MEMO

To:	Honorable Members of the Hibbing City Council John P. Suihkonen, P.E., Hibbing City Engineer Norm Miranda, Central Iron Range Sanitary Sewer District (CIRSSD)
From:	Mark Stone; Adam Salo; Alison Sumption Howard R. Green Company (HR Green)
Subject:	CIRSSD / Hibbing South Wastewater Treatment Plant (WWTP) Preliminary Engineering Study – Mercury Treatment Alternatives
Date:	June 11, 2009

Purpose and Objective

The Preliminary Engineering Study of Mercury Treatment Alternatives was conducted to evaluate alternative mercury removal technologies to facilitate selection of a preferred technology and identify location of required new processes at the existing Hibbing South Wastewater Treatment Plant (South WWTP). The primary goal of the study was to identity and confirm technologies that will achieve the Minnesota Pollution Control Agency (MPCA) mandated mercury removal limits and compare their associated capital and operating costs.

Background

The MPCA issued the most recent National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit (MN0030643) for the South WWTP on March 16, 2007. The permit, in part, requires the City of Hibbing (Hibbing) to submit plans and specifications for the mercury treatment facility to MPCA on or before September 1, 2009 and to comply with the total mercury discharge limits by March 31, 2011. The total mercury limits are a calendar monthly average limit of 1.8 nanograms per liter (ng/L) and a daily maximum permit limit of 3.2 ng/L.

A Mercury Treatability Study (bench scale), prepared by Northeast Technical Services Inc. (NTS) in November 2007 recommended piloting a conventional dual media gravity filtration technology to meet the NPDES permit mercury limits. However, in reviewing results from that study, MPCA expressed concern that this technology may not provide enough margin of safety against process upsets in the secondary treatment system. Consequently, a part of the Mercury Treatability Study, a dual media filtration pilot study was completed at the Hibbing South WWTP in 2008 to establish design criteria for a full scale system. However, final results of that pilot study indicated that this technology removed mercury to a level just below the mandated final mercury limit but could not provide consistent and sufficient mercury removal under changing wastewater feed characteristics and flows to consistently meet the mandated final limit. In our opinion, this technology did not provide Hibbing with adequate performance "cushion." As has been experienced, wastewater flows and loads at the South WWTP fluctuate throughout the year which would expose Hibbing to potential permit violations and subsequent fines and penalties.

Following above mentioned pilot work, in early 2009 Hibbing, in cooperation with HR Green, conducted a pilot study with an ultrafiltration membrane pilot plant provided by GE/Zenon. Testing services were performed by NTS and installation was by Bougalis Construction Inc. The pilot study consisted of a Zeeweed 1000 pilot scale plant, drawing effluent from the Third Stage Trickling Filter Clarifier effluent (secondary effluent). Results indicate that without any pH adjustment or additional chemicals, the membrane effluent average total mercury effluent was 1.05 ng/L, with a maximum single sample during the pilot test of 2.5 ng/L. The entire pilot plant was operated at high continuous flux rates (hydraulic loading of membrane); around 23 gallons per day per square foot (GFD) of membrane surface area. It is also important to note the pilot test was conducted during a period when the South WWTP experienced typical and significant fluctuations in flow and load due to spring weather conditions. The Pilot Plant Report prepared by GE staff (reviewed by HR Green staff) is found in Appendix A.

This Preliminary Engineering study evaluates site conditions, preliminary costs and requirements for a mercury treatment system for the Central Iron Range Sanitary Sewer District, (CIRSSD) at the Hibbing South WWTP, as well as the option of Hibbing South WWTP operating alone, outside of the CIRSSD. A Preliminary Opinion of Probable Cost (POPC) and a preliminary annual operating cost comparison was developed for each of the following technologies:

1. Dual media gravity filtration (Siemens Centrol ®)
2. Gravity fed ultrafiltration membrane (GE/Zenon Zeeweed ® 1000 - same as pilot plant)
3. Pressurized ultrafiltration membrane (Siemens Memcore CP 240)

Site conditions, hydraulics, and piping, were evaluated for future expansion of Hibbing South WWTP to handle current and future flows from communities within the CIRSSD service area, as well as the option of serving just the Hibbing service area.

