Nitrogen Contamination of Groundwater in Proximity to a Closed Landfill and Active Agricultural Fields

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Abstract

Carcinogenic compounds in drinking water are becoming a significant health problem. Increased use of artificial fertilizers, disposal of wastes, and land use are the main factors responsible for increased nitrate levels in groundwater over the last 30 years. This study examined the correlation between nitrate levels and proximity to a closed, inactive garbage dump located in Middlesex, Virginia. This study also examined the correlation between nitrate levels and proximity to agricultural fields. Twenty-five sampling sites were identified on the GIS tax maps of Middlesex County, Virginia. Fifteen sites were identified within a two kilometer radius of the VPPSA landfill, also the site of an abandoned town dump, and the remaining ten sample sites were identified around the county outside of the two kilometer radius. The mean nitrate levels at sample sites within a 2 km radius of the landfill were higher. Over the 125 data points sampled, it becomes evident that nitrate levels were higher in well water at sample sites within a 2 km radius of the landfill. Along with increased nitrate levels, nitrite levels exceeding 1 ppm, the highest contamination level for human consumption, were also measured at several locations. Groundwater contamination can cause major health issues, and it is often undetected in well drinking water due to lack of regular testing. Global health and welfare due to unregulated groundwater contamination is a crisis that demands more direct attention.

Introduction

The problem of carcinogenic compounds in drinking water is becoming a significant health problem. Sources of these compounds are ubiquitous on earth from both agricultural sources as well as waste disposal. Nitrate (NO_3^-) is a naturally occurring nutrient ion required by all living systems for photosynthesis (Environment Canada, 2003; IARC, 2010). Excessive amounts of nitrate in drinking water can be linked to severe health effects in infants such as “blue baby” syndrome, caused by disrupted oxygen flow to the blood (EPA, 2017). Nitrate is supplied to groundwater due to fertilizers, sanitary landfills, and garbage dumps. The National Primary Drinking Water Regulations set by the Environmental Protection Agency state that 10 mg/L of nitrate is harmful to human health. An increased use of artificial fertilizers, disposal of wastes, and land use are the main factors responsible for increased nitrate levels in groundwater over the last 30 years (WHO, 1985).

Industrial activities can also contribute to excess nitrate in groundwater. A study focusing on the effects of agricultural and industrial activities on drinking water quality in China found that nitrate was the most harmful to human health (Wu et al., 2016). In a study examining the effect of municipal landfills and how the water quality surrounding the area is affected, leachate percolation and irrigation return flow were a possible source of shallow aquifer contamination (Dongmei et al., 2014). Two-dimensional transport models utilizing stable isotopic compositions were constructed in order to further explain the aquifers and their conditions. An international company analyzed leachate and groundwater quality near a field of municipal solid waste management and a landfill site (El-Salam et al., 2014). Physio-chemical analyses of leachate confirmed that there was severe contamination of organics, salts and heavy metals, and that it was biodegradable and un-stabilized. It was concluded that certain parameters exceeded the World Health Organization and Environmental Protection Agency limits.

Agricultural activities can contribute to excess nitrate in groundwater (EPA, 2017). A study focused on the effect of agricultural land use on nitrate levels in groundwater found that in the well water of private homes tested, the conversion of grasslands to agricultural fields raised the nitrate level above 10 ppm (Keeler et al., 2014). This study shows that fertilizers and pesticides have an effect on groundwater. Nitrate was found to be the most common contaminant in a study done using monitoring wells (Bourke et al., 2015). In a comparison of core profiles and samples from monitoring wells, the core profiles allowed researchers to visualize how agriculture contaminates groundwater through spatial resolution in comparison to a permanent, unmoving well.

This study examined the correlation between nitrate levels and proximity to a landfill, previously a garbage dump, located in Middlesex, Virginia. This study also examined the correlation between nitrate levels and proximity to an agricultural field.

Hypotheses

H_{01}: If the sample site is within a two kilometer radius of the landfill, the concentration of nitrate will not be affected.

