promelas	<0.5-4	10-82	6.0-8.0

The iron concentrations resulting in a 10% effect (i.e. EC10s) were derived based on growth inhibition in *P. subcapitata*, reduced reproduction (i.e. number of juveniles per female) for *C. dubia*, and reduced growth (mean dry weight) for *P. promelas*.

2 Summary of model development approach and results

A step-wise multiple linear regression (MLR) analysis was applied to the iron EC10 data (dependent variable) as a function of DOC, hardness, and pH levels (independent variables). The significant water chemistry parameters identified in the MLR analysis were then used to derive equations describing iron EC10s as a function of water chemistry (Table 2.1). All of the toxicity data are based on total iron measurements as this was the best predictor of toxicity. The predicted versus observed iron EC10s are provided in Figures 2.1, 2.2, and 2.3 for *P. subcapitata*, *C. dubia*, and *P. promelas*, respectively. Predicted iron EC10s are within a factor of 2.0 of observed EC10s in 100%, 89%, and 67% of the *P. subcapitata*, *C. dubia*, and *P. promelas* tests, respectively. Overall, *C. dubia* is the most sensitive of the three species to iron, but *P. subcapitata* can become more sensitive in waters with a combination of low DOC and high hardness and *P. promelas* is more sensitive in waters with a combination of low DOC, low hardness, and low pH.

Table 2.1 Iron MLR model statistics and equations for estimating iron EC10s as a function of water chemistry

Species	Effect Level	n	DOC Slope (p-value)	Hardness Slope (p-value)	pH Slope (p-value)	Intercept	Adjusted R^2
P. subcapitata	EC10	25	0.666 (<0.001)	-0.126 (0.07)	0.174 (0.04)	7.131	0.89
Predicted *P. subcapitata* Iron EC10 = exp[7.131 + 0.666 × ln(DOC) – 0.126 × ln(hardness) + 0.174 × pH]							
C. dubia	EC10	18	0.467 (0.002)	0.173 (0.136)[1]	NS (0.97)	6.638	0.45
Predicted *C. dubia* Iron EC10 = exp[6.638 + 0.467 × ln(DOC) + 0.173 × ln(hardness)]							
P. promelas	EC10	9	1.099 (0.03)	0.705 (0.08)	0.963 (0.03)	-2.031	0.79
Predicted *P. promelas* Iron EC10 = exp[-2.031 + 1.099 × ln(DOC) + 0.705 × ln(hardness) + 0.963 × pH]							

[1] Although not significant at alpha = 0.10, hardness was included in the *C. dubia* model because it was marginally significant (p = 0.136) and removed the underestimation of iron toxicity at low hardness.

