POLLUTECH
ENVIRONMENTAL LIMITED
768 Westgate Road, Oakville, Ontario, L6L 5N2
Tel: 905-847-0065 Fax: 905-847-3840

September 29, 1998

Kostuch Engineering Limited
801 - 1290 Old Innes Road
Ottawa, Ontario
K1B 5M6

Attention: **Mr. James Johnston, P.Eng.**

RE: **VILLAGE OF ST. ISIDORE WATER TREATABILITY STUDY**

Dear James,

Further to your letter of September 23, 1998 we are pleased to provide our recommended treatment alternative for the St. Isidore Water Treatment Plant which includes the physical facilities and the "mandatory upgrades". We have performed an evaluation of the different alternatives presented in the Treatability Study report and have concluded that technically all of the solutions presented are viable. However, some of the proposed solutions have benefits related to operational flexibility, chemical and capital costs. The conclusion of our evaluation is provided below and is based on several mandatory requirements to ensure successful implementation of the preferred treatment alternative.

Based on previous experience and the results of the treatability testing performed, we would recommend the addition of an aeration tower for sulfide removal and pre-oxidation of iron followed by chlorination to oxidize the iron and manganese. The dosed water is then filtered through a sand filter to remove particulate matter and bacteria.

Successful implementation of the above treatment scheme would require that the following changes be incorporated into the new plant:

1. Addition of an aeration tower, vented to the outside of the treatment building to address corrosion issues associated with hydrogen sulfide. Without the aeration tower, the facility would require additional chemical treatment plus facilities for de-chlorination.

2. Upgrade backwash facilities to ensure proper washing of the filter media including an air scour so as to bring them within the required design parameters (15 USGPM/ft^2). Failure to do so will result in continued operating problems and negation of any of the proposed improvements.

3. Add retention time prior to the sand filter to ensure that the oxidation reaction is complete prior to filtration. This will address post precipitation issues typically associated with insufficient contact time. The test results indicate that approximately five minutes contact time is required prior to filtration. Note that the raw water concentration for iron and manganese was low during the testing period, hence a longer retention time may be required to account for fluctuations in influent conditions. Note also that we have assumed that the sulfides have been removed

by means of air stripping and oxidation, prior to chemical oxidation.

4. Ensure that the sand filters provide the required level of filtration. That is, the sand filter remove particles greater than approximately 0.5 micron in diameter. If in doubt, this issue should addressed by appropriate pilot or full scale demonstration testing. Improper media selection is a common problem at these types of facilities.

5. Confirm residual chlorine concentration and disinfection efficiencies in the distribution system. We have noted on other projects that the residual chlorine is rapidly consumed in systems with iron and manganese problems due to the formation of iron and/or manganese slags within the distribution system. Further, the source of the bacterial problem needs to be identified. An appropriate distribution system cleaning will most likely be required, as demonstrated by other municipal projects.

In relation to your other comments from the September 23rd fax, we note that disinfectant dose is indeed a function of pH and tends to increase with increasing pH. Theory indicates that a doubling of disinfectant dose would occur at a pH above approximately 8. The pH increase associated with aeration is within this range. Note however, that since the water is fluoridated, the treated water pH tends to be reduced to less than approximately 7. Therefore, it is hypothesized that post chlorination for bacterial control should not be influenced dramatically by the increased pH associated with air stripping of hydrogen sulfide. We would like to reiterate that the source of the bacterial problem be identified and the residual free chlorine in the distribution be determined. Furthermore, inadequate filtration is currently available with the Filox-R media to remove particulate matter and bacteria. Installation of 0.5 micron sand filter will remove bacteria in the raw water.

It is important to note that following implementation of an aeration tower, the capital equipment would be in place to operate the facility with potassium permanganate and greensand provided that sufficient contact time (10 to 30 minutes) is provided prior to filtration. You may wish to consider providing sufficient contact time prior to filtration to permit the flexibility to operate the facility with potassium permanganate and greensand filtration.

I must apologize for the late reply as I was out of the office last week. I trust the above addresses your concerns, however, if you have other comments, feel free to contact us at your earliest convenience.

Yours truly,

POLLUTECH ENVIRONMENTAL LIMITED

Dave Manku, P.Eng., M.A.Sc.
Process Engineer

CC: Cam Vatandoust @ OCWA

POLLUTECH ENVIRONMENTAL LIMITED
768 Westgate Road, Oakville, Ontario CANADA L6L 5N2
Tel: 905-847-0065 Fax: 905-847-3840
E-mail: dmanku@pollutech.com Internet: http://www.pollutech.com

fax transmittal

to:	James Johnston @ Kostuch Cam Vatandoust @ OCWA Jacques Breen @ OCWA
fax:	613-744-8877 416-314-8300 613-679-4735
from:	Dave Manku, P.Eng, M.A.Sc.
date:	September 18, 1998
re:	Second draft of Treatability Testing Report
pages:	20, including cover sheet.

Notes:

Jim: The comments of your fax dated September 16, 1998 and our telephone conversation of yesterday have been incorporated. If additional comments or questions come up, I will be back in the office on September 28, 1998.

Jacques: Can you provide a copy to J.P and OCWA staff for review.

Thanks,

Dave Manku.

