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Impact of providing in-home water service on the rates of infectious diseases: results from four communities in Western Alaska

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DISCLAIMER
The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Abstract

Approximately 20% of rural Alaskan homes lack in-home piped water; residents haul water to their homes. The limited quantity of water impacts the ability to meet basic hygiene needs. We assessed rates of infections impacted by water quality (waterborne, e.g. gastrointestinal infections) and quantity (water-washed, e.g. skin and respiratory infections) in communities transitioning to in-home piped water. Residents of four communities consented to a review of medical records 3 years before and after their community received piped water. We selected health encounters with ICD-9CM codes for respiratory, skin and gastrointestinal infections. We calculated annual illness episodes for each infection category after adjusting for age. We obtained 5,477 person-years of observation from 1032 individuals. There were 9,840 illness episodes with at least one ICD-9CM code of interest; 8,155 (83%) respiratory, 1,666 (17%) skin, 241 (2%) gastrointestinal. Water use increased from an average 1.5 gallons/capita/day (g/c/d) to 25.7 g/c/d. There were significant (*P*-value < 0.05) declines in respiratory (16, 95% confidence interval (CI): 11–21%), skin (20, 95%CI: 10–30%), and gastrointestinal infections (38, 95%CI: 13–55%). We demonstrated significant declines in respiratory, skin and gastrointestinal infections among individuals who received in-home piped water. This study reinforces the importance of adequate quantities of water for health.

Keywords

in-home piped water; water quantity; water-washed diseases

INTRODUCTION

Over the last 100 years, great success has been achieved in providing piped water and sanitation across the United States. In 1940, only 55% of US homes were ‘served’, i.e. had complete plumbing, defined as a running water service to a sink, a toilet and a shower or bathtub. In 2010, 99.6% of US homes had complete plumbing (United States Census 2010a). However, substantial areas of the country still lacked this service. Alaska is ranked last among all US states regarding complete plumbing; seven of the ten census areas in the USA ranked lowest in proportion of homes served are in Alaska (United States Census 2010a). In rural Alaska, 22% of occupied homes (State of Alaska 2014) (about 4,500 homes (State of Alaska 2013) with an estimated 20,250 residents) are un-served. Many more homes depend on aging and deteriorating systems that are operating beyond their expected lifespan.

Nearly all rural communities in Alaska have a water treatment facility where residents can access potable water (Village Safe Water Program Alaska Department of Environmental Conservation 2000); however, in un-served communities, residents must haul this water, (usually by four-wheeler, snow-machine, pick-up truck or by hand) and store it in the home, often in a 33 gallon (125 liter) plastic container. Five gallon buckets or ‘honey buckets’ serve as toilets. These buckets are emptied directly into a community sewage lagoon or into containers located around the community. These communities are often referred to as ‘self-haul’ or ‘honey bucket’ communities.

Hauling water requires manpower, time and money, and the amount of water that can be transported and stored in the homes is limited. A survey of 21 homes in a Northwest Alaskan community estimated average in-home water consumption was 2.4 gallons per capita per day (g/c/d) (Eichelberger 2010). Households headed by single mothers living with young children and who had no vehicle used considerably less water (Eichelberger 2010). The Sphere Handbook, a guide on minimum standards for humanitarian response, recommends a minimum of 2–4 gallons (7.5–15 liters) per person per day (The Sphere Handbook 2011). Limited water availability results in extreme water conservation practices, including multiple hand washes in the same basin of water and reuse of laundry water for multiple laundry loads in non-piped portable machines (T. Hennessy (tbh0@cdc.gov), verbal communication, November 6, 2014).

White *et al.* (1972) categorized water and infectious diseases into four groups. Waterborne infections are acquired by consumption of contaminated water (e.g. cholera). Water-washed diseases are acquired through person-to-person spread that can be interrupted by use of water for hand or body washing (e.g. bacterial skin infections). The other categories, water-based infections (e.g. schistosomiasis) and water-related infections (e.g. mosquitos transmitting malaria), are of less importance in the Arctic region. This paper will focus on waterborne and water-washed diseases.

