Source Drinking Water Challenges
Changes to an Arctic Tundra Lake

Center for Climate and Health

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This paper reports on a special health concern identified in Point Hope, Alaska during a recent Climate and Health Assessment: disruption of drinking water treatment influenced by temperature driven increases in organic material in an Arctic tundra lake. Blooms of organic material have been observed in the past in the source water lake in Point Hope, but conditions have been extreme over the last two years. If warm temperatures continue, organic blooms will become a reoccurring problem for Point Hope and other communities that depend on tundra lakes for their water supply. Analysis of source water chemistry and biology is recommended, as is an analysis of possible adaptive operational procedures or design modifications that could improve water system efficiency.

Introduction

In May of 2009, the Alaska Native Tribal Health Consortium (ANTHC) performed a Climate and Health Assessment in Point Hope, Alaska. It was performed by ANTHC's Center for Climate and Health in partnership with Maniilaq Association, the regional tribal health consortium for Northwest Alaska, and the North Slope Borough. The purpose of the assessment was to record local observations related to climate change and to explore adaptive strategies for community health. The purpose of this paper is to identify vulnerabilities and raise awareness about an emerging environmental health issue, and to identify potential adaptation strategies.

Background

Point Hope is an Inupiat community of about 700 residents. It is located on a gravel spit extending out into the Chukchi Sea. It is the furthest point west in the Northwest Arctic, roughly half way between Kotzebue and Barrow on the Northwest Arctic Coast. The climate is arctic and annual temperature ranges from -49^{o}F to 78^{o}F. Precipitation is light, 10 inches annually, with a cumulative annual snowfall of about 36 inches. The Chukchi Sea is ice-free from late June until mid September (AK Division of Community Advocacy, 2009).

During the assessment, twenty-two interviews were performed including the Mayor, Tribal Council President, as well as representatives from the school, health clinic, fire department, police department, and public works. Elders and youths were interviewed and a presentation about climate and health was made to students at the Tikigaq School. Interviews with water utility staff were performed over the course of two days in early April of 2009. Site visits were made to the drinking water treatment facility and the waste water facility, both operated by the North Slope Borough. The operators interviewed included Andrew Frankson (supervisor/primary), Eldon Hunnicutt, Reggie Oviok, and Michael Dirks. Operator experience with this water system ranged from five to ten years. Water system customers in Point Hope include approximately 180 homes with piped water and sewer, and eleven homes on a haul system with holding tanks.

Reduced water quality and quantity at the source lake was observed by Point Hope water operators during July of 2007 and 2008. However, there was no evidence of change in water quality or safety for Point Hope residents. There is no evidence of waterborne illness occurring in the community (Davenport, A., 2009). There is however, a negative effect to water system operation as the labor and consumables required to produce water has increased significantly during periods of reduced source water quality.

Point Hope acquires drinking water from “7 Mile Lake”, located seven miles east of the town. This tundra lake is recharged each year from snow melt and precipitation. There is a limited time frame when the lake is ice free, and when water can be pumped, treated, and transferred to above ground tanks for storage and use throughout the year. From late June until early September water is piped from the lake and treated. The operators work 12-hour shifts around the clock to produce enough water to last the entire year. In the summer of 2008 the operators treated approximately 8 million gallons of water.

At the deepest part of the lake (typically 10 to 11 feet) a screened intake is suspended at approximately 1.5 feet below the water surface. The water is pumped through a pipeline to the water treatment plant where it is passed through a bag filter (100, 200 or 400 micron depending on quality), and then through a micro-nano filter prior to chlorination. Operators use instruments to monitor pressure and raw water conditions, and perform regular analysis to measure total suspended solids, total dissolved solids, pH, biological oxygen demand, dissolved oxygen, arsenic, and total residual chlorine. Operators also keep a daily log book which includes entries for each time the system is shut down to change (clean) a bag filter.

As reported by Point Hope Water Operators, drought and high air temperatures during the summer of 2007 and 2008 were contributing factors to source water quality problems. During the past two summers the water level in 7 Mile Lake was lower than normal. Other tundra ponds located in the vicinity of 7 Mile Lake dried up completely. Nearby rivers were shallow enough to walk across and the lagoon located north of town was so shallow that boats had to paddle or drift out to deeper water before running outboard motors (Frankson, A., 2009). The dry and hot weather was thought by operators to have contributed to the water level decline.