POLLUTECH
ENVIRONMENTAL LIMITED
768 Westgate Road, Oakville, Ontario, L6L 5N2
Tel: 905-847-0065 Fax: 905-847-3840

TREATABILITY TESTING
ST. ISIDORE WATER TREATMENT PLANT

Submitted to:

Kostuch Engineering Limited
801 - 1290 Old Innes Road
Ottawa, Ontario, K1B 5M6

Attention: Mr. James Johnston, P.Eng.

File: 6621
Draft Issue Date: September 15, 1998

1.0 INTRODUCTION

Pollutech Environmental Limited was retained to conduct a treatability study to investigate alternative treatment options for addressing elevated concentrations of hydrogen sulfide, iron and manganese in the drinking water for the Village of St. Isidore. The treatability study consisted of evaluating aeration for hydrogen sulfide removal and various oxidants for removal of hydrogen sulfide, iron and manganese. This report outlines the results of the on site testing performed during the period of August 24th to August 26th, 1998.

2.0 BACKGROUND - EXISTING FACILITY

The Village of St. Isidore obtains drinking water from a series of ground water wells. The existing water treatment plant was designed to treat a blend of raw water from four wells. The water treatment plant is operated by the Ontario Clean Water Agency (OCWA).

Based on discussions with OCWA staff, Wells 1, 2, and 3 are characterized by elevated hydrogen sulfide concentrations and Well 4 contains elevated iron and manganese concentrations. The raw water from the different wells is blended in pipe prior to the water treatment plant. Due to operational difficulties (media fouling, high turbidity in treated water, high raw water bacteria levels), Well 4 is not routinely used.

The water treatment plant consists of the following unit operations:

- prechlorination;
- filtration through a proprietary manganese dioxide media, Filox-R;
- post chlorination; and
- fluoridation.

The prechlorination step was initiated recently by OCWA staff to promote regeneration of the Filox-R media during the filtration cycle.

3.0 TREATABILITY TESTING

The treatability testing was conducted between the period of August 24th to 26th, 1998 by Pollutech staff. The testing was conducted in the St. Isidore Water Treatment Plant. The treatability testing consisted of the following:

- aeration, with and without pH adjustment, to assess hydrogen sulfide removal; and
- jar tests to evaluate alternative oxidants for removal of hydrogen sulfide, iron and manganese. Oxidants evaluated included: potassium permanganate, sodium hypochlorite and hydrogen peroxide.

In addition to the above, process tests were performed on site to determine backwash rates for the Filox-R filters. Further, tests were conducted with the Filox-R media to confirm that it is capable of sulfide, iron and manganese removal.

4.0 TEST RESULTS

The results of the analytical tests conducted during the testing period are presented in this section.

4.1 Raw Water Characterization

The concentration of sulfide, iron and manganese in the raw water during the testing period is summarized in Table 1.

Table 1. Summary of the Raw Water Characteristics During the Sampling Period.

Well #	pH	Sulfide, mg/L	Iron, mg/L	Manganese, mg/L
1, 2, 3	7.9	0.78	0.06	<0.01
4	7.2	0.13	1.04	0.11
4	7.2	0.30	1.11	0.12
1, 2, 3, 4	7.6	0.73	0.23	0.03
1, 2, 3, 4	-	0.66	0.23	0.03
1, 2, 3, 4	7.5	0.54	0.24	0.04
Average 1, 2, 3, 4		0.64	0.23	0.03
Ontario Drinking Water Objective*	6.5-8.5	0.05	0.30	0.05

* - Aesthetic Objective.

Based on historical experience, the raw water characteristics changed depending upon the length of the pump cycle. As a result, the raw water tests were taken at various times during the pump cycle, corresponding to approximately one hour after startup and proceeding to the end of the pump cycle (approximately after eight hours of operation).

Based on the above analysis and discussions with OCWA staff, the raw water characteristics were typical of the water historically obtained from the four wells. Wells 1, 2, and 3 contained elevated sulfide concentrations and negligible iron and manganese concentrations. Well 4 contained elevated iron and manganese concentrations and relatively low sulfide concentrations. The data indicates that dilution as result of combining Well 4 with Wells 1, 2 and 3, produces a raw water with iron and manganese concentrations below the Ontario Drinking Water Objectives.

4.2 Aeration Test Results

The aeration tests were conducted in a one liter graduated cylinder by bubbling air at a known flow rate, for a specified contact time, through the blended raw water. The results of the aeration tests are summarized below in Table 2. All of the aeration tests were performed with an air flow rate of 1.1 LPM.

Table 2. Summary of the Aeration Test Results.

Test Series	Well #	Contact Time min	Initial pH	Final pH	Initial Sulfide mg/L	Final Sulfide mg/L	% Sulfide Removal
1	1, 2, 3	80	7.9	-	0.78	0.15	81
		120	7.9	-	0.78	0.11	86
2	1, 2, 3	30	7.0	-	>0.66	0.32	>52
3	1, 2, 3, 4	30	7.6	8.2	0.59	0.13	78
		30	6.3	8.1	0.65	0.12	82
4	1, 2, 3, 4	5	-	-	0.70	0.33	54
		10	-	-	0.70	0.18	74
		15	-	-	0.70	0.15	78
		20	-	-	0.70	0.13	82
		25	-	-	0.70	0.10	85
		30	-	-	0.70	0.10	86
		750	-	-	0.70	<0.01	>99

The removal of iron and manganese through oxidation with air was also assessed. The concentration of iron and manganese in the raw water was determine prior to and following aeration, Test Series 3. The iron concentration before and after aeration was 0.24 mg/L and 0.22 mg/L, respectively. The manganese concentration before and after aeration was 0.033 and 0.028 mg/L, respectively. Since the concentration of iron and manganese did not change significantly, additional analytical testing was not performed. That is, the aeration tests were conducted by monitoring the concentration of sulfide in the raw water.