Rates of hospitalizations for waterborne diarrhea among Alaska Native (AN) children aged <5 years have declined dramatically over the last 30 years and have been similar to the general US population of children <5 years since 1995 (Holman *et al* 1999; Singleton *et al.* 2007). Rates of diarrhea hospitalization in served and un-served communities are also similar (Hennessy *et al.* 2008). These successes can be attributed to the availability of potable water, vaccinations (measles, rotavirus), increased use of oral rehydration therapy and improved overall population health. However, as of 2004, rates of diarrhea hospitalization for AN infants and outpatient visits for children <5 years were still almost twice the US rates (Singleton *et al.* 2007). While emphasis has appropriately been, and continues to be, on prevention of diarrheal diseases, the consequences of insufficient *quantity* of water on ‘water-washed’ infections may not have been fully appreciated.

Several studies have demonstrated that AN people, the primary residents of rural Alaska, suffer dramatic health disparities when compared to the US general population, (Centers for Disease Control and Prevention 2003), with elevated rates of lower respiratory tract infections and skin infections (Landen *et al.* 2000; Lowther *et al.* 2000; Baggett *et al.* 2003; Holman *et al.* 2004; Peck *et al.* 2005). Recent studies have demonstrated an association between the lack of complete plumbing and elevated rates of respiratory and skin infections in Alaska. A 2008 analysis (Hennessy *et al.* 2008) of rates of infections in western Alaska showed that communities where <10% of homes were served had significantly higher infant hospitalization rates for pneumonia and respiratory syncytial virus, and outpatient *Staphylococcus aureus* infections and skin infection hospitalizations among all ages, compared to communities where >80% of the homes were served. These findings were reinforced by two other studies of respiratory disease in AN children (Gessner 2008; Wenger *et al.* 2010).

The above-mentioned studies support the argument that transmission of some acute respiratory infections (ARIs) and skin infections could be interrupted by a convenient and abundant water supply allowing for improved domestic hygiene practices, particularly washing hands and bathing. However, these studies are all ecological analyses and while they demonstrate strong associations and a dose-response relationship (Hennessy *et al.* 2008), they do not establish a causal relationship. Most prospective studies on disease outcomes and sanitation have been done in the developing world and have focused on diarrheal illnesses; a few have looked at the impact of hygiene interventions on water-washed infections. A study of a hand washing education campaign among US Navy recruits showed a 45% reduction in outpatient respiratory infection visits (Ryan *et al.* 2001). A study in Karachi, Pakistan, showed a 50% lower pneumonia incidence among children aged <5 years, a 53% lower diarrhea incidence and a 34% lower impetigo incidence among children aged <15 years in neighborhoods randomized to promote hand washing and bathing with soap compared to neighborhoods with no hygiene promotion (Luby *et al.* 2005).

In 2007 we began to examine health outcomes in four rural communities which were to receive complete plumbing for the first time. The objective was to conduct a prospective cohort study to assess rates of acute respiratory, skin and gastrointestinal infections before and after installation of complete plumbing and hygiene education in these communities.

METHODS

The Alaska Area and Centers for Disease Control (CDC) Institutional Review Boards, the two tribal health organizations (THOs) involved, and the participating communities approved this study. The study was conducted between 2007 and 2012 in four remote communities (referred to as A–D) located in western Alaska. The 2010 populations of these communities ranged from 187 to 627; 91–95% of the population were AN people (United States Census 2010a). Annual median household income ranged from $22,917 to $49,000 (Table 1), and the percent below the Alaska adjusted federal poverty threshold ranged from 15 to 44% (United States Census 2010b). American Indian/Alaska Native (AI/AN) people receive prepaid healthcare through the THOs by compact agreement with the US government. The THOs manage a clinic in each community and a hospital in the region’s largest ‘hub’ town. All medical encounters at the hospital and the community clinics are entered into an electronic medical record (EMR).

The timing and installation of piped water and wastewater disposal was dictated by engineering and funding factors outside the scope of the study. Rural Alaska Native communities are eligible for sanitation funding from the Indian Health Service, United States Department of Agriculture Rural Development, the United States Environmental Protection Agency and the State of Alaska. Distribution of funding is based on a prioritization of projects that factors the health impact of the proposed project, the severity of the deficiency that the project would correct, the capacity of the community/utility and costs. All households are eligible and must pay user fees to keep the system operational, but not construction costs (D. Beveridge (dbeverid@anthc.org), email communication, July 10, 2015). The 'intervention' consisted of installation of a piped distribution system in each community with connections to individual homes, and plumbing inside the homes with a shower, flush toilet, bathroom and kitchen sink. Prior to construction, a few homes in the four villages ($n = 33$) were served, primarily school teacher housing. Following this round of construction, three communities were considered fully served (i.e. all occupied homes were connected except a few where location or another factor prevented connection). Due to funding constraints only half the homes in community A were served.

