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# Should the Discharge Standards for Manganese Be Reexamined?

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Abstract. By law, effluent mine water is limited to an average concentration of 2 mg/L manganese and a 30-day maximum of 4 mg/L. These standards were selected based upon available technology, known problems with regard to downstream water utilization (brown stains on laundry, etc.) and a concern, based on the limited data available at the time, that a toxicity problem could possibly exist.

There are, however, several reasonable arguments against the low legal limits. Most operators, to meet the standards, raise the pH of mine water to about 10.5, increasing chemical treatment costs 20 to 100 pct. Precipitation of manganese then lowers the pH, but an effluent pH of 9 or even higher is common. The effect of the high pH water can be much more detrimental to stream biota than the manganese would have been.

Another potential problem associated with such treatment is that the manganese-bearing sludge represents a secondary pollution source. The sludge is stable in the alkaline settling ponds, but when the ponds are cleaned, the manganese can redissolve after exposure to neutral or acidic water. Mine sites that dispose of their sludge in the backfill (a common practice) can thus end up treating the same manganese over and over again.

Finally, there have been additional studies on the toxicity of manganese. Manganese toxicity at low concentrations is apparently only a problem in very soft or very pure water. Except in rare instances, manganese can be considered to be a simple nuisance pollutant. It is suggested that the manganese standards be reexamined in the light of this information.

#### Introduction

The initial effluent limitation guidelines for manganese<sup>\*</sup> in coal mine drainage were promulgated by the U.S. Environmental Protection Agency (EPA) in 1976, in response to the requirements of the 1972 Clean Water Act.<sup>1</sup> The EPA identified various metal ions, including iron, manganese, aluminum, nickel, zinc, and copper, as pollutants that were possibly deleterious to aquatic organisms. Manganese was also known to cause problems to downstream water users, such as stains on laundry and porcelain. The best practicable control technology (BPT) effluent

\*Throughout this paper, "manganese" refers to total manganese and the specific forms of manganese are referred to by chemical symbol. limitations were determined for iron and manganese based on the performance of selected acid mine water treatment facilities. Limitations on other metals were not promulgated because EPA found that the other metals were controlled by the specific iron and manganese limitations.<sup>1</sup> Manganese was limited to a daily maximum of 4.0 mg/L; the average for 30 consecutive days was limited to 2.0 mg/L.

The Clean Water Act of 1977 required the imposition of best available technology (BAT) effluent limitations to control 129 toxic substances, including a number of metals (but not manganese). Selection of a specific standard was a result of a survey of 314 acid water sources.<sup>2</sup> The EPA researchers verified that mine water treatment facilities surveyed were reducing manganese to approximately 2 mg/L, and therefore selected the BPT limit as a reasonable BAT effluent limit for manganese.<sup>3</sup> Also, eight toxic metals (arsenic, chromium, copper, lead, mercury, nickel, selenium, and zinc) were determined to be present in coal mine drainage, but once again were excluded from regulation because controlling manganese provided effective control of the toxic metals. Conventional removal of manganese requires a higher pH than treatment for iron alone and the control of these metals was linked by EPA to the manganese standard. State, NPDES (National Pollutant Discharge Elimination System) permits, and other Federal effluent limitations on point source discharges typically mirror these effluent limitation guidelines (cf. OSM program performance standards).4

To satisfy the needs of downstream water users, some states have enacted additional instream water quality standards. These standards incorporate the dilution available in the receiving stream in the vicinity of the point of discharge. Additional dilution available farther downstream is sometimes considered. For example, Pennsylvania's water quality standard for manganese is 1.0 mg/L for all stream waters. Colorado's standard is 1.0 mg/L for streams with fish and aquatic life (though a bioassay can be used to justify other standards), but if the receiving stream is a public water supply, the maximum permissible concentration at the intake point is 0.05 mg/L of manganese. Minnesota, Kentucky, North Carolina, Ohio, and Oregon also have a 0.05-mg/L limit for public water supplies but do not otherwise regulate manganese. Virginia has the same public water supply restriction and an additional limitation of 0.1 mg/L of manganese for high-quality receiving streams. Finally, Illinois has a 0.15-mg/L limit for public water supplies and a 1.0-mg/L limit for most other water.  $^5$  Other states do not regulate manganese levels in the streams, presumably because they believe the EPA effluent regulations and drinking water standards provide adequate protection.

