JAMES E. "JIM" KING, JR.
President

JOHNNIE BYRD
Speaker

STATE OF FLORIDA
OFFICE OF PUBLIC COUNSEL

ORIGINAL

c/o THE FLORIDA LEGISLATURE
111 WEST MADISON ST.
ROOM 812
TALLAHASSEE, FLORIDA 32399-1400
850-488-9330

EMAIL: OPC_WEBSITE@LEG.STATE.FL.US
WWW.FLORIDAOPC.GOV

Harold McLean
Public Counsel

Charles J. Beck
Deputy Public Counsel

November 18, 2004

Blanca S. Bayo, Director
Division of the Commission Clerk
and Administrative Services
Florida Public Service Commission
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850

Re: Docket Nos. 020896-WS & 010503-WU

Dear Ms. Bayo:

Enclosed for filing, on behalf of the Petitioners, are the original and 15 copies of the Direct Testimony of John H. Gaul, Ph.D.

Please indicate the time and date of receipt on the enclosed duplicate of this letter and return it to our office.

CMP ____
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OTH ____

Sincerely,

Charles J. Beck
Deputy Public Counsel

CJB:bsr

Enclosure

ORIGINAL

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Petition by customers of Aloha Utilities, Inc. for deletion of portion of territory in Seven Springs area in Pasco County	)	Docket No. 020896-WS
In re: Application for Increase in Water Rates for Seven Springs System in Pasco County by Aloha Utilities, Inc.	)	Docket No. 010503-WU
	)	Filed: November 18, 2004

DIRECT TESTIMONY

OF

JOHN H. GAUL, PH.D.

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Petition by customers of Aloha Utilities, Inc. for deletion of portion of territory in Seven Springs area in Pasco County	Docket No. 020896-WS
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JOHN H. GAUL, PH.D.

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Dockets Nos. 020896-WS & 010503-WU

DIRECT TESTIMONY

OF

JOHN H. GAUL PH.D.

Q. PLEASE STATE YOUR NAME AND ADDRESS.

A. My name is John H. Gaul and I reside at 7633 Albacore Drive, New Port Richey, FL 34655.

Q. WHO SUPPLIES YOUR DRINKING WATER AND FOR HOW LONG HAVE YOU BEEN A CUSTOMER OF THAT UTILITY?

A. I have been a customer of Aloha Utilities for 18 months (as of September 2004).

Q. HOW DID YOU COME TO BE INVOLVED IN THE ALOHA DISPUTE?

A. When I moved into my house, I had a severe black water and odor problem that persisted for many days despite extensive flushing. I had the problem in both the hot and cold water system. The original owner (seven years) had had several serious leaks in her copper piping due to corrosion and had resorted to completely removing the copper pipes and replacing them with CPVC. After talking to my neighbors I learned that black water, odor and corrosion had been an ongoing problem for many years in Aloha's territory and that

customers had been unsuccessful in getting the utility to do anything about it. I felt that my background in chemistry could be helpful to my neighbors in their discussions with the utility for the purpose of seeking a resolution. That is how I came to attend the Citizen's Advisory Committee meetings and ultimately joined that group.

Q. WHAT WERE YOUR OBSERVATIONS OF ALOHA'S ATTITUDE DURING THESE MEETINGS?

A. I have worked in the Chemical Industry for ~ 25 yrs as a scientist and manager in commercial divisions. I have come to learn, through repeated exposure to customers, the pitfalls of ignoring customer needs and the true meaning of "customer orientation." My most vivid memories of those first meetings I attended, where I heard Mr. Watford and Mr. Porter speak to us, was that this company's management had never had to learn what being "customer oriented" was. I was shocked by what I could only describe as an arrogant and blatant dismissal of customer needs and concerns. They were, and still are in my opinion, in complete denial of their overarching responsibility to provide a competitive and aesthetic product to their customers. I concluded that the worst consequences of a monopoly operation were being played out in the Seven Springs area. We were trapped and they knew it. As a result, they had done nothing to address these customer complaints and had no intention of doing anything. Furthermore, it appeared to me that customers were being "stiff armed" by an avalanche of technical misdirection designed to silence customers by convincing them there was

nothing Aloha could do and that the problems were all due to customers' pipes and water softeners. This cynical and transparent ploy, coupled with a complete disregard for their captive customer's quality of life, is at the heart of customers' anger and resentment of Aloha's management.

Q. YOU PARTICIPATED IN THE STUDY CONDUCTED BY DR. AUDREY LEVINE. WHAT WAS YOUR ROLE AND WHAT DID YOU OBSERVE?

A. Yes, I did participate. I helped coordinate the visits to customer houses and I accompanied Aloha and Dr. Levine as an observer for the customers.