Existing and Proposed Flows and Effluent Conditions

Following is a summary of flows and related effluent quality obtained from discharge monitoring reports (DMR) for the Hibbing South WWTP over a one year period from October 2007 through September 2008:

1. Average effluent flow was 2.59 million gallons per day (MGD)
2. Average effluent Total Suspended Solids (TSS) was 13.8 milligrams per liter (mg/l)
3. Average effluent Total Mercury (Total Hg) was 9.3 ng/l

During the membrane pilot study (conducted over 6 weeks from March 3 to April 10, 2009) twelve samples of Hibbing South WWTP secondary effluent and membrane effluent (permeate) were collected and analyzed for total Hg. Refer to the Pilot Plant Report in Appendix A for a summary of sampling and other pertinent operating data. Preliminary results indicate that the average Hibbing South WWTP secondary effluent total Hg was 9.3 ng/L (consistent with previous data) and permeate total Hg averaged 1.05 ng/L, with a maximum single sample event of 2.5 ng/L. Permeate TSS, due to the small pore size of ultrafiltration membranes, would generally be negligible, or near zero at all times. It is assumed that effluent quality from the secondary treatment system at the future flows would be similar to the existing effluent quality; therefore, associated mercury loads from the secondary effluent would increase proportionately as total flow increases.

The January 2008 Facility Plan for CIRSSD (Facility Plan), prepared by RLK Inc., projected the average wet weather flow (AWWF) to the proposed CIRSSD WWTP to be 7.25 MGD. As part of this study a separate evaluation analyzed the historical flows to the Hibbing South, Chisholm, and Buhl WWTP's. Also analyzed was the capability of the equalization/storage facilities at each WWTP site to accommodate peak wastewater flow (see Appendix B). Through this analysis, and based on the Facility Plan recommendation to increase secondary treatment capacity to 9.0 MGD: using a peak wet weather flow of 9.0 MGD (not 7.25 MGD) as the basis of the cost comparison for different mercury removal technologies is recommended. The premise is that all flow to the CIRSSD WWTP greater than 9.0 MGD would be diverted to and stored in the existing equalization ponds. That assumes that the ponds have been adequately cleaned, maintained, and had the recommended improvements made to accommodate the diverted flows.

The CIRSSD also hired Architectural Resources Inc. to prepare a report titled *Delineation of Service Area and Estimate of 20-year Plan Wastewater Demand.* That report indicates that the Hibbing alone would contribute 4.31 MGD (average wet weather flow) to the future CIRSSD. The report also allows an additional 620,500 gallons per day (gpd) of reserve capacity for CIRSSD. Assuming Hibbing would use a proportional amount of the reserve capacity based on total flow contribution of all communities, then Hibbing's future flow would be 4.74 MGD (very close to the existing treatment capacity of the Hibbing South WWTP of 4.5 MGD). For the purposes of this study, and assuming the existing equalization ponds have been properly upgraded to function solely for equalization, the mercury treatment system for Hibbing could also be sized for approximately 4.5 MGD.

General Site Consideration

The CIRRSD Facility Plan proposed that the mercury treatment building to be located on the northern end of the Hibbing South WWTP site, just northwest of the Anaerobic Digester Building and east of the North First Stage Secondary Clarifier. This would place the mercury treatment building over the access road and the effluent outfall sewer. After further consideration of the actual processes involved, the site piping, and available hydraulic grade line; a different location is recommended. From a process perspective, mercury treatment is a tertiary treatment system that would typically follow directly after secondary treatment and prior to disinfection (see Drawing P01 for the existing process flow diagram). Therefore, flow could be diverted to the mercury treatment system anywhere between the Second/Third Stage Secondary Clarifier Effluent Splitter Box and the Chlorine Contact Tank. Since there is currently land available south of the 2 acre equalization pond, and it is adjacent to the Chlorine Contact tank, the location is suitable for accommodating the mercury treatment building (see Drawing C01 for a site plan, which incorporates recent topographic work completed by RLK in 2009, and shows the proposed mercury treatment facilities, effluent diversion structure, and major site piping). The building shown generally represents the overall space required for the facilities. The actual building layout will depend on the mercury treatment technology utilized, as described later.