It is the intent of this paper to re-examine the basis of the manganese effluent limit for coal mine drainage in light of subsequent studies and to present certain impacts of this standard that were unknown when the regulations were enacted.

#### Effect Of Manganese On Water Use

Manganese is undesirable in domestic water supplies because, at concentrations above 0.2 mg/L, it causes dark brown stains on laundry and plumbing fixtures and forms deposits on food during cooking.<sup>6</sup> Cohen et al. found that a concentration of about 180 mg/L  $Mn^{2+}$  adversely affected the taste of spring water for most people, and that more sensitive individuals could detect the taste of  $Mn^{2+}$  at concentrations as low as 32 mg/L. In distilled water, taste thresholds dropped to 35 mg/L for the median and to about 0.9 mg/L for the most sensitive members of the group being tested.<sup>7</sup>

Industrial uses of water are adversely affected by the presence of manganese. Concentrations above 0.2 mg/L are detrimental in textile and food-processing plants; even lower levels are required in dairies, paper mills, and certain plastic manufacturing plants.<sup>6</sup> However, operations that require such a high degree of

purity will often treat influent water to remove other discoloring impurities, and so may be able to tolerate slightly higher in-stream manganese concentrations.

### Toxic Metals And BAT

During the process of developing BAT effluent limitations guidelines for the coal mining industry, EPA found that certain metals, such as chromium, copper, zinc, and nickel, were present in the untreated mine water. Water treatment specifically to control iron (neutralization and aeration) reduced the concentrations of these toxic metals, but not consistently enough to provide effective control as required by the Clean Water Act. However, the metals found were almost completely removed when manganese was controlled at 2.0 mg/L. Thus, a major factor in deciding to regulate manganese was to avoid having direct regulation of eight toxic metals.<sup>2</sup>

#### Table 1. Manganese and iron concentrations in acid mine water, from analyses already on record in authors' files.

	Total Mn	Total Fe
Site	(mg/L)	(mg/L)
PA - Greene Co.	211.4	729.4
PA - Greene Co.	121.0	286.9
PA - Venango Co.	87.7	51.3
PA - Clarion Co.	91.2	31.6
PA - Clarion Co.	106.8	691.6
PA - Clarion Co.	40.7	20.5
PA - Centre Co.	130.6	193.2
PA - Clearfield Co.	30.6	50.6
PA - Clearfield Co.	138.3	116.7
PA - Clearfield Co.	160.6	131.7
PA - Clearfield Co.	122.2	13.3
PA - Clearfield Co.	82.7	39.7
PA - Clearfield Co.	116.5	106.6
PA - Clearfield Co.	102.8	42.9
PA - Westmoreland Co.	138.0	100.0
PA - Westmoreland Co.	202.4	680.8
PA - Westmoreland Co.	108.0	19.7
PA - Westmoreland Co.	79.0	38.2
WV - Braxton Co.	72.1	1030.0
WV - Upshur Co.	158.6	43.9
WV - Upshur Co.	180.0	90.6
WV - Upshur Co.	69.8	21.3
WV - Kanawha Co.	257.0	14/.0
KY - Pike Co.	48.0	102.5
KY - Floyd Co.	100.0*	2500.0*

#### \*Approximate.

The average manganese concentrations of the untreated mine water in the EPA site survey used to develop BAT guidelines were 4.9 mg/L at underground mines and 17.7 mg/L at surface mines.<sup>2</sup> Manganese did not exceed 63 mg/L at any surveyed acid mine water site. However, our work indicates there are many mine sites with manganese levels much higher than those found by EPA. Also, the average iron-manganese ratio in the EPA study was 2.6 for surface mines and 27.6 for the surveyed underground mines with acid water problems.<sup>2</sup> Table 1 lists some examples of high manganese values, selected from analyses of various samples collected by the Bureau of Mines during the past few years. At many of these sites, manganese is actually higher than iron. Recent laboratory tests and previous work have shown that removal of manganese becomes

increasingly difficult as the iron-manganese ratio falls below about 2.5, presumably owing to the decrease of coprecipitation of manganese on ferric hydroxide. $^8$ 