National Weather Service data indicates that the Northwest Arctic climate has been gradually warming, with a 3.3°F total increase in annual temperature between 1949 and 2005. During the same period, the increase in summer temperature was 2.7°F, and 7.2°F in winter (Shulski & Wendler, 2007). Alaska is projected to experience an increase in temperature of 1.5°F to 5°F by 2030, and 5°F to 18°F by 2100. Consequently, the top 30 ft of discontinuous permafrost is projected to thaw over this century (Parson, 2001). Tundra ponds across Alaska have been shrinking as a result of increased evaporation and permafrost thawing (Riordan et Al., 2006). The specific permafrost conditions around 7-Mile Lake are unknown.

Records from the nearest transportation hub communities, Barrow and Kotzebue, illustrate changing recent summer weather conditions. In July of 2007, Barrow had a mere 4 hundredth of an inch of precipitation, the second lowest on record. This is only about 5% of the normal total (0.87 inches). Also that July, Barrow set three high temperature records, 67°F on the 6th, 73°F on the 7th, and 65°F on the 18th.

In July of 2008, Kotzebue set records for both high and low temperatures. On July 3rd, Kotzebue reached 76°F, breaking a record set in 1982. On July 4th, Kotzebue reached 80°F and broke another record. Kotzebue also set a record low of 37°F on July 21st, dipping below the record low of 38°F in 1953. Information on record events is available at the Alaska Center for Climate Assessment and Policy (ACCAP) website (http://www.uaf.edu/accap/awch/archives.htm).

Point Hope weather archives were available from the National Weather Service and other sources. Weather data in Point Hope is collected at the Federal Aviation Administration (FAA) automated weather observation station (AWOS) at the airstrip. From 1924 to 1954 weather data was collected and archived by the U.S. military (NWS, 2009). But the departure of the military from Point Hope interrupted the archives until 1991 when FAA records resumed. Point Hope weather data (temperature and wind) from 1991 until 2009 is available at the Weather Underground website (www.wunderground.com). Improved local weather observation and access to archive data would facilitate future climate assessment and research.

During the summer of 2007 and 2008, water temperatures at the Point Hope treatment plant were elevated. Operators reported raw water temperatures between 50°F and 60°F; whereas typical temperatures are between 40°F and 50°F (Frankson, A., 2009). In summer, warming of the raw water occurs during passage through the pipeline from the lake to the treatment plant. Lake water temperatures are not recorded. It was during the same period that operators began reporting changes in the quality of raw water entering the treatment plant. Specifically, increases in the amount of biologic slime in the "bag" filters. An increase in pressure at the treatment plant indicates the filters have become clogged and the operators must turn off the system to clean the filters.

Fig. 1 Operator Andy Frankson at bag filter bank Photo M. Brubaker

Water operators recorded that the number of filter changes was increasing dramatically, to the point where it was interrupting operations (see Figure 1).

Figure 2 below shows the number of bag filter changes recorded per month from 2005 until 2008. Generally, the operators clean the bag filters two to four times per full 24 hour day. The 2005 and 2006 data reflect a lower bag clean rate, suggesting either that fewer filters were used, that filters were not cleaned regularly, or that there were not regular filter changes log book entries. Nevertheless, operators report that decreased water quality and increased filter cleaning only emerged as a problem in 2007-2008, and would not have been reflected in 2005-2006 log records.

Figure 2 also shows that the increasing number of bag changes occurred mostly in July. Figure 3 below shows the number of filter changes per day during July of 2007 and 2008. The number of filter changes here are seen to rise and fall in wave–like fashion, as if related to a physical or biological cycle. For the water utility, additional filter maintenance translates into hours of labor. At the peak disruption period in 2007, operators were changing filters over twenty times per day. In 2008 the number of bag changes at times rose to almost 50 times per day.