H_{A1}: If the sample site is within a two kilometer radius of the landfill, the concentration of nitrate will be higher.

H_{02}: If the sample site is within one kilometer of an agricultural field, the nitrate levels will not be affected.

H_{A2}: If the sample site is within one kilometer of an agricultural field, the nitrate levels will be higher.

The distance from the landfill in kilometers (km) served as the independent variable. The dependent variable measured nitrate levels in parts per million (ppm). The constants in this study were the time of day that the groundwater sample was taken and the 25 sample locations remained the same.

Materials and Methods

Twenty-five sampling sites were identified on the GIS tax maps of Middlesex County, Virginia. Fifteen sites were identified within a two kilometer radius of the VPPSA landfill in Middlesex, Virginia, the remaining ten sample sites were identified around the county outside of the two kilometer radius. All twenty-five sites were sampled on the same day; at each site, the household water spigot was identified, and turned on and allowed to flow for ten seconds. Once the water had run for that amount of time, a sample was collected in a 140 mL container. This process was repeated for each site. After all 25 samples were obtained for the day; they were prepared for chemical testing using Water Works™ test strips. One strip was inserted into the water sample for two seconds without motion, and then the strip was removed. The strip was left to sit for one minute before being analyzed by comparison to the colorimetric chart provided on the test strip bottle. This process was repeated for each of the twenty-five samples. All samples were properly disposed of after the nitrate/nitrite levels had been tested. This entire method was repeated for five sampling dates: October 8th, 2017, October 9th, 2017, October 15th, 2017, November 11th, 2017, & November 18th, 2017 for a total of 125 data points.