In the EPA study, it was determined that the surveyed mine water treatment facilities were reducing manganese to an average value of less than 2.5 mg/L as required by BPT, resulting in the selection of 2 mg/L as the 30-day average value permitted.<sup>2</sup> However, EPA's determination reflects the relatively high iron-manganese ratio and the relatively low concentrations of manganese observed in their study. It should also be remembered that overtreatment with alkalinity (to a pH of about 9.5, and occasionally higher) was very common at the time since the relative cost of treatment was low. Thus, the discharge criteria were not selected to satisfy perceived downstream requirements or because such low limits were necessary for trace metal removal; they were targeted at the level observed to occur in the effluent waters of the surveyed water treatment facilities. If the sites listed in Table 1 had been included in the EPA survey, it is quite possible that a higher discharge standard would have been selected.

# Toxicity Of Manganese To Aquatic Organisms

Regulators selecting a manganese standard for the mining industry found that published literature on the tolerance of manganese was confusing and apparently contradictory, with reported toxic values ranging from 1.5 mg/L to 3,400 mg/L. Much of this discrepancy is attributed to the different species of fish used in the various studies and to differences in experimental conditions. As a case in point, let us critically examine the oldest, often-cited study. In 1915, Thomas reported on the effect of various substances on Fundulus heteroclitus, a small minnow.<sup>9</sup> In its natural environment (salt water), the minnow tolerated manganese at all levels tested (not specified, but probably 200 mg/L MnCl2). Thomas observed, however, that the minnow could survive in brackish water, and through experimentation, determined that it could even survive in fresh water, though presumably under stress. Thomas repeated his experiments in tap water simply to see what effect the fresh water would have, and reported that 12 mg/L  $\rm MnCl_2$  killed the minnows in 6 days.  $^9$  Subsequent publications cite the Thomas study by reporting this toxicity value and therefore are misleading. $^{2,10}$ 

Most of the reported studies examine the toxicity of manganese in tap water. Jones and Kaemmerer and Erichsen experimented with sticklebacks and respectively reported toxicity and a tolerance of 50 mg/L manganese for similar 3-day tests.<sup>11,12</sup> Oshima experimented with fresh water eels and reported no deaths in 50 hours of exposure to manganese concentrations greater than 2,700 mg/L.<sup>13</sup> Iwao, working with freshwater cyprinodonts (<u>Orizias latipes</u>), found 3,400 mg/L manganese to be the 24-hour toxic lethal limit.<sup>14</sup> Clemens and Sneed reported that channel catfish fingerlings tolerated a manganese disodium EDTA solution for over 96 hours at concentrations greater than 500 mg/L (equivalent to 40 mg/L Mn).<sup>15</sup> In tap water that contained 120

mg/L hardness,\* Agrawal and Srivastava determined a 96-hour LC50  $^{\star\star}$  for Colisa fasciatus to be 2,850 mg/L.16

Trout, especially rainbow trout, are very sensitive to manganese. Lewis, using distilled water, observed that the mortality of rainbow trout eggs increased from 7 pct at 0 mg/L of manganese to 12 pct at 1 mg/L, to 22 pct at 5 mg/L, and to 30 pct at 10 mg/L.<sup>17</sup> Fry and adult rainbow trout were unaffected by 10 mg/L or less.<sup>17</sup> England, using lake water with very low hardness (2 mg/L), determined a 96-hour LC50 for manganese to be 24.7 mg/L.<sup>18</sup> England and Cumming determined that the tolerance limit of rainbow trout fingerlings in 96-hour laboratory tests was 16 mg/L manganese for 59 to 65 mg/L hardness.<sup>19</sup> Hill, working with water that had a total hardness of 120 mg/L, found that the 96-hour TLm<sup>\*\*</sup> was 50 mg/L Mn<sup>2+</sup> for adult rainbow trout, but that these tolerance limits decreased in silty water.<sup>10</sup>