My first impression of Aloha's operation was that it was primitive by any self-respecting modern operation. Throughout my ~ 25 years of experience in the Chemical Industry, I have seen a wide range of chemical operations - and make no mistake about it, water treatment is a chemical operation - and I was shocked to see the lack of even the simplest automation which has been routine for years in chemical processing and is very reasonable to acquire and operate. Aloha had no automated monitoring on most of its wells. What was particularly glaring due to its complete absence was any feedback control on the critical step of chlorine injection. This was one of Dr. Levine's first observations in her Phase One Report. She stated, "A more comprehensive program for routine water quality monitoring should be implemented by the utility to facilitate improved process control and develop data for treatment upgrades." She went on to say that "…improved control of chlorine residuals in the distribution system may reduce the incidence of black water by

controlling the growth of sulfate reducing bacteria….. The absence of substantive improvement or operational changes has resulted in an untenable situation for the customers and the utility. There is a need to move forward with a resolution of this problem."

Q. WHAT IS THE SIGNIFICANCE OF YOUR OBSERVATIONS AND THE WRITTEN COMMENTS OF DR. LEVINE?

A. With just the minimum exposure to Aloha's operations it was immediately clear to me and most certainly to Dr. Levine that their systems were inadequate and yet could be readily and inexpensively improved. Improvements such as increased monitoring and feedback control of operations could and would have led to tighter control of their process and quite reasonably might have reduced customer complaints.

That these upgrades were so apparent to outsiders, and that Aloha, in the face of years of customer complaints, did nothing to implement even such obvious and modest upgrades is an indictment of Aloha's management and the clearest statement that it has abandoned its responsibility toward its customers. That Aloha continued to say that it could DO NOTHING all these years when Dr. Levine has stated so succinctly that they could, also points to their technical incompetence. Either they did not know that simple process automation for monitoring and feedback control could tighten their process windows as a first step in responding to customer complaints or they deliberately chose to do nothing and let their customers "stew." Either way, Aloha's managerial and

technical shortcomings constitute a breach of their obligations as a monopoly utility.

Q. WHAT IS YOUR OPINION OF ALOHA'S STATEMENTS THAT DR. LEVINE'S REPORTS EXONERATE THEM AND SHOULD GIVE CUSTOMERS SOME COMFORT?

A. I think this is another example of where Aloha attempts to "spin" technical information in order to misdirect and misinform customers and the PSC. Dr. Levine's report does not exonerate Aloha. Her recommendations for upgrades, some of which are so simple and obvious that they should have, and could have, been implemented years ago, is quick testimony to that. Be aware also that Dr. Levine's Phase II report was so superficial and the sampling protocol so restricted by Aloha that there was no conclusion possible on causes of black water. The only conclusion that Dr. Levine could draw from such a limited and narrowly constructed survey was that Aloha's water was typical of water drawn from the Floridian aquifer which is neither news nor exoneration. Dr. Levine's study made no attempt to establish a link between Aloha's processing and water chemistry to the black water problem, as it was not designed properly to do so, despite the OPC and customer's desire that it should. I testified to these facts in a hearing before the PSC on April 8th, 2004. In fact, there has yet to be an internally consistent and scientifically sound study of the black water problem in this area which is a fact that should shock us all after all the time and money that has been spent! What continues to be true however is that despite meeting FDEP standards, Aloha's water

continues to be a well-documented source of problems for its customers far in excess of what is encountered in surrounding communities.

Q. WHAT IS YOUR EVALUATION OF ALOHA'S TECHNICAL PERFORMANCE AS A DRINKING WATER PRODUCER?

A. I made a presentation during the April 8, 2004 PSC hearing in New Port Richey. I re-adopt that testimony (Exhibit JGH-1) and am available to answer questions about it.

Q. WHAT IS YOUR OPINION OF THE DIRECTIONS THAT ALOHA IS NOW PURSUING WITH DR. LEVINE AS IT RELATES TO UTILITIES' SUITABILITY TO BE A MONOPOLY WATER SUPPLIER?

A. I am very concerned by what is happening now and the directions and rationale that Aloha and Dr. Levine are espousing. First of all let me reiterate what I have just said…there has been no resolution or insight gained by either Aloha or Dr. Levine on the causes of black water in our area. Yet despite this, and much to our dismay, Dr. Levine recommended, and Aloha accepted, specific courses of action that will cost the captive customers of Aloha millions of dollars without **any** indication or technical justification that the causes of black water will be affected positively and cost effectively. That she conducted a study so anemic with respect to addressing the black water problem and yet has positioned herself to benefit personally and professionally from unsupported recommendations from that study is

extremely disturbing. That Aloha will undertake to install millions of dollars of capital without any technical justification, while in the past refusing to implement, or being ignorant of simple, low cost upgrades that could have done something to improve its process is appalling. The real truth behind the current course of action being taken by Aloha and Dr. Levine, and I suspect the real motivation for Dr. Levine's recommendations in her Phase II report, is the change to chloramine. This change has been something on the radar screen for a long time. Despite having had a long time to develop a safe and low-risk plan to meet this impending change, Aloha has selected a process which has absolutely no track record, which was recommended by Dr. Levine. This untested process is one of her current research interests that was rejected by Tampa Bay Water, and which Aloha will now fund. In choosing this route, Aloha will go from a simple process of polyphosphate addition followed by chlorine gas injection, to one in which they will adjust pH up to 8.0 or above, inject hydrogen peroxide, readjust pH downwards, inject liquid chlorine and balance that with a controlled injection of ammonia. For Aloha, this is a dramatic expansion in process complexity for which they have no in-house expertise. As if that weren't enough to give pause to Aloha's management, this process combination has never been studied thoroughly or installed anywhere in the US. Yet despite these Herculean obstacles, Aloha plans to study, develop, scale up and implement this in a matter of months on eight different wells!! This would be unheard of in a sophisticated chemical plant, let alone in a rudimentary operation like Aloha's, and is another example of managerial and technical incompetence and indifference to the needs of its