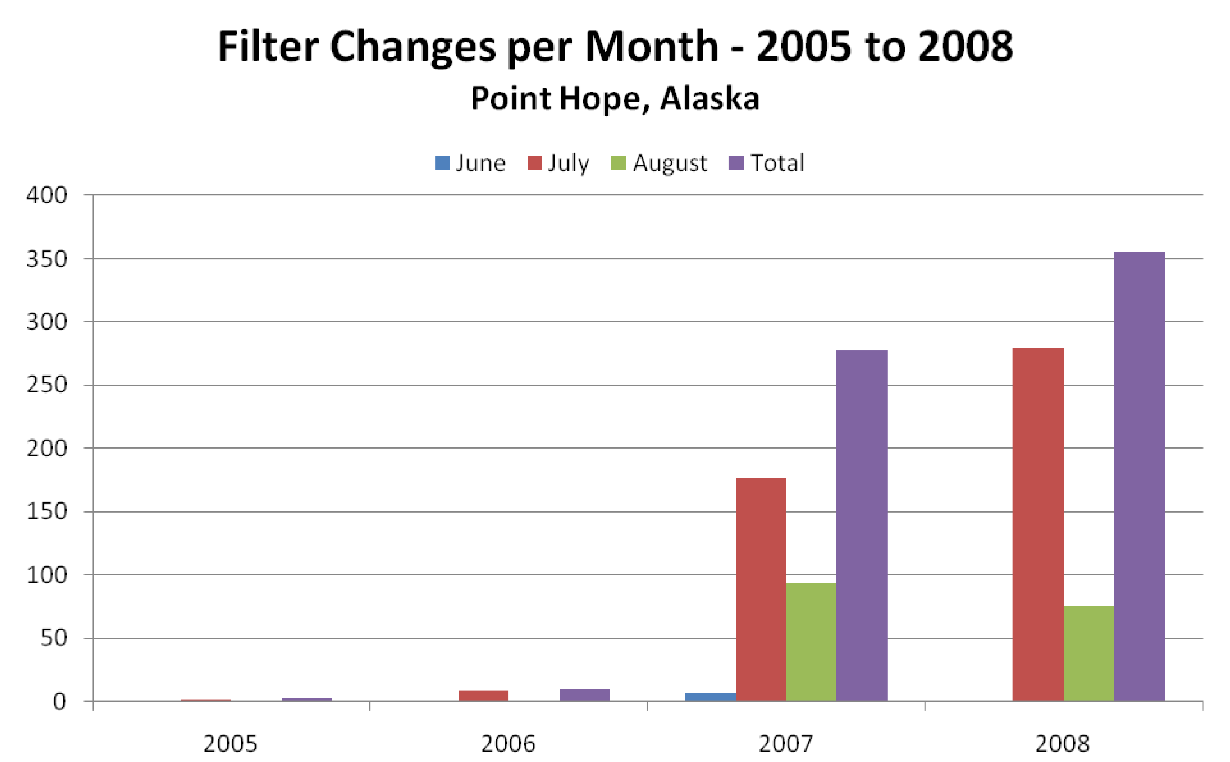

Fig. 2 Source: *Treatment Log Book, Point Hope Water Plant*

In 2008 operators began making water on July 12th and ended on August 29th, a total of 47 days. An estimate of average hours of labor to maintain filters under normal conditions was calculated and compared to the actual conditions during 2008. This was based on an average of ten minutes to remove, wash and replace the filters (Frankson, A., 2009). Under normal raw water conditions, operators change filters an average of three times per day. In 2008, there should have been a total of 141 bag changes during the 47 days when water was made. At 10 minutes per change, that calculates to 1410 minutes or ***23.5 hours*** of expected filter maintenance. The actual time based on operator records was 358 changes, an approximate 3580 minutes or ***59.6 hours*** *of filter maintenance*.

On July 27, 2008, at the peak of the source water quality problem, Point Hope operators were spending approximately eight hours, or 1/3 of each 24 hour shift performing filter maintenance.

In remote Alaska communities the cost for energy, fuel, and imported materials and supplies is extremely high. Utilities statewide are challenged by increasing costs and decreasing sources of revenue. When changing environmental factors increase the cost of providing services, it can undermine not just