In a series of reports and articles that followed the deaths of rainbow trout at soft water fish hatcheries in the Chattahoochee River watershed in Georgia and Arkansas, much lower manganese tolerance limits have been reported for rainbow trout. Ingols found that 1.0 mg/L . manganese resulted in the death of rainbow trout below Buford Dam on the Chattahoochee River in Georgia (Lake Sidney Lanier tail water).20 Ogelsby et al. implicated the interaction of 0.5 mg/L manganese, along with the presence of humic substances, in the death of rainbow and brown trout.<sup>21</sup> Grizzle conducted a detailed study with rainbow trout, brown trout, brook trout, and yellow perch in the vicinity of Buford Dam, Georgia, and found that only the first two were sensitive to low levels of manganese.<sup>22</sup> Grizzle also concluded that humic substances were not responsible for the apparent toxicity of manganese but that synergistic action from other contaminants, such as dissolved iron, copper, zinc, and cadmium, probably was significant.<sup>22</sup> This was followed by a series of bioassay experiments at Buford Dam and the associated Lake Sidney Lanier by Lehman et al. that demonstrated that oxidized manganese was not significant but that the 48-hour LC<sub>50</sub> for  $Mn^{2+}$  was approximately 0.65 mg/L (interestingly, Fe<sup>2+</sup> showed almost identical toxicity).<sup>23</sup> Lehman et al. also determined that although Fe<sup>2+</sup> and  $Mn^{2+}$  synergism was a possibility, the observed fish mortalities were primarily associated with  $Mn^{2+}.^{23}$  However, it should be stressed that these unusual toxicities have all been associated with one watershed, and that the effect of the manganese has conclusively been linked to the low levels of hardness observed in that river. In the same watershed, Nix and Ingols concluded that "oxidized" particulate manganese at 1.0 mg/L (rather than the soluble  $Mn^{2+}$ ) was responsible for the death of rainbow trout at the Greers Ferry Reservoir.<sup>24</sup> Adding 10 mg/L of hardness prevented trout mortality at 1.0 mg/L  $Mn^{2+}$ .<sup>23</sup> At 100 mg/L calcium (250 mg/L hardness), manganese was not

\*Throughout this paper, hardness is expressed as mg/L CaCO<sub>3</sub>.

\*\*LC50 refers to the lethal concentration for 50 pct of the test population. \*\*\*TL<sub>m</sub> refers to the mean tolerance level. <code>harmful</code> in a 120-hr period at a concentration of 24  $\mathrm{mg}/\mathrm{L}_{-}20$ 

Regarding other aquatic organisms, Lewis determined a 96-hour LC<sub>50</sub> for juvenile longfin dace to be 130 mg/L manganese in water with 224mg/L hardness.<sup>25</sup> The flatworm can tolerate up to 700 mg/b<sub>6</sub> (as MnCl<sub>2</sub>) or 660 mg/L (as Mn(N<sub>0</sub>3)<sub>2</sub>).<sup>26</sup> The threshold limit for Daphnia magna was 50 mg/L (as MnCl<sub>2</sub>).<sup>27</sup> Finally, a 7-day test at 15 mg/L of manganese had no adverse effects on crustacea, worms, and insect larvae.<sup>28</sup> In general, manganese is only slightly more toxic to aquatic organisms than potassium.<sup>11</sup>,<sup>29</sup>

#### Negative Aspects Of Manganese Limits

Although the preceding discussion certainly provides justification for an effluent limit on manganese, the control level selected may not be optimal. For example, the upper pH limit for most freshwater fish is 8.7 to 9.2.30 Thus a high-pH discharge, which is legally allowed if necessary to meet manganese effluent requirements, can itself be harmful to aquatic life. However, the literature does not allow a good comparison of the relative biological tradeoffs. In this section, we will instead examine the costs associated with the selected effluent limit, the long-term fate of the precipitated metals, and whether the effluent limit could be raised without losing control of the trace metals.

## Trace Metal Removal

A study by Wilmoth of EPA tested removal of spiked trace metals at the Crown Mine Water Treatment Plant. He found that the metals of concern were all removed at pH  $9.31\,$  In our own laboratory tests, which used two mine waters with very different iron-manganese ratios, nickel, zinc, copper, and chromium were all reduced to less than 0.2 mg/L at pH values of 8.5, 7.5, 7.0, and 6.8, respectively (Table 2). In both mine waters, reducing the concentration of manganese to 20 mg/L was sufficient to reduce all of these trace metals to concentrations below 0.20 mg/L. To reduce manganese below 2.0 mg/L, pH values of 8.3 and 9.4 were necessary. Since a more lenient manganese limit (for example, 10 mg/L) would still require treatment to a pH of 8.5 - 9.0, it would appear that a standard of 2 mg/L for manganese is not required to assure removal of other trace metals.