As indicated by the test results, the residual concentration of total sulfide in the raw water after aeration is dependent upon the length of the aeration cycle. Figure 1 shows that significant sulfides are removed in the first ten minutes. The concentration of sulfide was reduced by approximately 75% by aerating for ten minutes. Aeration for an additional ten minutes removed an additional 6% of the total sulfide in the raw water. As indicated by the graph, marginal sulfide removal is achieved at aeration times greater than ten minutes.

Test Series 1 and 2 were performed to determine the relative removal efficiency due to aeration. As a result, complete analyses were not performed. Test Series 3 confirmed the effect of sulfide removal on raising the treated water pH. Furthermore, the final pH attained following aeration appears to be consistent with both trials. Reducing the pH of raw water increased the amount sulfide removed by only 4%. Since the effect of aeration on pH was determined, additional analyses were not made while optimizing contact time, as indicated in Test Series 4.

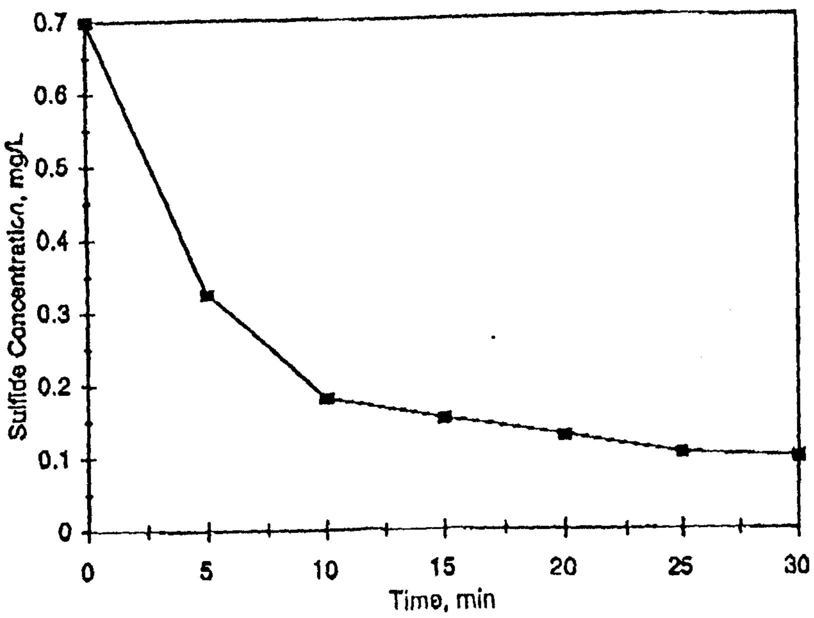


Figure 1. Plot of Sulfide Removal By Aeration

4.3 Oxidant Evaluation

The results of the oxidant evaluations are summarized in Tables 3 through 11, inclusive. The oxidants investigated include: potassium permanganate, hypochlorite and hydrogen peroxide. The initial tests were all performed by adding the oxidant to a one liter raw water sample, followed by a three minute rapid mix time and a thirty minute slow mix period. Once the most effective oxidant was identified, the contact time required to adequately treat the water was determined. The chemical analyses were performed on filtered water. That is, following the thirty minute reaction time, the treated water was filtered through a 0.45 μm membrane filter, to simulate filtration through a conventional sand filter.

Treatability tests which reduced the concentration of sulfide, iron and manganese to below the Ontario Drinking Water Objectives are shaded in the following tables.

Test Series 5 investigated the effectiveness of potassium permanganate in treating raw water from Wells 1, 2 and 3. The results shown in Table 3, indicate that a permanganate dose of approximately 5 mg/L is sufficient in reducing the concentration of sulfide, iron and manganese to below detection levels. It should be noted that iron concentration in the raw water was low in the raw water. The sulfide concentration without any oxidant addition represents a raw water sample which was just mixed for thirty minutes. As indicated by the aeration tests and confirmed by the above jar tests, significant sulfide reduction is achievable through aeration alone.

Table 3. Test Series 5 - Evaluation of Potassium Permanganate With Blended Water From Wells 1, 2 and 3.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.9	1, 2, 3	0	0.78	0.06	<0.01	Raw water
7.9	1, 2, 3	0	0.16	0.06	<0.01	clear filtrate, off white filter paper
7.9	1, 2, 3	1	0.07	-	<0.01	clear filtrate, pale yellow filter paper
7.9	1, 2, 3	2	<0.01	-	0.45	clear filtrate, yellow filter paper
7.9	1, 2, 3	5	<0.01	-	<0.01	pale yellow liquid, red-brown particulate formed. After 30 minutes, water was clear, not discolored. Brown filter paper.
7.9	1, 2, 3	10	-	-	-	pink, red-brown particulate formed
7.9	1, 2, 3	15	-	-	-	dark pink, red-brown particulate formed

Test Series 6, Table 4, was performed to further optimize the dose required to treat the residual concentrations of sulfide and manganese. The results indicate that sulfide is effectively removed with a dose of 3 mg/L and the manganese concentration is reduced to negligible levels at a permanganate dose of 5 mg/L.