The intervention also included an educational program promoting the use of water for hygiene (to be reported separately). In brief, the educational program was based on the social ecological model of behavior change and designed to be tailored to the individual communities and their needs. Prior to developing the project, formative assessment activities were conducted to establish the need for an educational intervention and to provide input on design. Key informants and local project staff were involved through each phase of the program to ensure community acceptance, cultural sensitivity, and effectiveness of the intervention activities.

Health education activities primarily took place in homes through informal discussions with study team members. Each piped home received a guide for safe water use and an orientation kit with water and health related items. Local project staff visited each home regularly to share healthy water use messages through kitchen table discussion. Community-level activities took place throughout the project period and included water treatment facility tours, school and community presentations, and social gatherings for new and expectant mothers (K. Hickel (khickel@anthc.org), email communication).

All un-served households were eligible to participate in the study. With the help of local research assistants, we obtained consent for study participation either through visiting households or through community meetings. All adults living in a household at that time were required to consent for the household to be included in the study. Participants consented to allow access to medical records for the period covering 3 years before anyone in the community received piped water, to 3 years after the date that piped water was available for all homes served. These dates differed for each community based on when construction was initiated and completed (ranging from December 2008 (Community A) to April 2010 (Community D)). Participants also consented to have their in-home water use tracked using water meters in the home.

A search was conducted in the EMR for all clinic and hospital encounters that occurred over the specified period for all participants that included an ICD-9-CM diagnosis code for the respiratory, skin and gastrointestinal infections of interest. For one community, the conversion to a new EMR system resulted in a period of incomplete reporting of medical visits, and consequently the follow-up period was reduced to 2.75 years. Codes used to define respiratory infections were: 033–033.9; 034–034.1; 038–038.2; 041.0041.9; 460–

466.19; 480–487.8; 490. Codes used to define skin infections were: 680–686.9. Codes used to define gastrointestinal infections were: 001–009.3. Some non-specific ICD-9-CM codes/ diagnoses such as bacteremia (790.7), cough (786.2) and diarrhea (787.9) were included in order to increase sensitivity. For these non-specific diagnoses, we examined accompanying diagnoses for that visit to determine applicability to this study. For example, cough associated with fever was included; cough in a person with chronic obstructive pulmonary disease and no fever was not included. The illness events were grouped into the broad categories of respiratory, skin or gastrointestinal infection. Visits with the same category of infection (respiratory, skin or gastrointestinal) for the same individual within 14 days of the initial visit were considered the same 'illness/infection' event and were excluded from the analysis. This resulted in the exclusion of 23% of all visits.

Annual illness event rates were calculated for each community for respiratory, skin or gastrointestinal infections for the 3 years before and after water service was initiated. To account for the aging of the cohort, rates for all ages and communities combined were age adjusted for the post-water service initiation period, reweighting according to the age distribution at the start of the pre-water service period. Rates for each infection category were presented by age classes (<10 years old, 10–19, 20–35, 35–50, >50 years). Rates prior to and after water service initiation, for all ages, were compared using a Poisson regression analysis with age class included as a covariate. A generalized linear mixed model (GLMM) was used to account for repeated observations on the same individual and to account for the clustering of study participants within households. In the comparison of rates of all four villages combined, the village was also included in the statistical model. The rate reduction and confidence interval for respiratory, skin, and gastrointestinal visits, for all four villages combined, was estimated from the GLMM. P-values < 0.05 were considered significant.

Movements of participants in and out of the community and between homes in the community were recorded to determine individual exposure to piped water. We also obtained records of when piped water to the house was turned on or off. Persons who moved into a non-participating household, moved out of the study area, or whose households had their water service terminated were censored at the time of the move or termination. Persons who moved or were born into a participating household were included in the analysis if study personnel were able to obtain consent.