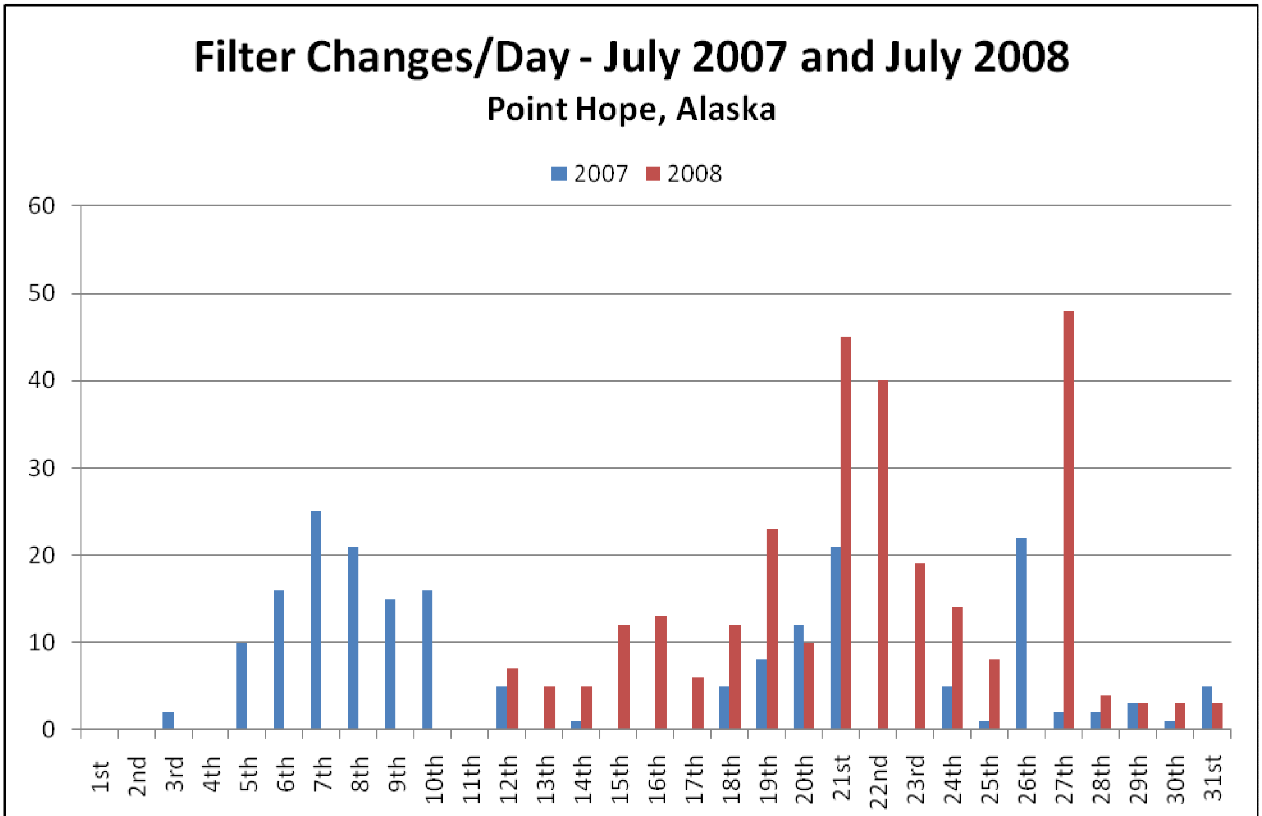

Fig. 3 Source: *Treatment Log Book*, *Point Hope Water*

the performance of a utility but also the financial condition of a community. In turn, the ability of local government to provide fundamental services such as safe drinking water can be affected.

The operators observed increases in mosquito numbers at 7 Mile Lake and increased amounts of what they identified as mosquito larvae in the filters. They also observed increased ambient air temperature at the lake and increased raw water temperature in the plant. The actual composition of the material in the filters was unknown because it has not been tested.

For years, blooms of aquatic life have been an occasional problem for Arctic water systems. The question is whether changes in the lake will continue to disrupt the system, and whether the problem will continue to grow. There is a variety of aquatic life that causes organic blooms in fresh water lakes. These include aquatic zooplankton and algae (Rinella, D., 2009) and photosynthetic cyanobacteria, that has been known to foul water systems in the past (White, D., 2009).

In periods of hot weather, cyanobacteria (blue-green algae) have been associated with huge surface blooms and negative effects on aquatic wildlife. Algae provide food for larval mosquitoes and other aquatic organism. They also provide another potential source of the biologic slime that can foul water filters. Bacteria and algae and insect larvae can be transported throughout the lake during rain, wind or other mixing events and be drawn into the water system intake.

Increased mosquito larvae are one symptom of changing temperature conditions in a tundra lake, and could therefore be used as a monitoring indicator. The minimum air temperature for mosquito development is between 46°F to 50°F, and the optimum temperature is 77°F to 80°F (McMichael et al., 1996). It only takes a few days of the right temperature for mosquitoes to hatch.

The Center for Climate and Health reviewed available climate data for Point Hope to compare historical and current trends in air temperatures. No lake water temperature data was available. Although there is limited data for Point Hope, wind and temperature records are available from 1924 to 1954. Figure 4 below shows historical data on the number of July days above and below the 46^{o}F mosquito development threshold.