NS not significant

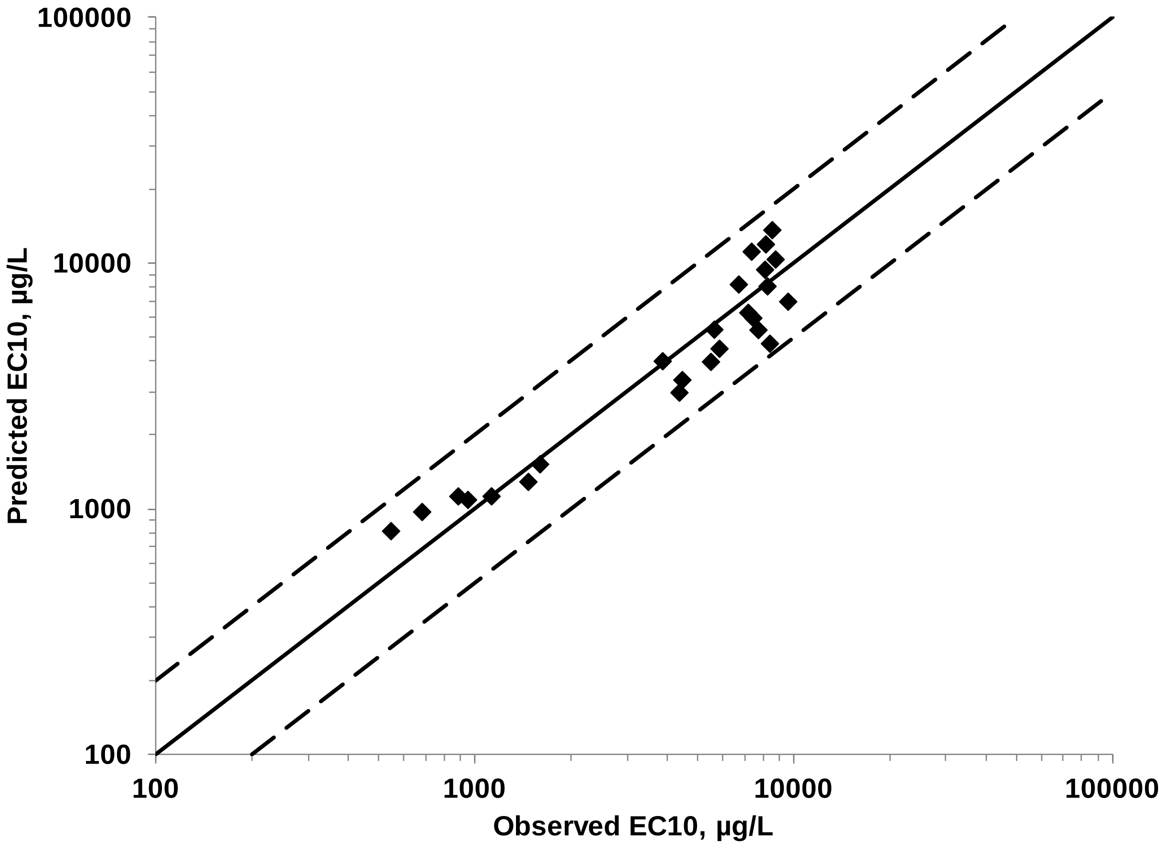

Figure 2.1 Comparison of MLR-predicted versus observed EC10 values for *P. subcapitata*