Table 4. Test Series 6 - Evaluation of Potassium Permanganate With Blended Water From Wells 1, 2 and 3, Dose Optimization.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.9	1, 2, 3	0	0.78	0.06	<0.01	Raw water
7.9	1, 2, 3	2	0.16	-	0.43	clear filtrate, straw colored filter paper.
7.9	1, 2, 3	3	<0.01	-	0.16	red-brown floc, clear liquid
7.9	1, 2, 3	5	<0.01	-	<0.01	red-brown floc, clear liquid
7.9	1, 2, 3	7	-	-	-	pink, not analyzed
7.9	1, 2, 3	9	-	-	-	pink, not analyzed
7.9	1, 2, 3	10	-	-	-	pink, not analyzed

Table 5 shows summarizes the results of Test Series 7, performed with raw water obtained from Well 4 only. As indicated by the test results, the most effective permanganate dose was approximately 2 mg/L.

Table 5. Test Series 7 - Evaluation of Potassium Permanganate With Water From Well 4.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.2	4	0	0.22	1.08	0.12	Raw water
7.2	4	0	0.03	0.35	0.13	clear filtrate, yellow filter paper
7.2	4	1	<0.01	<0.05	0.21	clear filtrate, yellow filter paper
7.2	4	2	<0.01	<0.05	0.04	red-brown flocs, clear water
7.2	4	5	-	-	-	red-brown flocs, pink water
7.2	4	10	-	-	-	abandoned based on above test results
7.2	4	15	-	-	-	abandoned based on above test results

Test Series 8 test results are summarized on Table 6. Test Series 8 was conducted using the results from Test Series 5 and 6 to assess the influence of pH on oxidant demand. For raw water obtained from Well 4, the permanganate dose was compared at a pH level of approximately 7.2 and 8. The permanganate dose of 2 mg/L resulted in clear treated water at the lower pH and a slightly discolored (pink) water at the higher pH level. The development of a residual pink color in the treated water is indicative of overdosing. Therefore, less oxidant is required if the pH of the raw water from Well 4 is increased. The opposite trend was observed with water from Wells 1, 2, and 3. That is, at the higher pH level, higher permanganate doses would be required to adequately treat the water.

Table 6. Test Series 8 - Evaluation of Potassium Permanganate With Blended Water From Wells 1, 2 and 3 and Well 4 to Investigate Effect of pH on Oxidant Requirements.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.2	4	0	0.22	1.08	0.12	Raw water
7.2	4	3	-	-	-	pink, no analysis
7.2	4	2	-	-	-	clear filtrate, yellow filter paper
8.1	4	3	-	-	-	pink filtrate
8.0	4	2	-	-	-	faint pink color in filtrate
7.0	1, 2, 3	5	-	-	-	faint pink color
7.9	1, 2, 3	5	-	-	-	light yellow water, with red-brown flocs

Test Series 9, Table 7, investigated hypochlorite as an alternative oxidant. Further, based on discussions with OCWA staff, additional tests were conducted with blended water from all four wells. Well 4 was put into service during the testing period at the preset flow rates as indicated in the facilities Certificate of Approval. Based on the test results, hypochlorite dose of 2 mg/L was sufficient to reduce the sulfide concentration to less than the detection limit. However, minor amounts of iron and manganese were oxidized at this dosage level. Increasing the hypochlorite to approximately 10 mg/L results in oxidation of all three components of interest to less than detectable concentration levels. Further, the residual total chlorine at the relatively high dose rate was 0.83 mg/L, indicating that essentially all of the hypochlorite had reacted.

Table 7. Test Series 9 - Evaluation of Hypochlorite With Blended Water From Wells 1, 2,3 and 4.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.6	1, 2, 3, 4	0	0.64	0.23	0.03	Raw water
7.6	1, 2, 3, 4	0	0.07	0.14	0.04	Total residual Cl_2 = 0.02 mg/L
		0.5	0.07	0.14	0.04	Total residual Cl_2 = 0.02 mg/L
		1	0.05	0.14	0.04	Total residual Cl_2 = 0.02 mg/L
		2	<0.01	0.09	0.03	Total residual Cl_2 = 0.01 mg/L
		5	<0.01	<0.05	0.04	Total residual Cl_2 = 1.71 mg/L
		10	<0.01	<0.05	<0.01	Total residual Cl_2 = 0.83 mg/L

The results of Test Series 10 are summarized in Table 8. Test Series 10 was performed to assess the performance of hydrogen peroxide as an altemate oxidant. Peroxide did not significantly treat iron and manganese and required relatively large doses (10 mg/L) to reduce the sulfide concentration to levels achieved with the other oxidants evaluated.