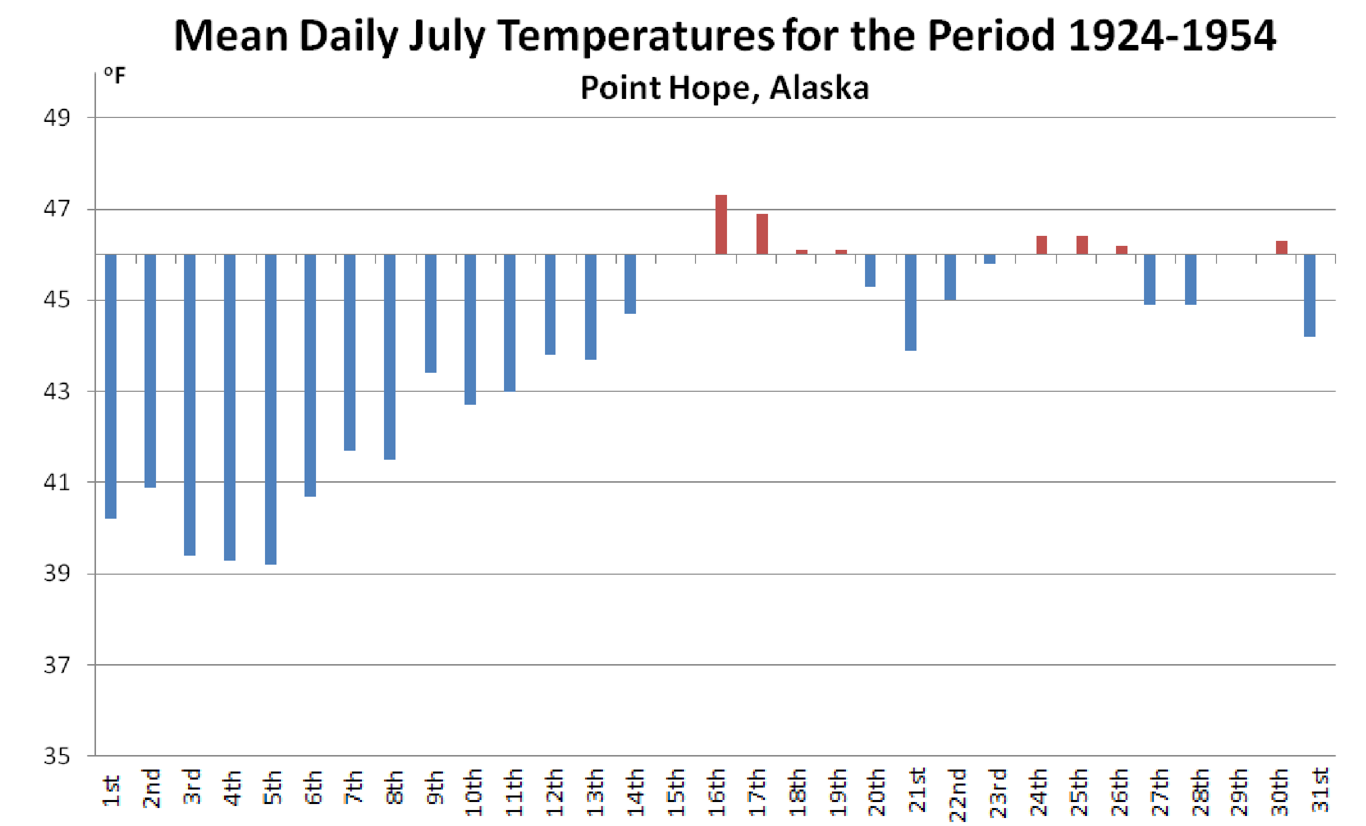

Fig.4 Source: *National Weather Service*

For this period, temperatures did not exceed the mosquito threshold until the middle of July; mean temperatures were not exceeding 48°F. Figure 5 below provides mean July temperature from the next available time period, 1991 through 2008. Again 46°F, is used as the threshold for mosquito development. Here warming is occurring earlier than in Figure 4, and the temperatures are on average higher, by about 1°F.

Figure 6 below shows July temperature data for 2007 and 2008. The mean daily temperatures begin to exceed the 46°F threshold earlier, and the mean temperatures are noticeably higher, reaching the 50°F degrees range by the middle of the month. The data shows that the period in which mosquitoes can survive has been gradually increasing and occurring earlier in the season. July temperatures were extreme during the past two summers. Mosquito larvae usually gather around the perimeter of lakes, where there is more algae growth (Sorenson, F., 2009).