Effluent from secondary treatment can be diverted just upstream of the Chlorine Contact Tank east to the proposed mercury treatment building. A diversion structure would direct flows of 9.0 MGD or less to the mercury treatment system, and excess flows could either be directed to the Chlorine Contact Tank or the Equalization Ponds. Normally, the secondary effluent would flow by gravity either directly to the process tanks, or into a wet well for which it would be pumped to the mercury treatment process. Each process will have a different arrangement to feed the filter system, as described later.

A WWTP hydraulic profile was developed for future flow conditions beginning at the upstream end of the Chlorine Contact Tank and ending at the discharge receiving waters; East Swan Creek. The 100-year flood-plain elevation at East Swan Creek was determined based on previous modeling work HR Green completed for the North St. Louis County Soil and Water Conservation District. The 100-year flood-plain elevation, at a point located immediately after a culvert under the road to the sludge pond, was determined to be about 1358.9 feet above mean sea level. For the purposes of the hydraulic profile, this was assumed to be 1360 feet on the upstream side of the culvert to account for headloss through the culvert and ditch. The hydraulic analysis revealed the following deficiencies and required improvements to increase the outfall sewer capacity to 9.0 MGD:

- The existing final effluent parshall flume has a 12-inch throat and only has a capacity of 6.0 MGD. It will have to be replaced with an 18-inch flume to accommodate flows greater than 6.0 MGD and up to 9.0 MGD. The proposed flume, due to its increased size, requires an invert elevation about 1-foot higher than the existing flume invert elevation to prevent submergence by the downstream water level, which would cause inaccurate flow readings.
- The effluent weirs in the Effluent Aeration Tank and the Chlorine Contact Tank will be very close to submergence at peak flow conditions. This could be further verified with more current survey data to tie weir elevations with predicted flood elevations and the parshall flume elevation. Modifications to the effluent weirs may be required to minimize flow restrictions.

Braun Intertec took five soil borings on March 31, 2009 at the proposed mercury treatment system building location (see soil borings report in Appendix C). The borings indicate the soils in the north and western areas of the site consist of fill material varying in thickness from 4 feet to over 17 feet, overlaying peat and native sandy soils. The borings also indicate that ground water was around 8 feet below grade. It is likely that dewatering of the site will be required to install most , if not all, of the proposed facilities. Shallow foundations will likely require piles or oversized spread footings. For construction of deep foundations and deep tank slabs, overexcavation may be required, as well as installation of thickened mat slabs extending several feet from the structures tank/foundation walls, partially to distribute the structures weight, and to overcome buoyancy effects caused by high ground water.

Technologies Evaluated

Dual Media Gravity Filters

For the purposes of comparison and cost estimating a four cell CenTROL® LP cluster filter by Siemens was used with design hydraulic loading rates as follows:

- 3.47 gpm/square foot (gpm/sf) with one cell off-line @ average flow of 7.25 MGD

- 4.34 gpm/sf with one cell off-line @ peak flow of 9.0 MGD

From the diversion upstream of the Chlorine Contact tanks, the secondary effluent would flow by gravity to a vertical turbine pumping station, and pump into an inlet flume of the filter cluster. A distributor column splits the flow evenly between all of the filter cells regardless of water level in the cells. The influent water flows into gullets, which overflow into the backwash waste troughs and then is distributed across the filter. The water then flows through the filter media, into the underdrain, out the isolation pipes, and into the effluent chamber. From there, it overflows a weir and flows by gravity to the Chlorine Contact Tank.