Table 8. Test Series 10 - Evaluation of Hydrogen Peroxide With Blended Water From Wells 1, 2, 3 and 4.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.6	1, 2, 3, 4	0	0.64	0.23	0.03	Raw water
7.6	1, 2, 3, 4	0	0.06	0.14	0.03	Clear, no visible flocs after 30 minutes
		0.5	0.04	-	-	Clear, no visible flocs after 30 minutes
		1	0.04	-	-	Clear, no visible flocs after 30 minutes
		2	0.03	0.10	-	Clear, no visible flocs after 30 minutes
		5	0.02	0.10	-	Clear, no visible flocs after 30 minutes
		10	0.02	0.13	0.29	Clear, no visible flocs after 30 minutes

Test Series 11, Table 9, investigated the effect of pH adjustment on the required hypochlorite dose to achieve the required treatment. Based on the results from Test Series 9, the maximum hypochlorite dose required to remove sulfide was approximately 2 mg/L. Based on the test results, the effect of reducing the pH to approximately 6.5 results in improved sulfide and iron removal and has a negligible impact on manganese removal.

Table 9. Test Series 11 - Evaluation of Hypochlorite at Different Raw Water pH Values.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.6	1, 2, 3, 4	0	0.64	0.23	0.03	Raw water
7.5	1, 2, 3, 4	1	0.10	0.14	0.03	Residual Total Chlorine = 0 mg/L
7.5		2	0.02	-	-	Residual Total Chlorine = 0 mg/L
7.5		3	<0.01	0.14	0.03	Residual Total Chlorine = 0.21 mg/L
6.6		1	0.10	-	-	Residual Total Chlorine = 0 mg/L
6.7		2	<0.01	0.18	0.03	Residual Total Chlorine = 0 mg/L
6.8		3	<0.01	0.09	0.03	Residual Total Chlorine = 0.49 mg/L

Table 10 summarizes the results of Test Series 12. Test Series 12 investigated the combined treatment potential of aeration followed by oxidation with hypochlorite. The combined treatment options appear to reduce the hypochlorite dose required to treat sulfides and iron, with no apparent effect on manganese removal efficiency.

Table 10. Test Series 12 - Evaluation of Aeration (15 Minute Contact Time) and Hypochlorite With Blended Water from Wells 1, 2, 3 and 4.

pH	Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
7.6	1, 2, 3, 4	0	0.64	0.23	0.03	Raw water
7.5	1, 2, 3, 4	0	0.11	0.13	0.03	pH after aeration = 8.1
		1	0.01	0.10	0.09	pH after aeration = 8.1
		1.5	<0.01	0.08	0.03	pH after aeration = 8.1
		2	<0.01	0.07	0.03	pH after aeration = 8.1

Results of Test Series 13 are shown in Table 11. Test Series 13 was performed to determine the reaction time required to oxidize the sulfide in the raw water. The time series tests were performed with hypochlorite as the oxidant at a dose of 2 mg/L. As indicated by the test results, approximately one minute is required to reduce the sulfide concentration by approximately 87%, from 0.7 mg/L to 0.09 mg/L.

Table 11. Test Series 13 - Evaluation of Contact Time Using Hypochlorite for Oxidation.

Well #	Oxidant Dose mg/L	Sulfide mg/L	Iron mg/L	Mn mg/L	Observations
1, 2, 3, 4	0	0.70	-	-	at time = 0 minutes
	2	0.09	-	-	at time = 1 minute
	2	0.05	-	-	at time = 5 minutes
	2	0.05	-	-	at time = 10 minutes

4.3.1 Oxidant Testing Summary

Based on the testing performed, the blended raw water contained marginally elevated concentrations of iron and manganese. Nevertheless, the most effective oxidant (in terms of oxidant dosage) for the removal of iron and manganese is potassium permanganate.

Hypochlorite effectively removed sulfide at a hypochlorite concentration dose rate of 2 mg/L. However, to effectively remove iron and manganese, the required hypochlorite dose rate is approximately 10 mg/L. It should be noted that treatment by hypochlorite improves if the raw water is aerated to strip the sulfides. Presumably aeration reduces the oxidant demand by removing the sulfides. This was indicated by the testing performed in Test Series 12. The concentration of iron is reduced by approximately 46% with a hypochlorite dose of 2 mg/L. In comparison to Test Series 11, which indicated marginal oxidation of iron at a dose rate of 3 mg/L.

The peroxide was not effective at treating the blended raw water, as indicated by Test Series 10.

4.4 Filox-R Media Testing

Tests were conducted with virgin Filox-R media to confirm that the media is capable of achieving sulfide, iron and manganese removal from the raw water. The time series tests consist of contacting approximately 5 grams of media with approximately 250 mL raw water sample and shaking for varying time intervals. This type of test allows for a quick assessment of treatment capability but does not provide any information related to capacity of the media or media performance at typical hydraulic flow rates.

Based on the peak flow rate through the treatment plant of 15 L/s (238 USGPM), the hydraulic retention time in each filter (2A and 2B) would be approximately 4 minutes. Assuming a low flow of approximately 5 L/s, the hydraulic retention time would be approximately 10 minutes in each filter. Therefore, the tests were conducted for a maximum contact time of approximately 10 minutes. The results of the testing are summarized in Table 12.

Table 12. Summary of the Filox-R Media Test Results.