customers. That they treat so lightly their responsibility to provide a stable, predictable and safe product is another glaring example of their unsuitability to remain a monopoly utility.

Q. IS THAT THE END OF YOUR TESTIMONY?

A. Yes.

EXHIBIT

EXHIBIT JHG-1

The following is the presentation made at the April 8th, 2004
PSC Hearing held in New Port Richey.

Customer's Technical Assessment of Aloha

To the Honorable Commissioners of the Public Service Commission,

My name is John H. Gaul and I reside at 7633 Albacore Drive, New Port Richey and I am a customer of Aloha Utilities in the Seven Springs area. I have a PhD in Chemistry from the University of Illinois and I have worked in the Chemical industry as a Scientist and a Technical and Commercial Manager since 1978. I currently teach Chemistry at a local college. I have been asked to author this document, with the collaboration of many others in our community, for the purpose of stating the technical issues existing at Aloha that have resulted in the poor quality water we receive from Aloha Utilities, and our very serious concerns regarding Aloha's ability to effectively resolve water quality problems in a cost effective way.

The problems with water quality (odor, black water, stains, bad taste, etc...) have been plaguing the Seven Springs area for a considerable time [1, 2] and are undisputed by all parties with the exception perhaps of Aloha. Aloha continues, to this day, to refuse to acknowledge the problems as their own or recognize that they have the key role to play in ameliorating these issues. In fact, Aloha's methodology is the PRIMARY source of these problems and Aloha is the ONLY source of a technical solution. We contend that Aloha has been knowledgeable of potential solutions and capable of making necessary improvements, yet has

failed to meet its obligations to satisfactorily address these customer complaints and rectify the unacceptable water quality situation.

Let us state some facts:

1. Customers are experiencing black water and dark stains in showers, sinks, toilets, washers etc. (1)
2. These dark materials are directly linked to copper sulfide which comes from the reaction of soluble copper (corrosion) with sulfides.
3. The most probable and reasonable source of these sulfides is from the action of sulfate and sulfur reducing bacteria (SRB) on soluble sulfate and suspended elemental sulfur in delivered water.(2,3,4)
4. Odor and bad taste are clearly associated with the presence of hydrogen sulfide (H_2S) and are widely experienced in the Seven Springs area even by those without copper pipes.
5. Adjacent water utilities are able, through appropriate chemical processing, to produce water without these problems (19).

It is a well recognized fact that hydrogen sulfide production in water distribution systems and domestic plumbing requires the presence of (1) sulfate and/or elemental sulfur, (2) electrons (corrosion), (3) bacteria (SRB), (4) low chlorine and (5) little or no oxygen. **If you reduce (or eliminate) one or more of these elements you can control odor and sulfide corrosion.** (5, 6, 7, 8)

These facts are known by Aloha Utilities. Aloha acknowledges that sulfate/sulfur reducing bacteria (SRB) are the probable cause of sulfide production in domestic plumbing and that sulfide production is highly corrosive to copper pipes and will generate black water and the attendant problems of odor and bad taste. (9, 10) Yet Aloha refuses to attach any significance to these events in customers' homes or link them to the processed water it delivers. We

wish to point out that Aloha's present processing method produces water [1, 2, 11, 12] that:

1. Contains suspended elemental sulfur and soluble sulfate [2, 11];
2. Contains sulfur reducing bacteria (SRB) - these are ubiquitous in the environment and are found in deep wells;
3. Often has low and highly variable chlorine levels [2];
4. Has little or no oxygen[1, 2];
5. Has low and highly variable pH [1, 12]; and is
6. Highly variable with respect to its corrosivity.

In other words, **Aloha's water is highly variable and unstable and contains all the elements necessary to produce the very problems the customers of the Seven Springs area have been complaining about for years.**

In an effort to deflect attention from its water processing, Aloha has attempted to assign blame for our water problems on a variety of sources such as:

- Lightning;
- Bad copper pipes;
- Home ion exchange water softeners that produce soft water and purportedly increase corrosion of metals [9];
- Home ion exchange water softeners that remove chlorine [9]; and
- Home ion exchange water softeners that remove the phosphate corrosion inhibitor.

Aloha has actually recommended removal of softeners and replacement of copper pipes as preferred remedies [9, 13].