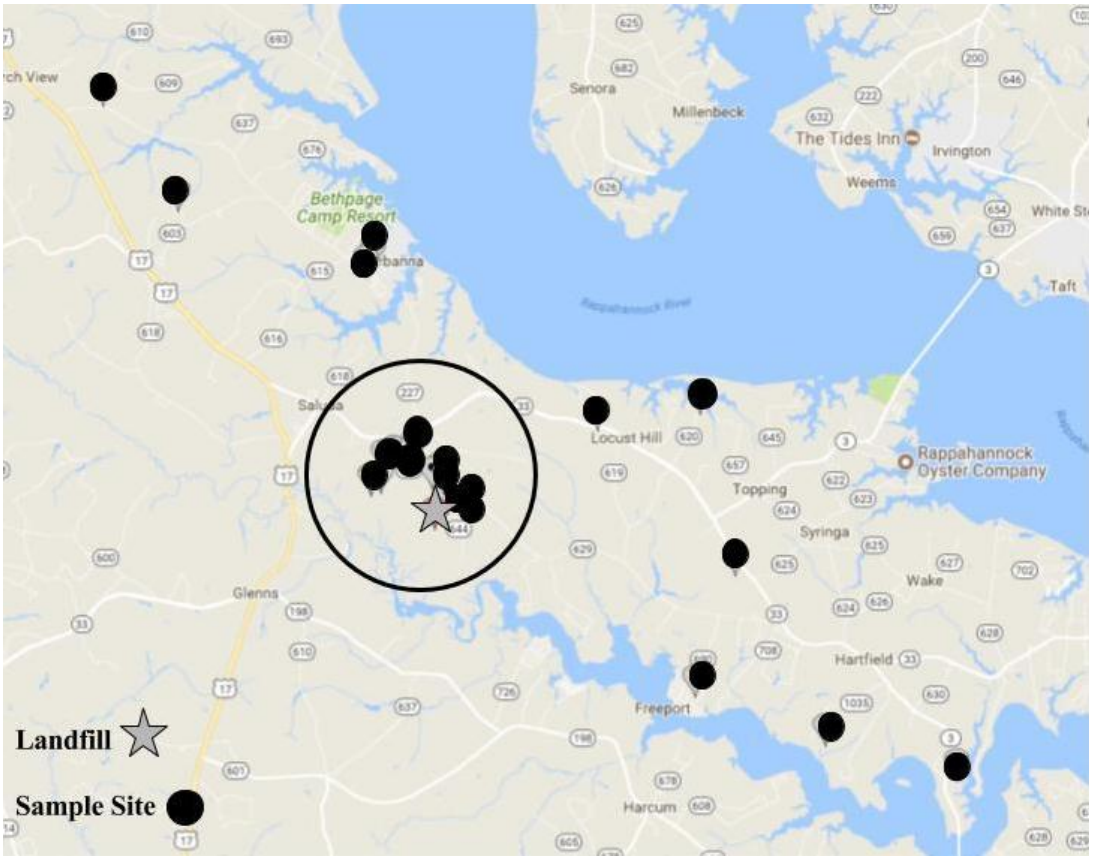

Figure 1. Map of the landfill location and the sample sites in Middlesex County, Virginia. The circle represents the 2 km radius of the landfill, indicated by the star. The sites sampled are indicated by the site markers on the map.

The Middlesex County Geographic Information System (GIS) was used to determine the physical address of each sample site as well as the VPSSA Middlesex County landfill. GIS allowed access to the 911 address of each sample site to establish whether it is within the one mile radius area of the landfill (Figure 1). Each address was then input into Google Maps, and the distance from the landfill was measured in kilometers using a tool that calculated the straight line distance between two points and avoided highways. This method was also used to determine the distance between the sampling site and the nearest agricultural field. All of the data were recorded in Excel spreadsheets and analyzed using linear regression analysis to determine relationships between the proximity to potential nitrogen pollution sources and nitrate in drinking water. A t-test was used for statistical analysis.

Results

One hundred and twenty five data points were analyzed in total. Nitrate levels were compared between locations within a 2 km radius of the landfill and locations outside of that range (Figure 2). Nitrate levels were also measured in relation to proximity to an agricultural field (Figure 3).