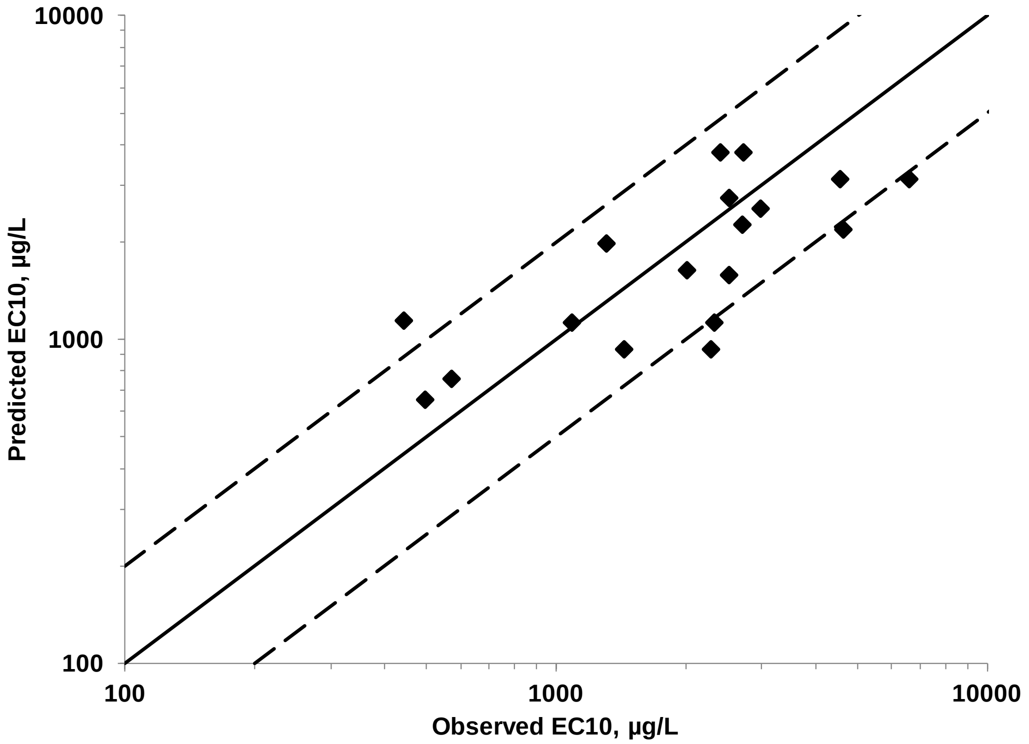

Figure 2.2 Comparison of MLR-predicted versus observed EC10 values for *C. dubia*

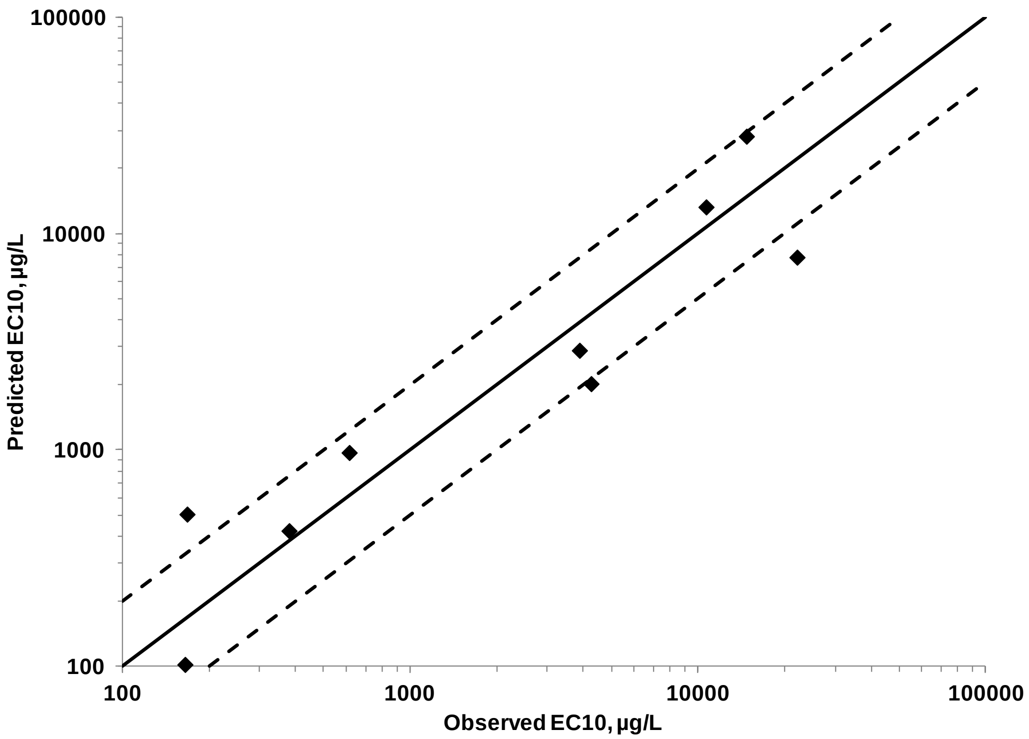

Figure 2.3 Comparison of MLR-predicted versus observed EC10 values for *P. promelas*

3 Summary of compliance assessment data

3.1 Data Selection

A set of iron compliance assessment data (EA dataset) was compared against a set of local water chemistry conditions (GB dataset) in order to establish a subset of sampling locations which were common to both datasets (Fe dataset). Sampling location matches were made based on identical UKOS National Grid References, and identifying individual sampling locations for which both iron exposure data and local water chemistry data were available. The local water chemistry data are based on a minimum of six samples over a minimum period of one year and are expressed as the mean pH value, the mean calcium concentration (mg/L), and the median DOC concentration (mg/L).