It is disingenuous for Aloha to invoke such unlikely, obscure and low probability causes for widespread black water and foul smells in domestic plumbing when

there are glaring inadequacies in the properties of the processed water coming from Aloha that are definitively linked to sulfide production and associated black water and foul smells. In addition, we dispute their claim that ion exchange water softeners increase corrosion by softening water [14, 15, 16] and we dispute their claim that ion exchange water softeners remove all the chlorine from incoming water and are the source of the problem [17]. Water softeners can reduce chlorine levels somewhat but customers who do not have home water softeners still experience the full range of problems [20]. Finally, it is known that ion exchange water softeners do not remove the corrosion inhibitor added by Aloha [17, 18].

The glaring inadequacies in Aloha's processed water that ARE the source of the problems in the Seven Springs area are:

1. Reliance on chlorination as the sole processing method for the dual purpose of sulfide oxidation and disinfection;
2. Lack of adequate process controls to ensure tight control of chlorine residual and other processed water parameters, and
3. Lack of oxygen in processed water.

In her phase II report, Dr. Levine did not state explicitly the technical inadequacies in Aloha's processing that would justify the upgrades that she is recommending. However, it is no coincidence that her recommended upgrades involve adding a second process, putting oxygen into the water and exercising tighter control over processing parameters [1].

Aloha has been or should have been aware that improvements in these three areas, taken together, would have made significant improvements in the quality of water they provided and would have gone a long way in addressing the issues the customers have been complaining about for years. Without addressing all

three of these issues together it will be almost impossible to solve the water quality problems currently being experienced.

However, we must also state clearly that even after focusing on the three areas listed above, the technical task will not be complete. Water chemistry is complex but manageable for organizations with technical depth and competence. In addition to employing multiple methods to remove sulfide, maintaining high levels of chlorine residual under tight tolerances, and oxygenating the water, there are other water parameters that must be balanced in this broad context to ensure that other problems are not created. It will be necessary to have a robust treatment process and control system that will maintain the correct balance [12] between dissolved oxygen, high pH, alkalinity and corrosion control additives (if necessary) to create safe and stable water. In other words, once the general approach to correct the water quality problem is decided on, there will be considerable work remaining to BALANCE and CONTROL other water parameters and find the correct process window that produces clear, clean and safe water that is free of problems significant to customers.

Based on Aloha's current performance in supplying water of unacceptable quality and variability, their refusal to deal with technical issues and a complete disregard for ever-increasing levels of customer dissatisfaction, the Seven Springs customers of Aloha are adamant in their belief that Aloha does NOT possess the technical skills and management attitude necessary to operate a more complex process. Aloha has not demonstrated the necessary motivation to exert themselves on behalf of their customers to provide a clear, clean and safe product above minimum standards free from water quality problems. Future processes will necessarily be more complex and require higher levels of professionalism, technical competence and customer-oriented problem solving. It is a major concern for us, as I'm sure it is for the PSC, that future problems coming from a

new process will be met with the same technical intransigence and denial that will involve us all in another cycle of complaints, technical misdirection (9, 10, 11) and legal maneuvers. We feel that any process that is approved must only be permitted to go forward with tight oversight by the PSC, other governmental bodies and customer-selected technical auditors to ensure that this cycle is broken.

But what is our situation today? Dr. Levine has submitted her Phase One and Phase Two reports of her analysis of Aloha's Processing and Distribution System. For the benefit of the Commissioners, we must first correct the impression that this analysis was an "audit" of Aloha. An audit implies a complete analysis without restrictions or limitations of any kind. The actual study that was conducted was a very cursory and "static" snapshot of Aloha's processing and distribution system. This is not a criticism of Dr. Levine but rather a reflection of the fact that this was all she could negotiate from a reluctant Aloha Utilities. Recall that Aloha fought the customers in seeking this technical review. This very cursory evaluation did not generate enough data for Dr. Levine to comment much beyond saying that they met minimum standards, something we have never disputed. I liken her task to trying to describe a movie plot using only two still frames from the film. You are certainly able to say something basic but you will never understand the full picture. Despite the limited scope of this analysis, I must point out that this set of data is probably the best data that exists on Aloha Utilities. Even with this limitation, Dr. Levine, as someone skilled in the art, was able to make generic recommendations for improvements to Aloha's system without the need for a large study. In fact, what was needed was so obvious that Dr. Levine shared her recommendations with Aloha before we even finished collecting the samples for the "audit" let alone doing the analysis. Therefore we must recognize that these recommendations did not evolve from data from the

"audit" but rather from a general knowledge possessed by Dr. Levine and which we contend Aloha should also have known.

To this day, Aloha formally denies any responsibility for the black water problem in its communications to customers. They continue to say there is nothing they can do. We know that this is not true. Aloha, now faced with an impending switch to chloramines in Pasco County, finds that they must make process changes quickly if they wish to purchase water from Pasco County after January 2005. Without any data to support their actions, they are now embracing Dr. Levine's suggestions but have cavalierly discarded any solutions that don't meet their January 2005 timeline. Their selection, made without any supporting data, is based entirely on expediency with respect to their objectives and is not based on solving customers' black water problems. In fact they go out of their way to be clear that they are not promising an improvement in black water, odor or taste. They are making this selection without conducting studies that will allow a proper technical or financial evaluation of the alternatives. They propose a crash study for only one option over a 4-6 week period that they admit has never been implemented anywhere in Florida. While the generic idea meets the criteria that should help alleviate the black water problem, the unknown technical and financial problems in this experiment are enormous.