In order to estimate the quantity of water being used prior to water service initiation, households were asked to log the number and volume of water hauls conducted over one month and/or were given a standardized survey to report the number of gallons of water hauled during a typical week. To estimate the amount of water used after installation, monthly water meter readings were obtained. We calculated the average gallons per capita per day (g/c/d) for the households several months after in-home piped water became available.

RESULTS

The total 2010 population of the four communities was 1,403; 1,032 (72%) individuals enrolled in the study and medical records were available on 982 pre and 975 post installation. Enrollment ranged from 65% in community A, to 96% in community D. In 2010 the total number of households in the four communities was 359, of these 265 (74%) were enrolled (Table 1).

Pre-installation water use obtained from 191 households indicated a mean of 1.5 g/c/d (5.7 liters) (range 0.9–1.8 g/c/d). In community A, 48 (47%) of the enrolled households were not served. Of the overall 217 enrolled households that were served, 139 (64%) had water meter data available for an average of 17 months (range 2–38 months). After installation, water use averaged 25.7 g/c/d (97.3 liters), ranging from 9.2 g/c/d (community D) to 37.9 g/c/d (community A) (Table 2).

We had a total of 5,477 person-years of observation, 2,816 person-years pre and 2,661 post installation. Among homes that were served we had 4,502 person-years of observation (Table 3). There were 12,752 clinic visits and hospitalizations for illnesses with at least one ICD-9-CM code of interest. After repeat visits within 14 days were excluded, there were a total of 9,840 visits for analysis; 8,155 (83%), 1,666 (17%), and 241 (2%) with respiratory, skin and gastrointestinal infection codes, respectively.

Overall, there were significant declines in clinic visits for respiratory, skin and gastrointestinal infections in served homes (Table 3). Respiratory infection visits declined by 16%, (95% confidence interval (CI): 11–21%), from 1.55 to 1.35 visits per person-year (py). Skin infection visits declined by 20% (95%CI: 10–30%), and gastrointestinal infections declined by 38% (95%CI: 13–55%) from 0.31 to 0.25 visits/py. At the community level, we saw a significant reduction in rates for respiratory and skin infection visits for communities B, C and D, and a significant reduction in gastrointestinal infection visits in community B only. However for community A we did not see a significant reduction in visit rates for any infection category in served or un-served homes (Table 3). A sensitivity analysis demonstrated similar rate reductions when repeat visits were included (results are not presented).

In the analysis of rates by age class (Table 4) we saw no significant changes in the homes of community A that were not served, other than for skin infection visits among those 0–19 years of age. Combining all homes in all communities that were served, among those aged <10 years we found significant reductions in respiratory (19, 95%CI: 8–28%) and gastrointestinal illness (63, 95%CI: 28–81%) visits, among those aged 10–19 years we found significant reductions in all illness categories. No significant reductions were seen in any illness category among those older than 19 years except in skin infections among those aged 35–50 years. In a post-hoc analysis of communities where all homes were served (B–D), we see significant declines in visit rates in the three illness categories in more age groups; respiratory illness - ages 0–19 years, skin infections - ages 0–50 years, and gastrointestinal infection - ages 0–10 years (Table 4).

DISCUSSION

This prospective cohort study was undertaken to describe changes in health outcomes in four communities transitioning from hauling water to receiving in-home piped water for the first time. A total of 1,032 people were enrolled, providing 5,477 person-years of observations. Consistent with other studies (Eichelberger 2010) very low quantities of water use (average 1.5g/c/d (5.7l/c/d)) were observed pre-water installation. As expected, an increase in water use was seen post installation (average 25.7 g/c/d (97.3 l/c/d)). Overall we observed 16%, 20% and 38% declines in respiratory, skin, and gastrointestinal infection clinic visits, respectively.

Extrapolating to the estimated 20,250 people in Alaska living in 4,500 un-served rural homes, we estimate that in the first 3 years following provision of piped water we would see 5,134, 1,299, and 397 fewer clinic visits or hospitalizations for respiratory, skin and gastrointestinal infections respectively *per year;* a total of 6,830 fewer infections per year. Note that 23% of the visits were repeat visits within 14 days and were removed from analysis, thus the burden on the medical system could be reduced by approximately 8,870 clinic visits/hospitalizations per year.