The site matching procedure resulted in matched data for 115 sites, from a total of 403 sites with iron exposure data (EA dataset). The ranges of iron exposures and local water chemistry conditions are summarised for the matched data set, and the source datasets, in Table 3.1.

Table 3.1 Comparison of dataset coverage for exposure data and local water chemistry data

Statistic	Fe (Total, µg/L)		pH		DOC (mg/L)		Ca (mg /L)	
Dataset	EA	Fe	GB	Fe	GB	Fe	GB	Fe
count	**403**	**115**	**1178**	**115**	**1178**	**115**	**1178**	**115**
min	17	32	3.91	6.31	0.3	0.9	0.6	4.3
5th %ile	**117**	**100**	**6.10**	**7.34**	**1.4**	**1.3**	**1.3**	**11.0**
25th %ile	305	264	6.90	7.57	3.4	2.1	3.7	35.8
50th %ile	**522**	**456**	**7.53**	**7.84**	**4.9**	**4.6**	**17.9**	**63.5**
75th %ile	864	741	7.91	8.00	6.9	6.2	67.9	108.6
95th %ile	**1614**	**1253**	**8.21**	**8.16**	**12.2**	**8.8**	**128.1**	**137.8**
max	32349	2706	8.74	8.25	67.7	12.4	991.2	991.2

Datasets

- EA Iron compliance assessment dataset (England and Wales)
- Fe Data subset used for iron toxicity calculations (matches from EA and GB datasets)
- GB Water chemistry parameters (Great Britain)

The ranges of the parameters in the dataset used for iron toxicity calculations are generally broadly comparable to the overall situation for iron exposure, but tend to include waters with higher pH and calcium concentrations than is seen for Great Britain overall. The dataset used for iron toxicity calculations does not include any sites from either Scotland or Wales, and the exclusion of these predominantly soft water regions is likely to have biased the comparison against the overall situation for Great Britain. *The slight tendency away from lower pH values and low Ca concentrations is likely to bias the Fe dataset away from the most sensitive conditions.*

In order to address this issue, additional data were obtained for areas where the potential for adverse effects due to iron on aquatic organisms is likely to be maximised. The selected conditions were waters with a mean pH of less than 6.5, and a median DOC concentration of less than 2.5 mg/L. Twenty-seven sites from the GB dataset met these criteria, and the majority of these sites also have low calcium concentrations. Two of the identified sites, both located in Cornwall, had low pH, low DOC and high hardness (mean calcium 74 and 86 mg/L). This dataset was compiled in order to assess the potential protectiveness of the proposed EQS under the most sensitive conditions.

3.2 Prediction of Iron Sensitivity of Aquatic Organisms

For each sampling location the local water chemistry parameters were used to calculate the EC10 value for three trophic levels (fish, *Daphnia*, and algae) according to the models previously developed. The models use water hardness, rather than calcium concentrations, as an input parameter. Water hardness was calculated from calcium concentrations by first estimating the magnesium concentration (Peters et al. 2011 IEAM 7:437), and calculating the water hardness from the calcium and magnesium concentrations.

The ranges of EC10 values calculated for each trophic level are shown in Table 3.2, along with the minimum EC10 value for each site (i.e. that for the most sensitive trophic level under the local conditions). All of the calculated EC10 values for these 115 sites are higher than the proposed EQS of 730 $\mu g\ l^{-1}$ total iron. A compliance assessment using the site specific iron exposure data indicates that none of these sites are expected to be potentially at risk, based on the species used in the toxicity testing programme. When assessed against the proposed EQS of 730 $\mu g\ l^{-1}$ total iron 29 of the 115 (25%) sites failed at face value, and 9 (8%) of these sites failed with 95% confidence. Several (6) of these apparently failing sites have moderate to high DOC concentrations (> 5 mg/L) which is likely to significantly reduce the potential for adverse effects from iron.