We arrive at this situation for one reason. Aloha has denied its responsibility for black water in the Seven Springs area for years. It has failed to seek cost effective solutions and it has not conducted any studies nor sought help (such as from Dr. Levine) to establish a sound database for proposing and implementing cost effective upgrades to its system. This appears to us as nothing short of managerial and technical incompetence on the part of Aloha. Today they are proposing using the customers of Seven Springs in an experiment to serve their own objectives and they want the PSC to direct them to do so! There is no data

to support their choices, no concern for solving our problems and no guarantee that they will reduce or eliminate the black water problem. All they are guaranteeing us is substantially higher rates. We do not want a company who apparently cannot run a simple process competently, conducting major experiments with our money and our water. They have not demonstrated a responsible and customer-caring attitude that would make taking such a risk prudent. There WILL be technical and cost problems ahead and the intransigence Aloha has exhibited in the past will still be with us in the future. No process should be approved by the PSC unless Aloha (1) can prove it can operate it under very tight control, (2) shows that it can and will substantially improve the black water problem and (3) proves that it can do so at competitive rates. Aloha's apparent incompetence should not be made the problem of the Seven Springs customers.

In conclusion, the Seven Springs customers of Aloha Utilities believe strongly that Aloha has known or should have known how to address and relieve its customers of the problems, costs, damage, embarrassment and emotional upset caused by the widespread incidence of black water, odor and foul taste of a product in their control. That Aloha chose NOT to exercise incremental and cost-effective control over their product and chose NOT to seek meaningful technical solutions to customer problems does not bode well for the implementation of future processes that are necessarily more complex. A technical solution is already at hand. Pasco County already produces a quality product with characteristics that the customers of the Seven Springs area want for a price we can afford. Aloha apparently cannot match that performance either in cost or quality. It is time for the PSC to support and reward us and not Aloha!

References

1. Audrey Levine. Phase II Audit Report. "Analysis of Well Water, Treated Water and Distribution System Water" – February 2004

2. Audrey Levine. Phase I Audit Report. "Technical Review of Production and Distribution of Drinking Water in the Seven Springs Area" – August 2003

- Seven Springs area, operated by Aloha Utilities, has been plagued by recurring occurrences of "black water" within residential plumbing systems since the mid 1990's.
- The Seven Springs Water System, as it is currently operated, meets all relevant water quality regulations for potable water imposed by the USEPA and the FDEP. However there is a need to reduce the recurrence of black water problems within the distribution system.
- Highest levels of sulfide are in wells 3, 8 and 9. Water from wells 8 & 9 are not premixed with the rest of the wells (unlike 3) which "essentially" localizes the impact of these wells to a specific portion of the system.
- A more comprehensive program for routine water quality monitoring should be implemented by the Utility to facilitate improved process control and to develop design data for treatment upgrades.
- Under the current treatment configuration, improved control of chlorine residuals in the distribution system may reduce the incidence of black water by controlling the growth of sulfate reducing bacteria.
- Based on data available, supplemental treatment for removal of hydrogen sulfide from wells 8 & 9 may help to alleviate some of the black water concerns.
- Design a treatment system to reduce H_2S based on water quality at the entrance to the distribution system.
- Develop remote monitoring capabilities to improve process control.
- Develop a hydraulic model of the distribution system to facilitate optimization of flushing, control of chlorine residuals, and assessment of DBP (disinfection by-product) formation.
- Optimize the flushing program with respect to location, time of day, volume of water used. Assess the potential for unidirectional flushing particularly in the area of wells 8 & 9.
- Currently chlorine demand is not routinely analyzed in the Seven Springs Water System (SSWS).
- When H_2S is oxidized by chlorine it is converted to elemental sulfur and/or to sulfate depending on pH.
    - $H_2S + Cl_2 \rightarrow S_0 + 2HCl$ (1)
    - $H_2S + 4H_2O + 4Cl_2 \rightarrow H_2SO_4 + 8HCl$ (2)