At the community level, we saw a significant reduction in rates for respiratory and skin infections for communities B, C and D where all homes were served. We observed no overall decline in rates of any infection category in community A regardless of whether individuals lived in served or unserved homes. It is conceivable that a certain proportion of the population provided with piped water needs to be reached to see improvement in health for a community. In the analysis by age class for all communities, significant reductions were seen, primarily in the younger age groups (<20 years), the ages usually most heavily impacted by respiratory, skin and gastrointestinal infections. It is possible that further reductions in illness rates could be seen as water conservation habits diminish and people use more water for hand washing and bathing. However, respiratory and skin infections can also be spread by droplets and/or fomites, which are unlikely to be affected by providing a water service.

We observed a significant reduction in gastrointestinal illness visits, particularly in children <10 years of age. This could be attributed to increased hand washing and a lower likelihood of drinking contaminated water. Prior to installation of complete plumbing, about 30% of homes used an untreated water source (T. Ritter (tlritter@anthc.org), verbal communication, November 6, 2014) and for those that used treated water, there were still multiple opportunities for contamination of that water. Hauled water is often stored in large open plastic containers and accessed by dunking a jug into the container, thus providing a mechanism for contamination of previously potable water.

There are limitations to this study. Due to financial and logistical considerations we did not include un-served comparison communities, which would have strengthened the study design considerably by allowing us to control for year-to-year variability in infection incidence. Therefore, declines in infection rates may be due to other factors such as annual variation, increased immunization, or other unaccounted for factors. However, the calendar years of the pre and post period differed from village to village. A particularly severe individual respiratory season could have contributed to the post-water installation rates in one village while contributing to the pre-water installation rates in another village, mitigating to some degree the impact of a period effect via annual variation in disease rates.

The reduction in rates of three classes of infection with three different epidemiological patterns strengthens the argument that the observations are not just a consequence of annual variation in one disease type. Other limitations include the lack of control of the intervention by the investigators and that we did not observe or record changes in hand washing or bathing behavior. In surveys conducted after installation, participants reported that they and their children were bathing and washing hands more frequently (T. Ritter (tlritter@anthc.org), verbal communication, November 6, 2014). Some individuals may seek care outside the Tribal Health system, so would not be included in this analysis; however alternate options for health care in rural Alaska are limited. By measuring only clinic/hospital visits, we likely have underestimated the overall reduction in disease burden. Many water-washed illnesses are mildly symptomatic and may not result in a person seeking medical attention.

The US government is committed to the protection of health and well-being of American Indian and Alaska Native peoples (U.S. Code 25 1976) and there is a need for water and sanitation infrastructure in much of rural Alaska. Based on recent estimates, about $750 million is needed for initial installation of water treatment and delivery of services, or to provide upgrades to aging systems. These estimates are based on the installation of the traditional piped water and sewage system, which is an expensive system in the Arctic setting (Griffith 2013).

The Safe Drinking Water Act (Safe Drinking Water Act 1996) requires community water systems to provide potable water. This water is then used for every function in a household: drinking, cooking, bathing, laundry, toilet flushing, etc. If ensuring potability of community water systems entails having to pipe it from a centralized treatment facility, then this has often resulted in an ‘all or nothing’ situation, where ample quantities of (potable) water are available in piped communities, but in un-piped communities, residents must exercise severe water restriction practices. Efforts to increase the quantity of water are left to the individual homeowner; many supplement treated water supplies with river water, ice blocks from lakes and rainwater from rooftops. Cairncross, in his paper (Cairncross 1987) on the benefits of water supply states: ‘for many of the world’s poor, the first health requirement is not for cleaner water but for more water, whatever its quality, to wash things and keep them clean’. For many communities in Alaska, the provision of complete plumbing is unlikely to happen in the near future. There is a need to think ‘outside the pipe’ and explore alternative ways for households to have *potable* water for consumption (e.g. point-of-use treatment) and adequate *quantity* for personal hygiene and household uses. In 2013, the Alaska Department of Environmental Conservation announced a request for proposals for a multi-phase project to research, develop and test innovative and affordable technologies to provide basic water and sewer service to homes in rural Alaska (State of Alaska 2013). The multidisciplinary US Arctic Research Commission Alaska Rural Water and Sanitation Working Group (Alaska Rural Water and Sanitation Working Group) has also recommended conducting research into alternative systems for communities where a centralized piped water system is infeasible (Alaska Rural Water & Sanitation Working Group 2011).