Table 3.2 Ranges of EC10 values (µg/L total iron) predicted for three trophic levels based on local water chemistry data for 115 sites

	P. subcapitata	*C. dubia*	*P. promelas*	**Minimum**
min	2,411	1,311	990	990
5th %ile	2,886	1,843	3,865	1,843
25th %ile	4,357	2,537	21,658	2,537
50th %ile	6,904	3,787	44,187	3,787
75th %ile	8,309	4,495	87,983	4,495
95th %ile	11,010	5,289	160,222	5,289
max	14,096	8,227	649,945	7,616

Site specific EC10 values were also calculated for each trophic level for the 29 sites identified as potentially sensitive to iron, based on their local water chemistry. The two sites with high hardness were not identified as being especially sensitive to iron, and are not considered further in the following discussion. At the remaining 27 sites fish were predicted to be the most sensitive trophic level, and the EC10 for fish was predicted to be below the proposed EQS of 730 µg/L total iron in all cases. The predicted EC10 values for fish ranged from 52 to 707 µg/L (total iron), with a mean and geometric mean of 344 and 261 µg/L, respectively. The actual iron exposures, and hence also risks, at these potentially sensitive sites are unknown. These sites are expected to represent approximately the most sensitive 2% of sites in Great Britain.

A comparison of the compliance assessment based on the proposed EQS of 730 µg/L, and the minimum EC10 from the recently developed iron toxicity models is shown in Figure 3.1.