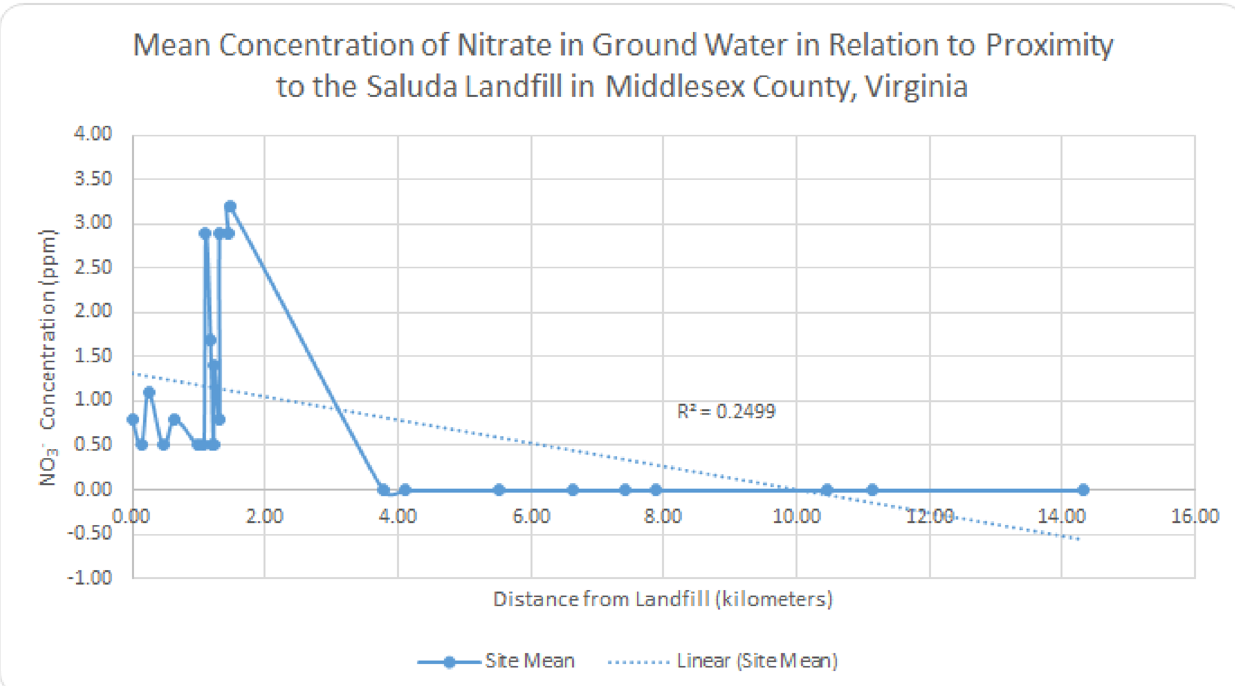

Figure 2. Mean nitrate had a maximum value of 3.2 ppm at 1.47 km from the landfill. All sample site locations outside of the 2 km radius yielded a minimum mean nitrate level of 0 ppm.

The mean nitrate levels at sample sites within a 2 km radius of the landfill were higher. The maximum mean nitrate level was measured to be 3.2 ppm 1.47 km from the landfill (Figure 2). The minimum nitrate value measured was 0 ppm at all sample sites outside of a 2 km radius of the landfill (Figure 2). The increased distance from the landfill yielded lower mean nitrate levels in the field (Appendix A: Table 1)