Well #	Contact Time minutes	Sulfide mg/L	Iron mg/L	Manganese mg/L
1, 2, 3, 4	0	0.73	0.23	0.03
1, 2, 3, 4	2	<0.01	<0.05	<0.01
1, 2, 3, 4	5	-	-	-
1, 2, 3, 4	10	-	-	-
1, 2, 3, 4	15	-	-	-

Based on the test results, a contact time of two minutes is sufficient to reduce the concentrations of sulfide, iron and manganese to below detection levels.

4.5 pH Adjustment Tests

The concentration of hydrogen sulfide in solution is strongly pH dependent. Theoretically, only 10% of the sulfide is present as hydrogen sulfide at a pH of approximately 8. The amount of hydrogen sulfide in solution increases to 50% of the total sulfide concentration at a pH of 7. Therefore, to increase sulfide removal by means of air stripping, pH adjustment of the raw water was investigated. The results were presented previously in Table 2 and discussed in Section 4.2.

Based on discussions with OCWA staff, hydrofluosilicic acid is used to fluoridate the treated water. Further, OCWA staff indicate that there is significant natural fluoride in the raw water, which is not being removed by any of the unit processes at the existing plant (chlorination and /or filtration through the Filox-R media). It was suggested that pH adjustment tests be conducted using the 0.25% hydrofluosilicic acid to adjust the pH of the raw water. The results of the pH adjustment tests are summarized in Table 13.

Table 13. Summary of the pH Adjustment Tests Using Hydrofluosilicic Acid.

Well #	Fluoride Dose mg/L	pH
1, 2, 3, 4	0	7.6
1, 2, 3, 4	0.2	6.9
1, 2, 3, 4	0.3	6.4
1, 2, 3, 4	0.4	6.2
1, 2, 3, 4	0.5	5.9

The typical dose currently used by OCWA staff is approximately 0.4 mg/L, which maintains treated water fluoride concentration between 1.2 to 1.5 mg/L.

4.6 Full Scale Filter Backwash Rates

The backwash rates achievable with the existing filters and Filox-R media was estimated by performing draw down tests at the full scale facility. The results of the draw down tests are presented in graphical form in Figures 2 through 4, inclusive. The backwash rate tests were performed with both filters in operation and no augmentation by an external water source. Hence, the backwash rate represents the rate achievable based on the hydraulic head in the filter reservoir. The slope of the regressed line is shown on each graph and was used to estimate the backwash rate.

Figure 2 is a regression plot of the backwash cycle and represents an average backwash rate. Analysis of the raw data indicates that there are two distributions. The first distribution corresponds to the initial set of data points, up to the first three minutes of the backwash cycle, which exhibits a relatively steep slope. The initial maximum backwash rate is shown in greater detail in Figure 3. Towards the end of the backwash cycle, the head of water in the filter has decreased resulting in a decreased water flow rate. This second distribution, the minimum backwash rate, is depicted in Figure 4 and represents data collected after the third minute to the end of the backwash cycle.

The backwash rates calculated based on the above test results ranged between 7.7 and 3.2 USGPM/ft^2. The average backwash rate was approximately 6.2 USGPM/ft^2. The recommended backwash rate for the Filox-R media as specified by the supplier is between 12 and 15 USGPM/ft^2.

OCWA staff typically augment the water used to backwash the filters by recycling treated water to the filter. The flow rate of the water used to augment the backwash flow rate was determined by measuring the time required to fill a known volume. The amount of water added to augment the backwash cycle was equivalent to approximately 280 USGPM. Therefore, the average combined water flow available to backwash the filter is approximately 450 USGPM or approximately 16 USGPM/ft^2.

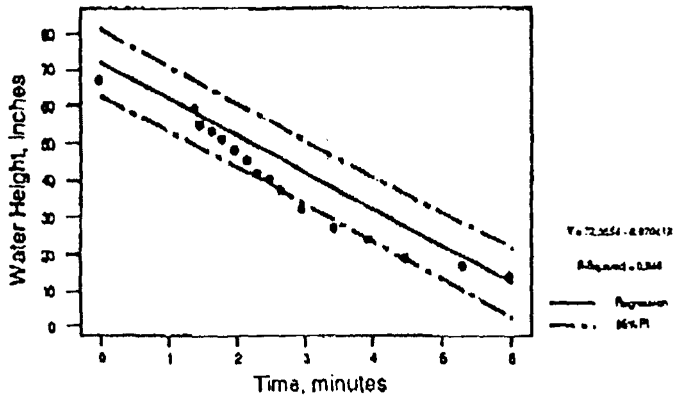


Figure 2. Plot of Water Height Versus Time to Determine Average Back Wash Rate.

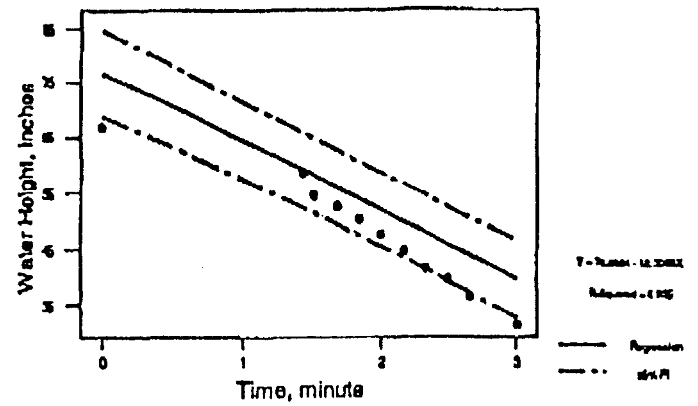


Figure 3. Plot of Water Height Versus Time to Determine Maximum Back Wash Rate.