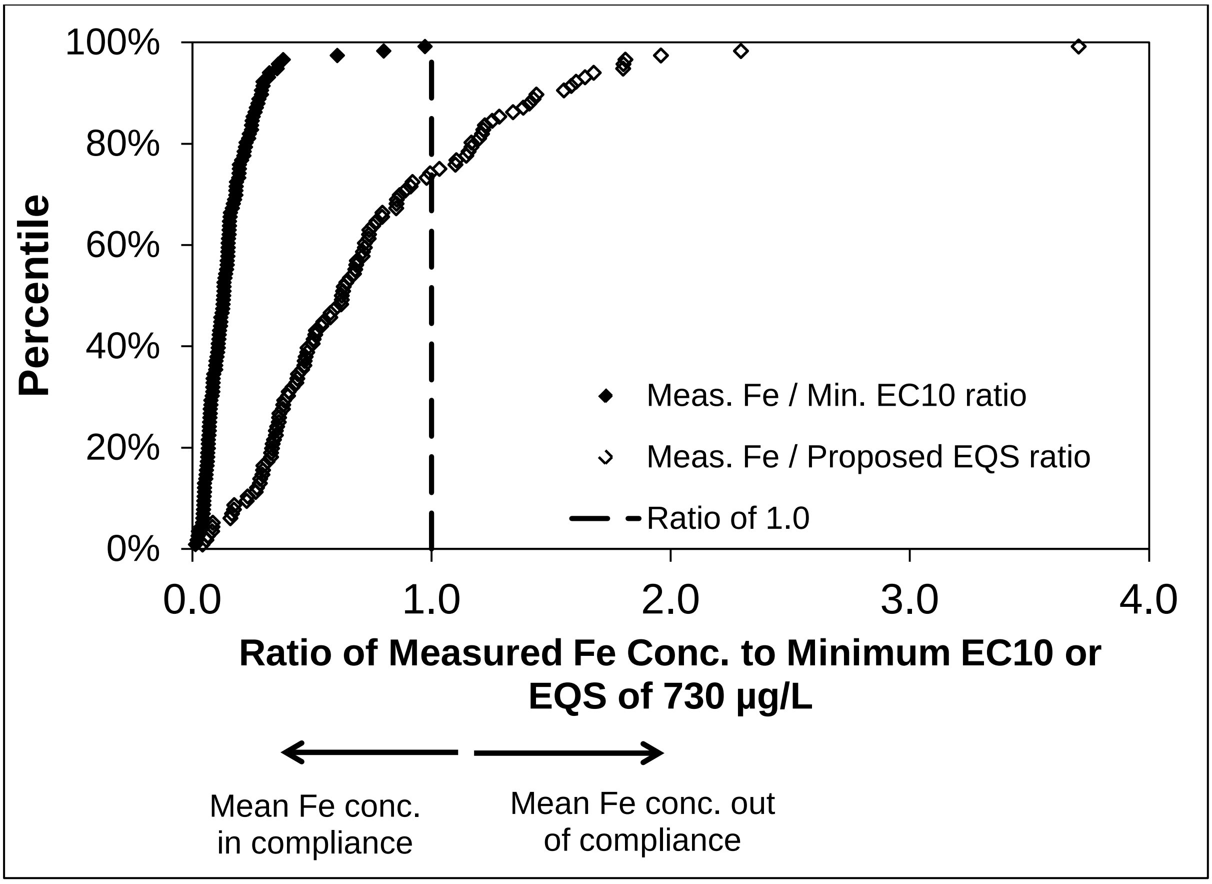

Figure 3.1 Cumulative distributions of ratios of mean measured total Fe concentrations to (1) minimum of estimated EC10 values for *P. subcapitata*, *C. dubia*, and *P. promelas*, and (2) the proposed EQS of 730 µg/L for the subset of matched sites (Fe dataset, n = 115).

4 Comparison with proposed EQS

The findings of the present study support the suggestion made in the EQS proposal that invertebrates are likely to be the most sensitive organisms to any adverse effects of iron in the majority of surface water types which are likely to be included in assessments of compliance against an EQS for iron. In addition, the present study supports the suggestion in the EQS report that there is likely to be an effect of water chemistry on the potential for iron toxicity to aquatic organisms, and the concern that a standard derived to be protective of average conditions may not necessarily be protective of all conditions. We believe that there may now be adequate information to enable the EQS to take account of the effect of water chemistry on the potential for iron toxicity.

Whilst the derivation of the standard from field data is based only on invertebrates it does cover a considerable diversity of organisms, the majority of which are not routinely tested in laboratory experiments. We would expect analyses which are based on changes in the abundance of organisms to be more sensitive than analyses which are based on the presence or absence of organisms at sites, as is indicated by the EQS report. We also believe that the approach which focuses on the abundance of the more sensitive members of the community is broadly consistent with the aims of EQS derivation from laboratory test data.

Analyses of the field data which reflect average or typical field conditions (assumed to be a pH of between 7.2 and 7.7, a calcium concentration of between 30 and 100 mg/L, and 2 mg/L of DOC) have resulted in thresholds for the whole community which are comparable to the predicted EC10 for *Ceriodaphnia dubia*, the most sensitive of the three tested organisms, under similar conditions. EC10 values for *C. dubia* under these conditions are between 2-3 mg/L. This suggests that the most sensitive organisms found in the field are likely to be more sensitive than *C. dubia* under the same conditions, although EC10 values for *C. dubia* are likely to be able to provide an indication of the sensitivity of the benthic macroinvertebrate community as a whole.

We would suggest that further consideration is given to the potential sensitivity of other trophic levels, as identified by the EQS report. The findings of the present study would suggest that the critical trophic level is likely to be fish, and that they are likely to be most sensitive to the adverse effects of iron under conditions of low pH, low DOC, and low water hardness (or calcium concentrations).

5 Conclusions

1. Studies of the toxicity of iron to fish, *Daphnia*, and algae have indicated that there is a significant effect of water chemistry on toxicity.
2. Models have been developed to predict the EC10 for iron to fish, *Daphnia*, and algae according to local water chemistry conditions.
3. The proposed EQS for iron is likely to be protective of aquatic communities under the majority of conditions.
4. The proposed EQS for iron is likely to be over protective under many circumstances, especially given the observed co-variation between iron and DOC levels, and the protective effect of DOC on iron toxicity.
5. In some especially sensitive areas the proposed EQS for iron may not be adequately protective of fish communities based on laboratory studies with fathead minnows.
6. We recommend that the EQS for iron be based on an approach that allows for the number to vary as a function of water chemistry to avoid over regulation as well as under protectiveness.
7. We welcome further dialogue on this topic.