TABLE 2. Metal removal from two mine waters with addition of NaOH

Concentration of untreated AMD (mg/L)		pH required to meet desired levels*		
	I	II	1	II
Fe Mn Cu Ni	7.7   84.3   0.27   2.87	7,300 76.5 22.6 15.8	<7.0 9.4 <7.0 8.5 7.4	8.3 8.3 <6.8 7.4
Cr	BDL**	1.82	BDL	<6.8

\*3.0 mg/L for iron, 2.0 mg/L for manganese, and 0.2 mg/L for other metals.

\*\*BDL = below detectable limits of 0.04 mg/L.

#### Potential Cost Savings

The cost of meeting the manganese effluent standards has risen with the costs of chemicals and labor, while profit margins in the coal industry have decreased. If manganese is removed by increasing the pH to 10 or above, the material costs of chemical treatment are increased 20 to 100 pct over the costs for iron removal. The alternative technique of treating to a neutral pH, aerating to remove the iron, and then using a chemical oxidant to remove the manganese increases costs about 500 pct.32,33

Figure 1 illustrates the costs of removing manganese by adding sodium hydroxide with optimal control of pH, as calculated at three mine sites with manganese concentrations of 12 to 100 mg/L. If the manganese standard was 10 mg/L, a site with an average influent manganese concentration at 25 mg/L would spend about \$100 extra for chemicals to treat 1 million gallons of water beyond the pH of 7 to 8 normally needed to remove iron. At a standard of 5 mg/L, this cost is almost doubled. To meet 2 mg/L costs still another \$100 for every million gallons of water. So, for a treatment facility handling 1 million gallons per day, the annual savings would be \$71,200 if the effluent limit were raised to 10 mg/L and half that if the effluent limit were raised to 5 mg/L.



Figure 1. Range of additional chemical costs (sodium hydroxide) for manganese removal. Chemical cost for pH adjustment to achieve regulatory compliance with iron standard is not included. Graph is based on results from three mine sites where manganese concentration ranged from 12 to 100 mg/L.

It should also be remembered that the expense of water treatment continues long after mining has ceased and coal sales are no longer producing revenue. There are now several reclaimed mine sites where the mine water meets all of the water quality criteria except for manganese. In such cases, water treatment has had to be maintained to control manganese, typically without release of bond money. For example, at one site in Somerset County, PA, the presence of 8 to 10 mg/L of manganese is causing the company to spend \$52,000 a year on sodium carbonate (soda ash briquettes), while at the same time preventing the release of \$75,000 in bond money. At another site in the same county, a \$200,000 bond is being held owing to manganese in the mine water.

#### Treatment Effectiveness

A potentially greater problem has recently been discovered. The manganese sludge produced by neutralization of mine water is susceptible to dissolution. Although stable in alkaline solutions, it was determined in the laboratory that about 25 pct of the manganese is quickly resolubilized if recently formed sludge is exposed to water of neutral pH; at pH 5, over 60 pct is rapidly resolubilized. As can be seen in Figure 2, at pH 4 (the pH of much of the rainfall in the Eastern United States), about 80 pct of the manganese is rapidly dissolved. The sludge does become more stable as it ages in an alkaline environment, but still approximately 20 and 40 pct of 3-month-old sludge is immediately resolubilized upon exposure to water of pH 7 and 5, respectively. It should be mentioned that such redissolution should not be a problem at those rare sites where the manganese is removed with chemical oxidants.  $^{33}\,$ 



Figure 2. Resolubilization of manganese from sludge precipitated by the high-pH method (pH>10). Curves were generated by acid addition to sludge to various final pH values. "Fresh" and "Aged" refer respectively to freshly precipitated sludge and to sludge that had aged for 3 months.

Our laboratory tests also indicate that nickel, zinc, copper, and chromium precipitated from coal mine drainage by addition of alkalinity are also susceptible to dissolution when exposed to more acidic conditions. Concentrations greater than 0.20 mg/L nickel, zinc, and copper are resolubilized (or desorbed) at pH values of 7.0, 6.8, and 5.3, respectively. Chromium, however, is stable down to pH 3.0.