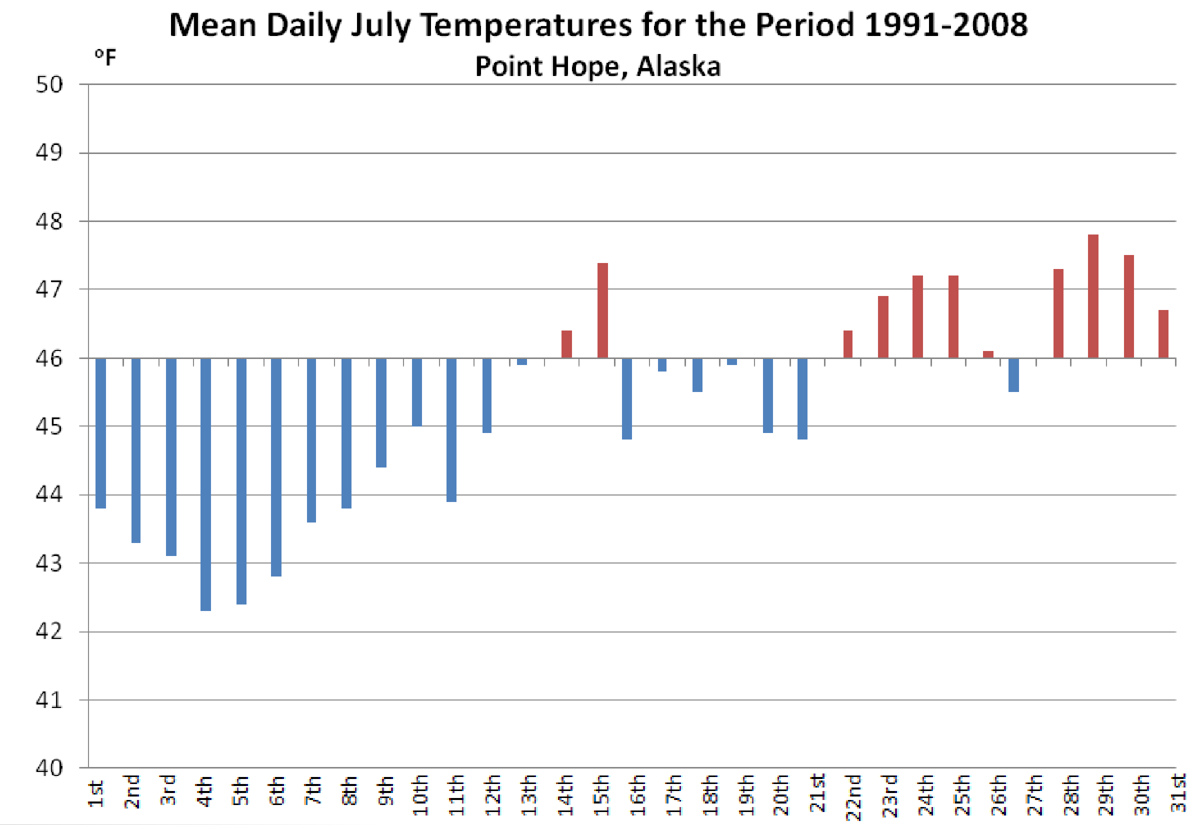

Fig. 5 Source: *National Weather Service*

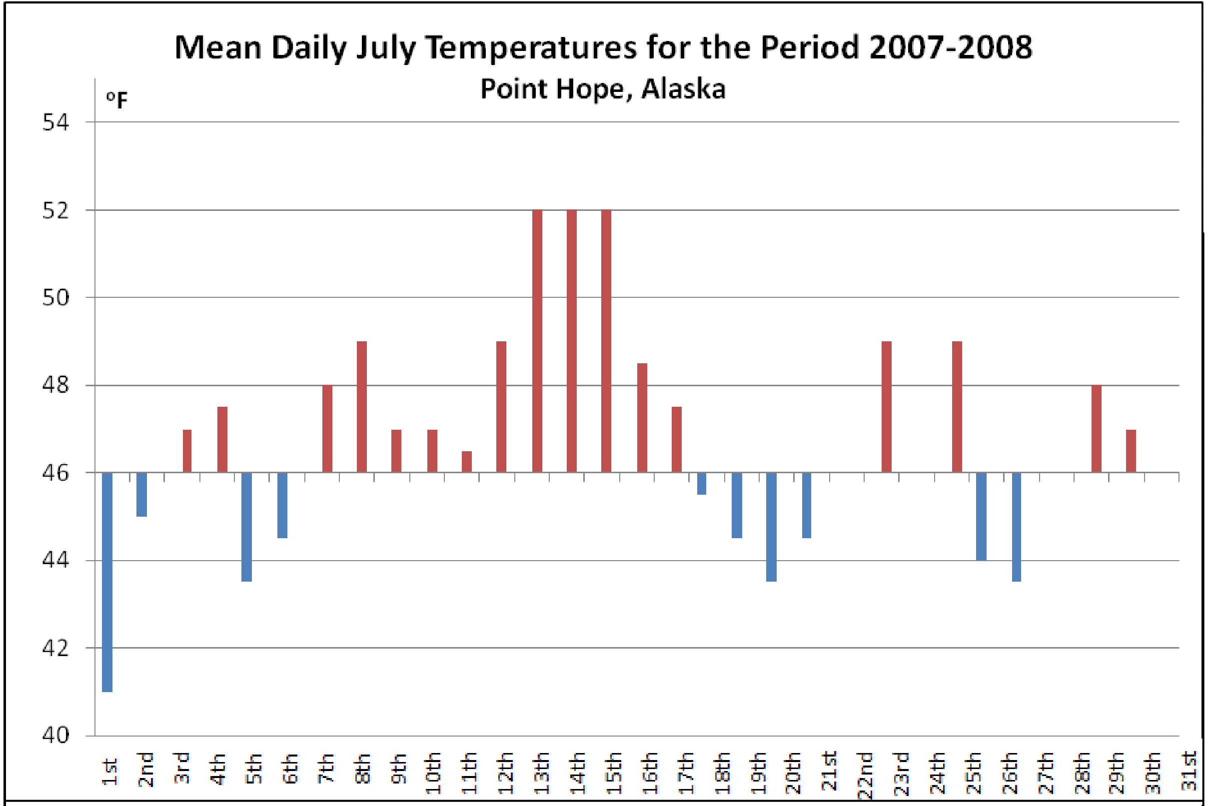

Fig. 6 Source: *Weather Underground*

The intake for the water system is located off the lake bank and at a depth of 1.5 feet. Although decreasing water level results in the intake being closer to the bottom and closer to the water's edge, an explanation is needed on how larvae and other organic material are possibly transported to the intake point. As observed by Frankson and his co-operators, many of the biggest filter problems occurred after wind and rain events.

Figure 7 below includes air temperature, wind and bag filter data for July 2008. The blue line shows air temperature increasing until it reaches a sustained temperature above 46°F (red line) on about the 9th of July. The temperature then drops as the wind (green line) picks up around the 19th and continues to build and then decrease through the 25th. The number of filter changes (orange bars) increase with wind, after a sustained warm period. There appears to be a strong correlation between wind velocity and number of filter changes. This suggests that there are at least two factors influencing source water quality: temperature that encourages biologic growth, and wind that mixes the lake and transports the material to the drinking water system intake.