- It has been reported that the oxidation is a two stage reaction first going to sulfur and then to sulfate (Black and Goodson, 1952). The reaction rate is a function of pH, temperature and chlorine concentration. Typically a combination of the two reactions occurs in drinking water systems.
- When elemental sulfur is produced it forms colloidal particles ranging form 0.01 to 1 μm in size. Turbidity tests on suspended solids can be used as an indirect measure of the presence of colloidal particles.
- It is likely that both sulfate and elemental sulfur are formed from sulfide oxidation.
- Oxidation reactions do not remove the sulfur and either form of sulfur (sulfate or sulfur) can revert back to sulfide under condition of low dissolved oxygen, low chlorine residual, the presence of metal catalysts, and/or when growth conditions are favorable for sulfur reducing bacteria.
- Figures 22 and 23 of this report (Phase 1) show chlorine residuals of **zero** on certain occasions in both wells 8 & 9.
- Water at dead end locations can become stagnant and the chlorine residual can decay resulting in increased biological growth and potential water quality problems.
- Unidirectional flushing can help to improve water quality and reduce the quantity of water used. Aloha needs to reduce the water it uses in flushing.
- Black water has been reported in both hot and cold plumbing in the SSWS especially since wells 8 & 9 came online.
- The most likely explanation (for black water) is that sulfur in the treated water reacts with either iron or copper to form chemical precipitates. Some of these reactions are mediated by microorganisms, whereas other reactions are controlled by the chemistry of the water and the piping system.
- There must be a (1) source of sulfur in the water, (2) the dissolved sulfur must contact a dissolved metal (3) the temp, pH and contact time must be adequate to promote the reaction.
- The key to avoiding the formation of these precipitates is to prevent the reactions from occurring.
- Sources of sulfur are (1) SRB reactions, (2) naturally occurring sulfide and (3) elemental sulfur.
- The release of sulfide and reduced metals is mediated by either sulfate or iron reducing bacteria. These bacteria can only proliferate in the absence of oxygen. The presence of chlorine will also inhibit growth of these bacteria. Stagnant water lines where chlorine levels are depleted and oxygen levels are low provide an ideal habitat for the growth and proliferation of these microorganisms.

- The byproducts of the biological reaction produce dissolved metals and sulfides that can react to form black particulates.
- In a water pipeline, microbial reactions tend to occur in biofilms that are attached to the pipe wall. Chemical reactions occur either at the pipe wall or in the bulk water. Products of microbial reactions may be sequestered within the biofilm and released intermittently. It is possible to have multiple forms of sulfur present concurrently.
- The two forms of sulfur that are implicated in black water formation are sulfides and elemental sulfur. Sulfates are not directly implicated but can be converted back to sulfide by SRB.
- Some species of bacteria grow on the surface of elemental sulfur as an electron acceptor and provide sulfide during heterotrophic or lithotrophic respiration.
- The disproportionation of elemental sulfur in water yields sulfide and sulfite as shown: $3S + 3H_2O \rightarrow 2H_2S + H_2SO_3$.
- It is evident that some action must be initiated to help control the problem of black water in the SSWS.
- It is likely that the performance standard of 0.1 ppm sulfide at the point of entry into the distribution system could be met by Aloha with the existing system if the chlorine dose was controlled more closely (and presumably unidirectional flushing used as well).

3. Canadian Government HECS Publication "Sulphide (as H_2S)" September 1992 (Canada)

- An aesthetic objective of 0.05ppm has been established.
- Oxidation of H_2S is a function of temp, pH and ionic strength. The rate of oxidation was found to increase with increasing temperature and pH up to pH 8. Above pH 8 oxidation was found to be independent of pH.
- In well-aerated water, H_2S is oxidized to sulfates or to elemental sulfur by natural biological systems.
- Sulfides can also react with oxygen in a slow complex reaction to produce thiosulfates, sulfite and sulfate.
- The presence of sulfate reducing bacteria in water distribution systems can be a major cause of taste and odor problems in drinking water because of the formation of sulfides from sulfate.
- **H_2S is typically removed by chemical oxidation and aeration and levels of 0.05ppm can be obtained.**
- **Chemical oxidants include chlorine, potassium permanganate, ozone, ferrate and hydrogen peroxide**.
- Odor and taste thresholds are estimated to be in the range of 0.05 to 0.10 ppm. (ref 3, 6 within)

- H_2S solutions have properties of a weak acid and can therefore promote corrosion. (ref 67 within)
- H_2S in association with soluble iron produces black stains on laundered items and can cause black deposits in water distribution systems pipes and on fixtures and silverware. (ref 10, 15, 69 within)
- Presence of sulfides in drinking water results in unpleasant tastes and odors.

4. World Health Organization – Water and Sanitation

- At pH 7.4 one third of sulfide is undissociated H_2S and the rest is HS^-.
- In well-aerated water H_2S is readily oxidized to sulfates and elemental sulfur. In anaerobic water microbial reduction of sulfate to sulfide can occur. (ref 7 within)
- Taste and odor threshold reported to be 0.05 – 0.1 ppm. (ref 5 within)

5. American Water Works Association - Volume 22 No. 3 March 1996

- Requirements for H_2S production include (1) sulfur, (2) electrons (corrosion), (3) bacteria, (4) time, (5) low chlorine (6) little or no oxygen. If you reduce (or eliminate) one or more of these elements you can control odor and sulfide corrosion.
- Sulfate can be reduced by the gain of 8 electrons which in the water heater come from the oxidation of magnesium. The electron flow to the steel tank is in excess of that which is needed to provide galvanic protection for the steel. Therefore they are available for SRB use. In the distribution system the electrons come from corrosion of pipes and fittings.
- SRB have enzymes that accelerate the reduction of sulfate (or sulfur) to sulfide but cannot do so without an energy source such as electrons from corrosion processes.