As the filter accumulates solids and headloss increases, water level in the individual filter cells also increase. When a certain preset high water level is reached in a filter cell, the feed inlet valve is closed and the filter is allowed to continue filtering to bring the water level down. The water level in the filter drops to the level of the wash troughs. The level in the effluent chamber is then higher than the level in the washtroughs, and water is forced from the effluent chamber back up through the underdrain, and up through the media. Air from an air wash blower is injected through an air wash header and distributed evenly by the underdrain. The use of simultaneous air and backwash water improves the efficiency of the backwash. The backwash water is collected in washtroughs and flows into the gullet, through the backwash waste valve, and out the backwash waste pipe. After the backwash cycle, the air is turned off and the backwash continues, purging the air out of the filter and restratifying the media. Then the backwash waste valve is closed, the inlet valve is opened, and the filter comes back on-line.

The filter operation and backwash sequence is controlled by a PLC-based control panel. The levels are monitored by ultrasonic level transmitters for each cell and the effluent chamber.

A preliminary process flow diagram for this system can be found on Drawing P02 and a conceptual building layout, equipment information and quote can be found in Appendix D.

Gravity Fed Ultrafiltration Membranes

Tertiary treatment of the third stage Secondary Clarifier effluent to remove mercury can be accomplished with a Zeeweed membrane system from GE. This system is an ultrafiltration membrane process with the membranes located in open tanks. The preliminary equipment selection for the CIRRSD option includes 4 membrane trains; each train containing 5 cassettes, each cassette containing up to 60 modules. Each module has 500 square feet (sf) of filtering surface area. The total installed membrane surface area would be 600,000 sf, and 450,000 sf with one train off-line. The design flux rates (lower than those piloted) are as follows:

- 16.1 gallons per day per sf (gfd) with one train off-line @ average flow of 7.25 MGD
- 20.0 gfd with one train off-line @ average flow of 9.0 MGD

If only Hibbing flows were treated at the WWTP, then the design average flow would be reduced to 4.5 MGD. Based on GE/Zenon's rule of thumb design criteria, this would require 3 membrane trains; each train containing 5 cassettes, each cassette containing up to 60 modules. The total installed membrane surface area would be 450,000 sf, and 300,000 sf with one train off-line, essentially three-fourths the size of the CIRRSD option. Overall facility size does not decrease proportionally to the decrease of design flow, because of redundancy requirements for the membrane trains. This is reflected in capital costs summarized later.

Flow enters this process from a splitter box after the Second/Third Stage Secondary Clarifiers, just prior to the Chlorine Contact Tank. First, flow passes through a strainer to remove any large particles to prevent damage to and fouling of the membranes. Then flow enters the membrane tanks by gravity. Secondary effluent passes under vacuum through the membranes with a permeate pump. The membrane permeate is discharged into and equalization/backwash tank, which overflows to the Chlorine Contact Tank. Each permeate pump has a magnetic flow meter on the discharge side in order to accurately measure the permeate volume.

In order to keep the membrane system functioning there are some cleaning processes included with the membrane trains. First, a equalization/backwash tank will be continuously filled with permeate and be used to backpulse the membranes whenever they shut down for a backwash cycle. The backwash can also be dosed with potable water, acid or chlorine. Chemical dosage will be determined by final manufacturer and operator optimization, depending on the actual wastewater composition and required cleaning cycles.

A clean in-place (CIP) system will be used weekly for minor cleanings (maintenance cleans) and a few times annually for more thorough cleanings (recovery cleans). This system has a pump to recirculate water in the tank and to pump to the membrane trains. The CIP tank has an electric heater to get the cleaning solution to optimum cleaning temperature, and is fitted with injection points for acid and bleach.

The system has blowers and compressors for process and control. The blowers are used to clean the membranes during backwash cycles and during maintenance and recovery clean sequences. The compressors are used in cleaning the membranes as well as to operate any pneumatic equipment in this system. The bubble test system for maintenance and trouble shooting of the membranes also uses the compressors.