We did not determine the actual quantity of water required for optimal health. Community D had the lowest water use at 9.5 g/c/d (361/c/d) after installation, and still demonstrated significant reductions in respiratory and skin infection visits. In 2003, the World Health Organization (WHO) reviewed the requirements for water for health-related purposes (Howard & Bartram 2003) and categorized health concern based on available water. Levels below 1.32 g/c/d (51/c/d) were associated with a very high level of health concern, levels of 5.28 g/c/d (201/c/d) were associated with a high level of health concern and those above 13.21 g/c/d (50 l/c/d) were associated with a low level of health concern. Our estimates of 1–2 g/c/d water used in self-haul communities places them in the WHO category of high to very high health concern.

CONCLUSION

The situation in Alaska with isolated communities where most residents obtain comprehensive lifelong medical care through one health system offered a unique opportunity to assess the value of installation of complete plumbing. We demonstrated the beneficial impact on infectious disease rates by increasing the quantity of water available to homes in rural Alaska. More efforts are needed to increase levels of service to the remaining residents of Alaska who lack access to sufficient *quantity* of water. These efforts need to focus on both traditional and alternative technologies that are appropriate for remote, Arctic and sub-Arctic environments.

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Table 1

Alaska Impact of In-home Water Study 2007–2013: Characteristics of the four study communities[*]

	Community			
Demographic characteristic	**A**	**B**	**C**	**D**
Community population	627	346	243	187
% AI/AN[**]	96	95	95	93
% < 5 years of age	10	10	14	12
Number of households	150	90	76	43
Mean number of persons per household	4.2	3.8	3.2	4.4
% of households 1.5 persons/room	28.2%	29.8%	22.9%	25.0%
Median household income ($USD)	43,700	40,000	22,917	49,000
% below federal poverty threshold	24	28	44	15
Enrollment rates				
Population enrolled	405 (65%)	296 (86%)	152 (63%)	179 (96%)
Households enrolled	102 (68%)	71 (79%)	53 (70%)	39 (91%)

[*] Data obtained from the United States Census (United States Census 2010a) and American Community Survey (United States Census 2010b).

[**] American Indian/Alaska Native.

Table 2

Alaska Impact of In-home Water Study 2007–2013. Mean household water use before and after water service installation (gallons per capita per day (g/c/d))

				Water Use g/c/d (l/c/d)	
Community	**Households enrolled (*n*)**	**Households with water meter data**	**Date range water service initiated**	**Before water service**	**After water service**
A (served)	54	26 (48%)	May 2006 –Dec 2008	0.9 (3.4 L)	37.9 (143.5 L)
B	71	56 (79%)	Dec 2007 – Aug 2009	1.8 (6.8 L)	24.6 (93.1 L)
C	53	27 (51%)	Oct 2009 – Dec 2009	1.6 (6.1 L)	33.3 (126.1 L)
D	39	30 (77%)	April 2010	1.5 (5.7 L)	9.2 (34.8 L)
All	217	139 (64%)		1.5 (5.7 L)	25.7 (97.3 L)

This table shows the number of households enrolled that received piped water and the number/proportion that had water meter data available. Shown are dates when the first household received piped water in each community and the date the last home received piped water. In Communities A–C, households were supplied with water sequentially as they came ‘on-line’. In Community D, water was not initiated until all homes were connected. The table shows the water use in gallons per capita per day before and after water service.

Table 3

Alaska Impact of In-home Water Study 2007–2013. Number, person-years of follow-up and visit rates (per person-year) for each community for all age classes combined pre and post in-home piped water installation