6. Corrosion by sulfate reducing bacteria – G.F. Yuzwa Oct 11th, 1991

- Corrosion by SRB requires the presence of SRB, sulfates or sulfur, an external energy source and a temperature below 150 °F. It also requires anaerobic conditions and low chlorine levels.

7. Cornell – (HOME) Water Treatment Notes – H_2S in Household Drinking Water

- Sulfur problems occur less frequently in surface water because flowing water is aerated naturally so that the H_2S reacts with oxygen and escapes as a gas or settles as a solid.

- Sulfur bacteria are found in many drinking water wells and household distribution systems.
- Ozone is a powerful oxidant converting sulfides to solid sulfur, and also breaks down the slime produced by sulfur bacteria and rapidly degrades to oxygen. Ventilation is required. Pre-filtration is also recommended to remove solids and slimes that may coat the ozone generator.
- Catalytic carbon is also effective.
- Anion exchange resins are also effective.

8. University of Nebraska NebGuide – Cooperative Extension G96-1275-A

- SRB live in oxygen-deficient environments such as deep wells, plumbing systems, water softeners and water heaters.
- A nuisance associated with H_2S includes its corrosiveness to metals such as iron, steel, copper and brass.
- The odor of water with as little as 0.5ppm H_2S concentration is detectable by most people. Concentrations less than 1ppm give the water a "musty" or "swampy" odor. A 1-2ppm H_2S concentration gives water a "rotten egg" odor and makes the water very corrosive to plumbing.
- Shock chlorination will reduce but not eliminate SRB.

9. Written Communication from Aloha to Donna Vaurio (customer) Oct 27th 2003

- "The Aloha representative determined that the water discoloration you are experiencing is being caused by the formation of copper sulfide (a black residue) within the copper piping of your home. This is not a problem that can be corrected by our utility as the problem occurs in your copper piping after the water enters your home."
- They have suggested that water softeners, RO and filters should be removed because they cause the water to become more corrosive. (*Author's comment – For ion exchange water softeners this is not true.*)
- Some units prevent their corrosion inhibitor from performing its intended function (*Author's comment – This is not true.*)
- They suggest replacing the copper piping.

10. Porter. "Letter to Mr. Bramlett of Pasco Utilities from Porter Sept 11, 1997"

- "All hydrogen sulfide is oxidized to sulfate. The chemical equation related to this reaction is well known and well understood. ….. Please note that no elemental sulfur is produced in this reaction…only the sulfate form of sulfur remains.

$H_2S + 4Cl_2 + 4H_2O \rightarrow H_2SO_4 + 8HCl$"
(*Author's comment - This is not accurate and contradicts testimony given by Mr. Porter before the PSC (in 1996). Additionally this reaction is only one of two general reactions that occur in Aloha's system. The other DOES produce sulfur – see Dr Levine's report.)*

- "Therefore it is more likely that facilities utilizing air stripping will produce elemental sulfur than will facilities utilizing chemical oxidation." (*Author's comment – The differences would be negligible as Aloha's process produces significant levels of "non-sulfate" sulfur.*)
- "The main problems associated with converting H_2S to elemental sulfur are related to finished water turbidity increase and the negative effects that increased water turbidity produces (like lower disinfection efficiency, increased chance for bacterial contamination and growths in the distribution system, etc.)." (*Author's comment - This is true and shows that the reasons for black water could occur where elemental sulfur is formed, as it does in Aloha's delivered water which has been substantiated by Dr Levine's Scanning Electron Micrographs (SEM) - refer to fig. 24 and 25 of her Phase II report.*)
- "First, chemical oxidation of hydrogen sulfide with chlorine does not produce any appreciable quantities of elemental sulfur as shown in the chemical equation presented on page one of this letter." (*Author's comment – This is not true.*)
- "After Aloha's water is treated at its well sites, there is no appreciable quantity of hydrogen sulfide present in the finished water…it has been converted to sulfate." (*Author's comment – the first part of this appears to be generally true but the second comment is not true.*)
- "We (Aloha) believe that ….sulfate is reduced to sulfide by SRB. This sulfide then combines with copper, leached from the customer's piping as part of the natural process of copper pipe corrosion. Copper pipes corrode with time under all water conditions; however, recent research has shown that water containing naturally occurring sulfides accelerates this process."
- "In fact, since the concentration of copper in the water is directly related to the formation of copper sulfide the incidence of black water must logically be more pronounced in your (Pasco's) system than Aloha's (since Pasco's copper concentration was reported to be 28% higher than Aloha)." (*Author's comment – Reports from Pasco and Aloha customers would not seem to support this contention.*)