The extent to which redissolution actually occurs in the natural environment is probably related to disposal conditions. The extent of compaction of cover material, the thickness of sludge, the neutralization potential of the backfill material, the presence or absence of vegetative cover, and many other factors would presumably affect resolubilization. However, a possible explanation of the high manganese levels currently observed at many mine sites is that manganese is being recirculated. For example, the first seep listed for Greene County in Table 1 is located immediately down-gradient of a sludge disposal area. It is likely that the 211.4 mg/L of manganese reflects redissolution of manganese sludge, since water elsewhere on the site contains 100 to 130 mg/L manganese. If indeed precipitated manganese redissolves after disposal of the sludge, then the current stringent standard simply transfers current manganese levels into the future by providing a more concentrated source of manganese. Ironically, a more lenient limit that is yet adequate to protect downstream users and aquatic life could thus also serve to reduce future manganese levels.

Alternative methods of water treatment, nonexistent a decade ago, further complicate effluent limits based upon conventional neutralization. For example, the In-Line System (ILS) can remove manganese at neutral pH if the iron-manganese ratio is fairly high.<sup>8</sup>,<sup>33</sup> Similarly, chemical oxidants and constructed wetlands have been used to remove manganese at neutral pH.<sup>32</sup>,<sup>33</sup> However, with these alternative methods, which operate at neutral pH, one can ask whether the manganese criterion is still a reasonable surrogate for the trace metal standards.

# Conclusion And Discussion

Manganese can have an adverse effect on downstream water users and certain fish. In addition, the use of manganese in effluent limitations guidelines as a surrogate for toxic metals at conventional mine water treatment facilities is a sensible alternative to regulating a long list of metals. However, the specific industry-wide discharge criteria that were adopted, based primarily on observed levels of manganese attained at certain treatment plants appear, in retrospect, to be more stringent than required. One alternative is a case-by-case adjustment of effluent limits. Specifically, the regulations state -

(b) In establishing national limits, EPA takes into account all the information it can collect, develop and solicit regarding the factors listed in sections 304(b) and 304(g) of the Act. In some cases, however. data which could affect these national limits as they apply to a particular discharge may not be available or may not be considered during their development. As a result, it may be necessary on a case-by-case basis to adjust the national limits, and make them either more or less stringent as they apply to certain dischargers within an industrial category or subcategory. This will only be done if data specific to that discharge indicates it presents factors fundamentally different from those considered by EPA in developing the limit at issue.  $^{34}\,$ 

Perhaps owing to the complications caused by the superimposition of OSM and EPA enforcement, no such exemption has ever been granted for a site with manganese problems. However, allowing such flexibility for manganese would appear to be reasonable, especially for sites with relatively high manganese-iron ratios, if the site was otherwise suitable. Specifically, if the trace metals of concern are either absent or removed at pH 9 or below, if the stream water has sufficient hardness to protect sensitive fish, and if sufficient dilution is available to avoid adverse effects on downstream users then it would appear that more lenient effluent limits could be substituted without adverse consequences. Also, under current regulations, more lenient effluent limits can be negotiated for surface mines with the state regulatory agency after mining is completed since the effluent limits for manganese are not applicable.<sup>3</sup> At sites where manganese is the only water quality problem, a favorable analysis with respect to such factors as hardness, downstream water users, etc., should result in a higher negotiated limit.

The fact that manganese values today often exceed the highest concentrations observed in the EPA survey may reflect redissolution of manganese from mine drainage sludge. If such is true, the low effluent limits on manganese may lead to higher subsequent concentrations and may recirculate the associated trace metals as well. Alternative procedures that produce a stable sludge would increase treatment costs about 5-fold. Either OSM or EPA should investigate the long-term liability of manganese recirculation and whether relaxing the manganese standard would lessen the effect of manganese redissolution. At the same time, mining companies should examine their sludge disposal practices, in light of the laboratory data presented herein, and determine if they are adding to their water treatment costs by retreating manganese in their mine water.

Finally, we should address the question posed in the title of this article. The scientific evidence certainly provides justification for a reexamination of the manganese limits. The range of water quality being treated and the treatment techniques being used have changed significantly since the EPA survey a decade ago. At the same time, new information that relates manganese toxicity to fish to hardness clarifies much of the confusion that previously existed in the literature. In addition, it would appear that even high levels of toxic metals are reduced to acceptable limits in treatment of mine water to manganese concentrations of 10 to 20 mg/L. The effluent limits for manganese were selected based on the best information available at the time; it would now appear to be a suitable time to reexamine these limits to determine if they can be made more lenient without harm to the environment.

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