A preliminary process flow diagram for this system can be found on Drawing P03 and a conceptual building layout can be found on Drawing P04. Equipment information and quote can be found in Appendix E.

Pressurized Ultrafiltration Membranes

Tertiary treatment of the third stage secondary clarifier effluent to remove mercury can also be accomplished with a Siemens Memcor membrane system. This system is a low pressure membrane filtration process. The preliminary equipment selection for the CIRRSD option includes 5 membrane units with 240 modules in each unit. Each Memcor unit forms an individual fitter. The units operate independently of each.

5 units provide a net capacity of 9 MGD, with all units working (no spare unit). Each unit has a flow of 1,464 gpm. The flux rate 28.53 gfd, corrected to 20 degrees Celsius (C), much greater than that proposed by GE/Zenon.

If the Hibbing flows only were treated at the Hibbing South WWTP, then the design average flow would be reduced to 4.5 MGD and only 3 membrane units would be required. Decreasing the design flow of the membrane facility does not decrease overall facility size proportionate to flow. This is reflected in capital costs summarized later.

The secondary clarifier effluent flow will be fed to the membranes by variable speed turbine pumps. The feed water will be strained to prevent fouling prior entering one of the units. Each unit functions independently and is controlled by the plant PLC.

Membrane fouling causes downtime of the membrane system. Periodic cleaning can prevent membrane fouling. Each unit is chemically cleaned individually while the other unites remain online. The cleaning takes 4 to 6 hours and includes recirculation and soaking periods. Once the cleaning solution is drained from the filter unit, raw water is introduced and a backwash sequence is initiated. This process is known a Clean-In-Place operation (CIP). A shorter version of the CIP without a soaking period in completed in 30 to 60 minutes. The shorter cleaning version is called the Maintenance Wash. In the Maintenance Wash process a diluted cleaning solution is recirculated through the membranes.

A critical system in the Backwash process is the air scour on the outside of the membrane fibers. Low pressure air is introduced on the feed side of the system to scour the membrane and ensure full recovery of the membrane permeability. 2 multistage blowers (one duty, one standby) are used for the air scour system.

The membranes require a compressed air system for valve actuation, air-assisted liquid backwash, and integrity testing. The air-assisted liquid backwash is a exclusive system for the Memcor membranes. The compressed air assists with removing solids from the membrane during backwash by re-directing filtrate waters in the filtrate manifold back towards the membrane.

A preliminary process flow diagram for this system can be found on Drawing P05. A conceptual building layout provided by the manufacturer, equipment information and quote can be found in Appendix F. The building layout was provided as an example but was for a larger system. For costing purposes only 5 filter units would be needed instead of the 12 shown. The example layout requires a building with internal dimensions of 75 feet x 87 feet. The CIRSSD mercury building layout would only need to be 60 feet by 77 feet internally. Overall dimensions would be 63 feet by 80 feet. In addition, separate chemical storage and electrical/control rooms would be required. For costing purposes these have been assumed to be similar to that shown for the gravity membrane building.

Impacts of Backwash

The three technologies evaluated are all of the filtration type; therefore, all three technologies require backwash systems to clean the filters and maintain acceptable flux through the filters. The primary impact of a backwash system is large surges in flow over short periods of time. For example, the dual media gravity filter can conceivably backwash at the same flow rate as the influent feed rate, 9.0 MGD. Since the existing Hibbing South WWTP facilities do not have capacity to handle such large bursts of flow, the most practical option is to direct this flow to an equalization facility, particularly the 2 acre equalization pond. The flow surge can be dampened in the pond and slowly pumped back to the head of the primary clarifiers via the existing pumping station. Future expansion of the Hibbing South WWTP to handle 9.0 MGD could include provisions to allow direct pumping of the backwash system to the primary clarifiers.