11. Porter. "PSC Dockets 950615 SU and 960545 WS"

12. Water Technology Magazine – March 1999 - Corrosion in copper pipes can be prevented

- Pitting in cold water pipes occurs when the pH = 7.0-7.7, the dissolved oxygen is above 3 ppm and the carbon dioxide level is 25 ppm or higher. The water chemistry is even more likely to cause pitting corrosion when the sulfate to chloride ratio is 3:1 or greater. Pitting is primarily a cold water problem, but can also occur in hot water lines.
- The primary causes of general and pitting-type corrosion are low pH (7.0 to 7.7) and high carbon dioxide and oxygen levels. Raising the pH above 8.3 with lime (calcium hydroxide), caustic soda (sodium hydroxide) or soda ash (sodium carbonate) will reduce the corrosivity of the water by bringing the carbon dioxide level down to below 5 ppm. Free carbon dioxide cannot exist above a pH of 8.3.
- Reducing the corrosion potential by pH adjustment will also help control the soluble copper and lead in drinking water. An effective treatment approach is to add sodium bicarbonate (baking soda) to control the pH within 8.0 and 8.5 while maintaining a total alkalinity of from 25 to 50 ppm.
- Supplemental injection of silica into the water has also proved effective in controlling copper corrosion. Silica reacts at the metal surface to create a chemical barrier that insulates the metal from contact with carbon dioxide and oxygen. Generally, enough silica is added to increase the naturally occurring silica concentration by 15 to 20 ppm.
- Pitting corrosion in hot water systems is typically caused by iron, manganese or aluminum impurities in the water. Iron is common in well water supplies, but also originates as a byproduct of corrosion in steel tanks and pipes.

13. Aloha Newsletter 1997

14. Water Quality Association – Corrosion and Softened Water

- Softening water with cation exchange does not make water more corrosive. The US EPA and the American Water Works Association (AWWA) have recently corrected their enclosed brochures as to the misconception that ion exchange softening has an effect on the corrosivity of water.
- Metal leaching is not affected by the absence or presence of hardness minerals confirming the minimal effects of these cations on corrosion.
- Neither the water pH, dissolved oxygen content, TDS concentration, electrical conductivity, ammonia, chloride or sulfide amounts, temperature nor flow velocity are significantly altered by home water softening.

- Soft water will deposit less scale but will not alter the water's corrosivity or lack of it.
- Scale in home systems is often porous and soft and not protective.
- It is rare that scale deposition is uniform in household plumbing as the heaviest scale deposits where heat transfer is greatest or at low points in a system.
- Even in homes with hard scale the irregular nature of deposition does not guarantee protection.

15. Ion Exchange Softening – Effects on Metal Corrosion (Schock and Sorg – EPA) AWWA August 1999, Volume 91. No. 8. Pages 85-97

- Naturally soft waters are known to be corrosive to metal piping but ion exchanged (artificially softened) soft water is not. Naturally soft waters are low in pH and Total Dissolved Solids (TDS). Ion exchange does not affect TDS, pH or other general water parameters that are characteristic of naturally soft water.

16. Water Technology Magazine – July 1997
- Softened water does not cause corrosion.

17. Van Hoofnagle. "Pasco County Black Water Study" August 1999
- The presence or absence of home water softeners (ion exchange) had no effect on the generation of hydrogen sulfide and the subsequent reaction with the copper pipes.
- The water conditioning units did not remove the orthophosphate being added to the water by the Utility to inhibit copper corrosion.

18. A personal communication with Dr. Levine indicated that she has concluded that ion exchange water softeners do not remove orthophosphates added to treated water for corrosion control.

19. Bramlett. Pasco County Administrator – Utilities. Letter to Mike Fasano August 28, 1997

20. PSC staff observation reported in PSC Memorandum dated Oct.23, 1997, pp7-8

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CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a copy of the foregoing has been furnished by U.S. Mail or hand-delivery to the following parties on this 18th day of November, 2004.

Charles J. Beck

Rosanne Gervasi, Esquire
Division of Legal Services
Fla. Public Service Commission
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850

F. Marshall Deterding, Esquire
John Wharton, Esquire
Rose, Sundstrom and Bentley, LLP
2548 Blairstone Pines Drive
Tallahassee, FL 32301

Mr. Harry Hawcrof
1612 Boswell Avenue
New Port Richey, FL 34655

V. Abraham Kurien, M.D.
1822 Orchardgrove Avenue
New Port Richey, FL 34655

Edward O. Wood
1043 Daleside Lane
New Port Richey, FL 34655

Senator Mike Fasano
8217 Massachusetts Avenue
New Port Richey, FL 34653

Aloha Utilities, Inc.
Mr. Stephen G. Watford
6915 Perrine Ranch Road
New Port Richey, FL 34655-3904

John H. Gaul, Ph.D.
7633 Albacore Drive
New Port Richey, FL 34655

Wayne T. Forehand, Chairman
Citizens' Advisory Committee
1216 Arlinbrook Drive
Trinity, FL 34655-4556

James Mitchell, Jr.
Riviera Home Owners Association
5957 Riviera Lane
New Port Richey, FL 34655

Ann Winkler
Riverside Village Estates, Unit 4
4417 Harney Court
New Port Richey, FL 34655

John Parese
Riverside Villas
4029 Casa del Sol Way
New Port Richey, FL 34655