Infection type	Period	Statistic	A (self-haul)	A (piped)	B	C	D	All homes with piped water (4 communities combined)
		n-Pre (person years follow-up)	161 (469)	219 (642)	283 (820)	152 (452)	167 (433)	821 (2,347)
		n-Post (person years follow-up)	174 (506)	225 (627)	273 (781)	150 (365)	153 (382)	801 (2,155)
Respiratory	Pre		1.88	1.68	1.81	0.93	1.49	**1.55**
	Post		1.76	1.46	1.73	0.82	0.92	**1.35**
		P-value	0.08	0.06	**0.03**	**0.03**	**< 0.0001**	**< 0.0001**
		% Change (95% CI)	−11% (−22, 3%)	−11% (−20, 0.3%)	−9% (−17, −1%)	−16.6% (−29, −2%)	−38.9% (−47, −30%)	−16% (−21, −11%)
Skin	Pre		0.44	0.44	0.27	0.31	0.22	0.31
	Post		0.36	0.51	0.17	0.12	0.16	0.25
		P-value	0.06	0.18	**0.0001**	**< 0.0001**	**0.049**	**0.003**
		% Change (95% CI)	−19% (−35, 1%)	13% (−6, 36%)	−39% (−52, −22%)	−56% (−70, −37%)	−29% (−49, −0.4%)	−20% (−30, −10%)
Gastrointestinal	Pre		0.06	0.06	0.06	0.03	0.03	0.05
	Post		0.06	0.04	0.02	0.02	0.04	0.03
		P-value	0.80	0.20	**0.0003**	0.57	0.30	**0.005**
		% Change (95% CI)	−3% (−43, 65%)	−31% (−61, 22%)	−69% (−83, −42%)	−22% (−67, 88%)	51% (−31, 227%)	−38% (−55, −13%)

n = number of individuals.

Table shows the pre and post in-home piped water respiratory, skin and gastrointestinal illness encounter rates (per person-year) for each community and for all homes that received piped water combined for all age classes combined. Rates after water service installation are presented adjusted by age class. *P*-values and % change are from a generalized linear mixed model and *P*-values < 0.05 were considered significant.

Table 4

Alaska Impact of In-home Water Study 2007–2013. Visit rates (per person-year) for each community by age class. Community A (self-haul) compared to all homes with piped water in the four communities and all piped homes in communities where all homes were piped (B, C, D)

		A (self-haul)				**All piped homes (4 communities combined)**				**All piped homes (communities B, C, and D combined)**			
Age class	**Period**	**n***	**Resp**	**Skin**	**Gastro**	**n***	**Resp**	**Skin**	**Gastro**	**n***	**Resp**	**Skin**	**Gastro**
< 10 Years	Pre	56	3.42	**0.63**	0.14	235	**3.01**	0.47	**0.14**	162	**2.85**	**0.43**	**0.14**
	Post	43	2.88	**0.35**	0.07	164	**2.47**	0.46	**0.05**	114	**2.13**	**0.37**	**0.013**
	P-value		0.06	**0.02**	0.14		**0.008**	0.83	**0.004**		**0.007**	**0.04**	**0.006**
10–19 Years	Pre	41	1.70	**0.46**	0.00	229	**1.34**	**0.27**	**0.02**	164	**1.34**	**0.24**	0.01
	Post	62	1.55	**0.22**	0.05	240	**1.11**	**0.21**	**0.00**	163	**1.16**	**0.12**	0.003
	P-value		0.86	**0.01**	0.66		< **0.0001**	**0.01**	**0.01**		**0.002**	**0.005**	0.16
20–35 Years	Pre	36	1.22	0.30	0.03	171	0.94	0.29	0.03	134	0.89	**0.20**	0.02
	Post	30	1.13	0.27	0.06	205	0.83	0.24	0.02	165	0.77	**0.10**	0.02
	P-value		0.78	0.79	0.47		0.08	0.33	0.97		0.07	**0.002**	0.99
35–50 Years	Pre	33	0.97	0.38	0.02	176	0.92	**0.29**	0.01	120	0.99	**0.26**	0.01
	Post	42	1.03	0.40	0.02	149	0.83	**0.13**	0.03	98	0.76	**0.13**	0.02
	P-value		0.95	0.87	0.84		0.91	< **0.0001**	0.21		0.35	**0.0007**	0.58
> 50 Years	Pre	25	1.14	0.31	0.07	154	1.10	0.23	0.04	120	1.13	0.17	0.04
	Post	36	1.11	0.24	0.07	193	1.11	0.24	0.05	145	1.15	0.14	0.05
	P-value		0.83	0.23	0.96		0.92	0.81	0.15		0.80	0.70	0.18

*n** = number of individuals.

Table shows the pre and post in-home piped water respiratory, skin and gastrointestinal illness encounter rates (per person-year) by age class for the self-haul homes in community A, all homes with piped water in the four communities (A–D) and all piped homes in communities where all homes were piped (B, C, D). *P*-values and % change are from a generalized linear mixed model and *P*-values < 0.05 were considered significant.