Pretreatment, or sidestream treatment, of the backwash prior to return to the primary clarifiers was considered. Based on the high capital costs of the mercury removal systems evaluated, it was deemed cost prohibited to provide more filters or more tankage to settle solids when the backwash water quality would be hard to differentiate from the existing effluent quality, except for total mercury. Therefore, no costs or provisions have been made at this time for treatment of the backwash streams. After a successful installation of any mercury removal system and after it has achieved stable and reliable operation, additional investigation of enhanced settling in the Primary Clarifiers should be conducted. Improved solids settling in the Primary Clarifiers can provide a means to reduce recirculation mercury load by reducing the amount that goes back to the secondary treatment system.

Preliminary OPC and Operating Costs Summary

For each technology evaluated a preliminary opinion of probable cost (OPC) and annual operating cost was prepared. These costs were based on manufacturer quotes and operating costs information, known existing site piping, site layout, and known soil and ground water conditions. Costs for rehabilitation (such as pond cleaning, re-roofing, TF distribution arm replacement, etc.) and improvements (such as effluent parshall flume upgrade) to the existing facilities were not included in the OPCs. Preliminary estimates for facility rehabilitation of existing equipment and structures is currently estimated by Hibbing at between $1,000,000 and $1,500,000 or engineering costs.

Table 1 below summarizes the preliminary OPCs and annual operating costs for each technology for the CIRSSD option. Annual operating and maintenance (O&M) costs include energy, labor, chemicals, maintenance and miscellaneous supplies. Annualized equipment and membrane replacement (R) costs are the annual funds required to be set aside each year (on average) for full equipment and membrane replacement respectively, over a 20 year operating life. Preliminary OPC breakdown/summaries for both tables are summarized in Appendix G.

Table 1
CIRSSD Option - AWWF = 7.25 MGD

Technology	Preliminary OPC	Annual Operating & Maint. Cost	Annualized Equipment Replacememt	Annualized Membrane Replacement	Total Annualized O,M & R
Dual Media Gravity Filters	$6,657,000	$66,000	$27,000	None	$93,000
Gravity Fed Ultrafiltration Membranes	$12,196,000	$196,000	$45,000	$50,000	$291,000
Pressurized Ultrafiltration Membranes	$14,778,000	$214,000	$86,000	$50,000	$350,000

Table 2 below summarizes the preliminary OPCs and annual operating costs for each technology for the Hibbing flow only option. Capital costs were based on the CIRSSD cost breakdowns with adjustments for the smaller facilities. Operating costs were reduced proportionately based on design average wet weather flow.

Table 2
Hibbing Option – AWWF = 4.5 MGD

Technology	Preliminary OPC	Annual Operating & Maint. Cost	Annualized Equipment Replacememt	Annualized Membrane Replacement	Total Annualized O,M & R
Dual Media Gravity Filters	$5,237,000	$41,000	$17,000	None	$58,000
Gravity Fed Ultrafiltration Membranes	$9,397,000	$122,000	$28,000	$31,000	$181,000
Pressurized Ultrafiltration Membranes	$10,995,000	$133,000	$53,000	$31,000	$217,000

Conclusions

Based on the successful results of the membrane pilot study, membranes can achieve the required mercury limits, provided the dissolved fraction of mercury in the secondary effluent remains less than the permit limit. However, implementation of the membrane technology into a full scale operation will be very cost intensive to build and operate, and may be cost prohibitive to the City of Hibbing and its customer base. In addition, the existing Hibbing South WWTP site has available land for a mercury treatment system but the ideal location for process considerations also has poor soil and ground water conditions that will increase construction costs.