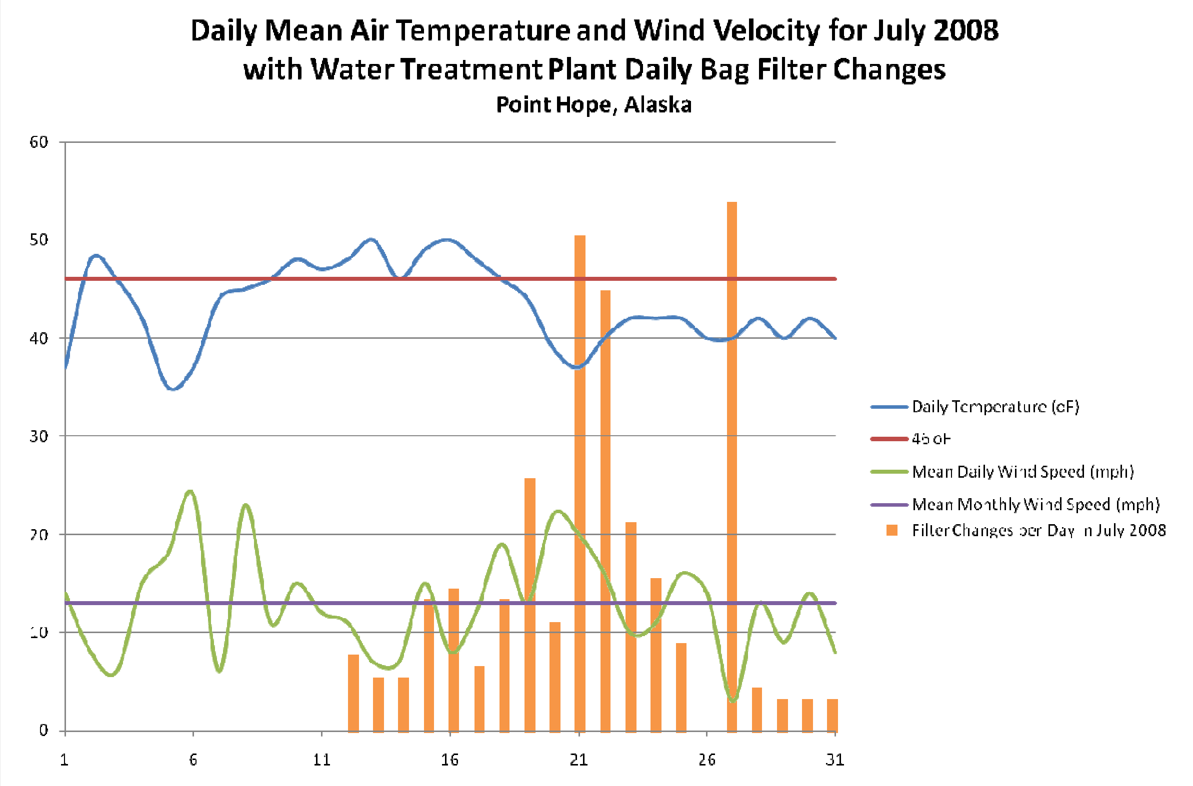

Fig. 7 Source: *Treatment Log Book, Point Hope Water Plant, Weather Underground*

Vulnerability & Adaptation

Point Hope is susceptible to water shortages due to changes in annual precipitation, temperature, and increased evaporation and transpiration. Added vulnerability posed by thawing permafrost at 7-Mile Lake is not well understood. If warming continues as projected, adaptation strategies will be needed to ensure efficient operation of the water system. During exceptionally hot summers, water levels have dropped in the lake, negatively effecting raw water quality. Point Hope experienced wintertime water shortage in 2005, but this was related to water line breaks rather than source water changes. However, a *Water Shortage Emergency Response Plan* was developed that identifies hazards, alternative water sources, procedures (winter and summer), and action levels based on the water level in storage tanks (CH2M Hill 2005). Measures such as the installation of a snow fence around 7 Mile Lake to increase thaw water capture, may be appropriate.

Point Hope is also susceptible to reduced source water quality, related to reduced water levels and new weather related influences to the source lake. To better understand the problem and to develop appropriate responses, continued log recording and regular monitoring of source water levels and temperature is recommended. Additionally, a source water assessment would be needed in order to evaluate lake water conditions and quality. Sampling and analysis of the filter contents and lake water conditions would be part of this assessment. Further long-term monitoring of local weather and the water conditions would be needed to confirm a climate change relationship.

A variety of adaptive responses are possible. These responses apply engineering or ecological approaches and focus on either improving the source water quality, or adapting water treatment procedures or equipment. Engineering responses may include modification of treatment procedures based on weather or water quality conditions or improved filtration. Pre-filters are already in place at the intake and operators are experimenting with use of different mesh size bag filters and placement of the intake based on weather and lake conditions.

Biological responses may include manipulation of algae or species that prey on mosquitoes and mosquito larvae or other biological factors that effect water quality. Mosquitoes have many natural predators including dragon flies, swallows, and fish. In California, mosquito control agencies distribute "mosquitofish" *Gambusia affinis* to add to lakes and ponds. One of these fish is capable of eating over 100 mosquito larvae per day (Alameda County Mosquito Abatement District, 2009). Resident fish in 7

Mile lake are likely already preying on mosquito larvae. Optimizing lake conditions to support beneficial fish species may be considered.

Utility operators may want to contact their design engineers or Water Shortage Emergency Response Plan consultants to seek advice on system improvements. The University of Alaska and the State of Alaska have expertise in aquatic ecology and can provide guidance on performance of source water assessment.

Discussion

Blooms of organic material have been reported in Point Hope and in other tundra lakes in Alaska. Further analysis of water chemistry and biology is recommended, as is a review of operational procedures to improve water system efficiency. Any response should be locally driven, culturally appropriate, economical, sustainable and consistent with regulatory requirements. Adaptive strategies can help to reduce the negative effects of climate on water infrastructure. Without adaptive measures, disruption to water treatment will likely continue.

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