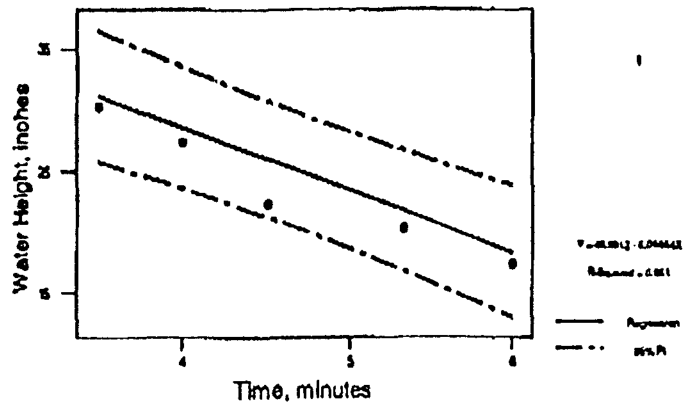


Figure 4. Plot of Water Height Versus Time to Determine Minimum Back Wash Rate.

4.7 Turbidity and Bacterial Related Problems

Based on discussions with OCWA staff, elevated turbidity and bacterial problems were intermittently experienced at the full scale facility. Correspondence with Kostuch Engineering indicate that some of the turbidity problems were related to treatment configurations which gave rise to elevated turbidity in the treated water (chlorination and sand filtration). It is hypothesized that the white precipitate is due to post precipitation of sulfides in the clear wells.

The bacterial and turbidity problems may be alleviated through proper maintenance of the filters and filtration through an appropriate micron sized filter. The existing level of filtration is insufficient (that is; the equipment supplier indicates that the Filox-R media is not capable of removing solids less than 90 microns in diameter) and periodic sloughing of bacteria from the filter media and/or in the raw water influent will pass through the treatment system.

Note that since all the analysis conducted during the treatability testing filtered the treated water through a 0.45 micron membrane filter, turbidity was not measured.

5.0 CONCLUSIONS

Based on the testing conducted, we conclude the following:

- Aeration of the raw water for approximately 10 minutes reduced sulfide concentration by approximately 75%. It should be noted that air stripping is limited to removing only the hydrogen sulfide from the raw water and that the hydrogen sulfide concentration is a strong function of pH. Theoretically, at a pH of 8, only 10% of the sulfide is present as hydrogen sulfide and at a pH of 7, 50% of the total sulfide is present as hydrogen sulfide. However, the test results indicate that significant sulfide reductions are achievable. .This may be attributable to oxidation of the sulfide by oxygen. Further, the pH of the aerated raw water will rise following the aeration step.

- Potassium permanganate can effectively treat the raw water to remove sulfide, iron and manganese. The permanganate dose required to treat Wells 1, 2 and 3 was approximately 5 mg/L. The permanganate dose required to treat Well 4 was approximately 2 mg/L.

- Sodium hypochlorite can effectively remove sulfide, iron and manganese at a concentration dose of approximately 10 mg/L. The residual total chlorine concentration was determined to be approximately 0.8 mg/L.

- Peroxide did not effectively remove sulfide, iron and manganese at the dosages tested.

- Reducing the pH of the raw blended water improved sulfide and iron removal using hypochlorite with minimal effect on manganese removal.

- Aeration of the raw water for sulfide removal, resulted in a reduced hypochlorite dosage rate for the removal of iron. Aeration did not reduce the hypochlorite concentration required for adequate manganese removal.

- The batch media tests indicate that sulfide, iron and manganese can be reduced to below detection levels with the Filox-R media. A contact time of two minutes was sufficient to reduce the contaminant concentrations to below the detection limit.

- Hydrofluosilicic acid can be used to effectively reduce the pH of the raw water prior to aeration for sulfide removal. Based on the natural fluoride concentration, it is hypothesized that addition of the hydrofluosilicic acid to the raw water will not adversely effect treatment.

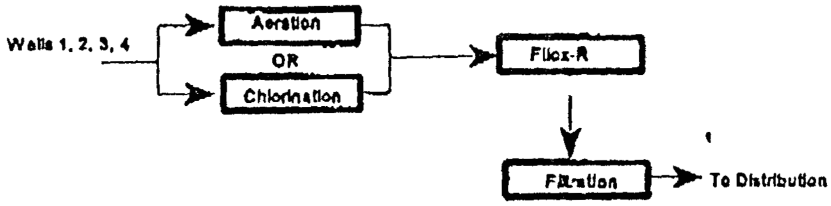
- The backwash rates achievable with the filters as designed are insufficient to effectively clean the Filox-R media. OCWA staff have implemented a temporary solution whereby a portion of the treated water is used to augment the backwash water. The modified backwash procedure achieves backwash rates (16 USGPM/ft^2) consistent with required backwash rates (12-15 USGPM/ft^2) specified by the Filox-R media supplier.

6.0 RECOMMENDATIONS

Based on the testing conducted and discussions with OCWA staff, we recommend that consideration be given to the following unit treatment configurations, each of which is capable of providing treated water quality consistent with the Ontario Drinking Water Objectives for sulfide, iron, manganese, turbidity and fecal coliform (microbiological):

1. **Aeration or Chlorination Treatment Options:** The following treatment configurations include the addition of aeration or chlorination unit processes to the existing treatment plant.