There are additional benefits which could be realized by installation of a membrane facility, which should be considered in light of the capital and operating costs noted above:

- Ultrafiltration membranes have the ability to capture most bacteria (only some viruses) and can therefore reduce or eliminate fecal coliform based disinfection requirements. Hutchinson, MN WWTP utilizes a parallel secondary treatment process which includes oxidation ditches and clarifiers in one half of the process, and membrane bio-reactors in the other half (activated sludge system with solids separation via membranes). Their membrane facility has demonstrated that E. coli counts are typically less than 1 MPN/100 ml. MPCA has eliminated their NPDES requirement for E. coli for effluent from the membrane process.
- With chemical optimization improvements, using membranes can reduce the use of chemicals for phosphorus removal.
- The effluent of a membrane plant could potentially be a valuable water resource for landscape and farm irrigation, aquifer recharge and grey water systems. High quality reclaimed wastewater can be a source of income and reduces the total discharge to the receiving stream, which is favorable to environmental groups opposed to expansion of WWTP flows and loads to the receiving streams.

Recommendations

In light of the results of this study and the City of Hibbing's recent separation from the CIRSSD, following are steps which should be considered by Hibbing to provide the most advantageous outcome to the mercury removal requirement.

Due to the high capital and operating cost of the membrane system it is recommended that Hibbing request a variance for mercury removal compliance schedule in order to look closer at other technologies that may be able to meet the discharge limit with lower installation and operating costs. A position document should be prepared relative to implementation of a mercury treatment strategy and will be used to lead negotiations with the MPCA. In addition to evaluating other technologies, it is recommended that negotiations with MCPA include discussions relative to the current stringent discharge limits. A less stringent (relaxed) limit may open the door for more technologies not yet considered or previously dismissed due to the very tight limit (such as dual media filtration). Furthermore, since the mercury treatment problem is a regional issue affecting many neighboring communities which can benefit from past and future research being conducted and funded by Hibbing, it is recommended that negotiations include a request for MPCA funding to support this effort through technology selection.

It is recommended Hibbing consider submitting requests for available project funding. HR Green has provided draft Corps of Engineer Section 569 and State of Minnesota 2010 Capital Budget requests for your review and execution. These application processes have submittal deadlines of July 31, 2009 and June 25, 2009, respectively. However, applicants are encouraged to submit requests as soon as possible.

Assuming Hibbing is successful in securing a NPDES Permit variance; proposals would be secured from equipment manufacturers to perform pilot testing. Such proposals will follow a defined work plan with required third party performance testing and a project schedule consistent with what we assume will be included in the agreement for the variance. Based upon the results of the additional pilot testing and the financial capabilities of the City, a preferred technology will be selected with subsequent engineering design, construction and facility commissioning. We are hopeful that the variance will include a refined schedule of compliance requiring the City to achieve final limits no earlier than sometime during the 2012 – 2017 NPDES Permit cycle.

Following are other treatment technologies that have the potential to remove particulate and dissolved mercury:

- **Blue Waters Technologies – Blue Pro:** The Blue Pro system utilizes an adsorptive filtering media composed of a moving bed (up-flow) sand filter. The sand is coated with hydrous ferric oxide which is continuously regenerated with addition of ferric sulfate to the filter. This system has been shown to remove mercury down to levels lower than Hibbing's mercury limit at a municipal facility in Idaho. This technology would have the ability to remove a portion of the dissolved fraction of mercury. A preliminary treatability study completed in November 2007 on the Hibbing effluent indicated that the single test performed did not remove enough mercury to meet the limit, but the manufacturer indicated that additional measures could be taken to meet the mercury discharge limit. Additional pilot work would be required to determine the treatability of Hibbing's effluent with this process.

- **Johnson Screens – CoMag:** The CoMag process is marketed as a "precipitated particulate removal process that produces an effluent equivalent to ultra-filtration". It is an enhanced solids settling process which utilizes coagulants and magnetized ballast material to greatly enhance settling. This system has potential to remove mercury at low levels but actual performance hasn't been tested. Jar testing and any subsequent pilot work would be required to determine mercury treatability of this technology.

- **GE – JelCleer™ or JelCleer™ Plus:** A filtration medium which performs similarly to coagulation fed filters. JelCleer™filter media has an "active surface" which is supposed to trap particles and colloids. Proprietary media consists of glass beads coated with polyacrylate ester and coagulant.