Configuration 1:



Aeration or chlorination to remove sulfide, followed by treatment with the Filox-R media to remove iron and manganese. The combined, treated water needs to be properly filtered to remove any particulate precipitates and bacteria.

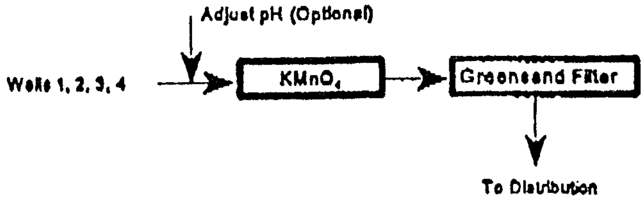
Configuration 2:

Chlorination to remove sulfide, iron and manganese followed by filtration through a conventional sand filter. The existing filters can be retrofitted and the Filox-R media changed for sand.

In the event that the chlorination alternative is selected, additional testing would be required to determine the headloss characteristics associated with the increased oxidized solids loading rates. Assessment of the filter solids loadings would be required to determine if the existing filters can accommodate the increased solids loading rates associated with this option.

2. **Potassium Permanganate Treatment Options:** The following treatment configuration includes the addition of potassium permanganate and greensand filtration units to the existing treatment plant.

Configuration 3:



Based on the testing performed, potassium permanganate effectively removed sulfide, iron and manganese from the raw water. Hence, oxidation with permanganate followed by greensand filtration is technically feasible.

OCWA staff have indicated historical problems with proper dose control using potassium permanganate. Additional investigation would be required to determine the cause and corrective actions required to address these operational concerns. The scope of the additional work would encompass dose and time optimization trials at the pilot scale as well long term pilot scale testing to determine the impact of raw water variability on treatment performance.

Key Success Factors:

Implementation of any of the recommended technical alternatives will ensure that the water produced at the St. Isidore Water Treatment Plant is consistent with the Ontario Drinking Water Objectives for sulfide, iron, manganese, turbidity and fecal coliform. However, some critical factors which must be incorporated into the design can be summarized as follows:

- The operating and capital cost implications associated with the different alternatives need to estimated.

  We have conducted a cost comparison of a capital expenditure for an aeration tower versus the increased chemical costs (hypochlorite) required to precipitate sulfide prior to the Filox-R media.

  The net present value for the supply of an aeration tower is approximately $48,000 plus installation costs (based on a quotation by John Meunier to Kostuch dated February 13, 1998). The net present value of the increased hypochlorite costs to precipitate the sulfides prior to treatment with the Filox-R is between $15,500 and $31,000, based on a dose rate between 2 mg/L and 4 mg/L, respectively. The cost comparison is performed assuming a twenty year equipment life cycle, with a 2.5% allowance for inflation and at a 7% interest rate.

Note that the electrical requirements for a typical aeration tower are only about 2 HP, hence power costs are not included in the cost comparison.

Operating and capital costs are required for additional retrofit items which are common to all of the treatment alternatives (improving backwash rates, purchase of sand, piping modifications, etc.) and maintenance costs associated with corrosion due to hydrogen sulfide within the treatment plant.

- Based on visual inspection of the non-stainless steel components in the water treatment plant, significant corrosion is beginning to occur. Hence to reduce operating costs (replacing valves, fittings, wiring, etc.) it is recommended to remove the sulfide in a closed environment to minimize contact of the corrosive hydrogen sulfide with plant components. This could be accomplished by either stripping the sulfide in a closed environment or sealing the distribution tank near the filters.

- Based on discussions with the equipment supplier, the minimum particle size which will be retained by the Filox-R media is approximately 90 to 100 µm in diameter. Therefore, the Filox-R media is not providing sufficient filtration. It is recommended that a conventional filter be installed following contact with the Filox-R media. Typical sand filters will retain particles larger than approximately 0.5 µm. It may be feasible to operate the existing filters (1A/1B and 2A/2B) in series, with the second filter filled with conventional sand.

- Proper backwash rates need to be maintained throughout the backwash cycles to ensure thorough washing of the filter media. This may include an additional pump and the incorporation of an air scour.

- Permanganate is generally operated with difficult to treat waters since some buffering capacity is available from the greensand to remove overdosed permanganate. Nevertheless, based on previous operational experience, potassium permanganate is difficult to control given the nature of the raw water. Additional investigation would be required to determine the cause and corrective action required to address these operational concerns.

- pH adjustment of the raw water may be implemented using hydrofluosilicic acid to improve sulfide removal and/or to reduce oxidant requirements. The impact, if any, of adding the fluoride prior to any treatment should be confirmed.

- Due to the relatively high chlorine doses, a trihalomethane formation potential (THMFP) test should be conducted if chlorine is to be used as an oxidant. The

THMFP test should simulate typical holding time in the distribution system. The THMFP tests should be conducted to simulate the retention time of the treated water in the distribution system.

- As discussed above, the existing Filox-R media does not provide sufficient filtration and the media is not washed properly due to low backwash rates. Addressing these two concerns may alleviate the intermittent bacteriological problems experienced with the treated water.