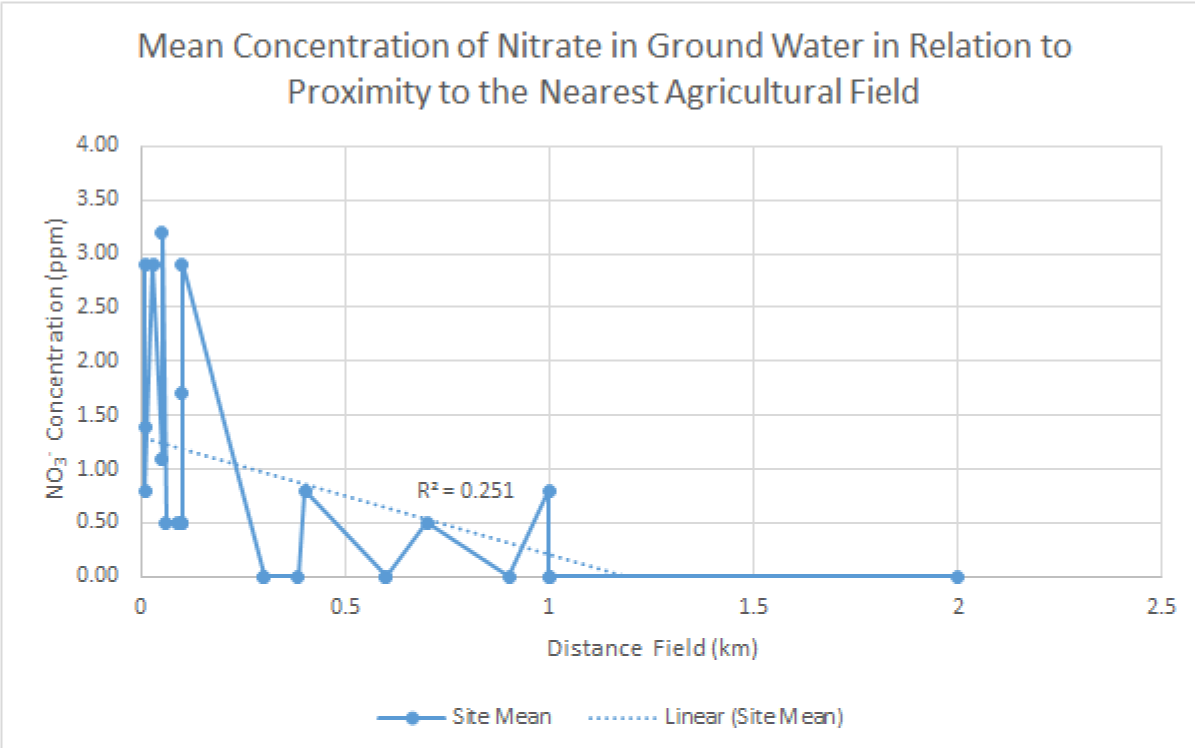

Figure 3. Mean nitrate levels had a maximum value of 3.2 ppm at 0.05 km from the nearest agricultural field. Mean nitrate levels had a minimum value 0 ppm at 9 sample sites >1km away from agricultural fields.

The mean nitrate level of 0.9857 ppm was measured at sample sites less than 1 km from the nearest agricultural field (Figure 3). The mean nitrate level was 0 ppm for locations 1 km or more away from the nearest agricultural field (Figure 3). The increased distance from the agricultural fields yielded lower mean nitrate levels in the field (Appendix A: Table 1)

A t-test for two samples assuming unequal variances (Appendix B: Table 2) yielded a p = 0.0001. The mean nitrate level of all 15 sample site within a 2 km radius of the landfill was 1.34 ppm (Appendix B: Table 2). The mean nitrate level for the 10 sample sites outside of the 2 km radius of the landfill was calculated to be 0 ppm.

Discussion & Conclusion

Over the 125 data points sampled, it is evident that nitrate levels were higher in well water at sample sites within a 2 km radius of the landfill. The average nitrate level within the 2 km radius was 1.34 ppm, and the average nitrate level outside of the radius was 0 ppm. This suggests that the landfill has an impact on well water with nitrate. The mean nitrate level less than 1 km from the nearest agricultural field was 0.99 ppm. The mean nitrate level 1 km or more from the field was 0 ppm. A t-test statistical analysis yielded a $p = 0.0001$. This is statistically significant, therefore the null hypothesis, *if the sample site is within a two km radius of the landfill, the concentration of nitrate will not be affected*, can be rejected. The null hypothesis, *if the sample site is within one kilometer of an agricultural field, the nitrate levels will not be affected*, can also be rejected.

Based on these findings, the Saluda Landfill, as well as active agricultural fields, are point sources of nitrate. Along with increased nitrate levels, nitrite levels exceeding 1 ppm, the highest contamination level for human consumption (EPA, 2017), were also measured at several locations. Though this study sought to find a correlation between proximity to a landfill and nitrate levels in groundwater, further data analysis showed that agricultural activities are a main contributor of nitrate. Runoff from farms and fields leads to an increase in nitrate levels due to the chemicals present in fertilizers and manure.

Previous studies on the effect of landfills on nitrate in groundwater have found similar results. Leachate percolation is found to be a main contributor of nitrate into groundwater (Dongmei et al., 2014). A study conducted in Egypt found that while groundwater near landfills was not severely contaminated, the nitrate levels did exceed World Health Organization and Environmental Protection Agency Standards (El-Salam et al., 2014). These studies resulted in further investigation of the correlation between landfills and nitrate levels in groundwater. A study conducted in the Netherlands analyzed the correlation between nitrate used in agriculture and the presence of nitrate in groundwater found that nitrate was higher in areas closer to the farmland (Oenema et al., 1998). Applications of manure and fertilizers yield a higher nitrate level in groundwater (Spalding et al., 1993). Agricultural activities actively contribute nitrate into groundwater, and these sources are often unregulated, which is consistent with the results found in this study. In Middlesex County, Virginia, groundwater flows from the mountains to the bay, so the NO_3^- is displaced eastward from the source, which also contributes to the natural fluctuation of nitrate levels in proximity to the agricultural fields.

This study could be conducted on a much broader scale to more accurately and completely represent the groundwater quality of the entire county. An increase in sample sites and more frequent data collection would make the study more representative of the population. This study could be conducted in any area that has a landfill or dump. In order to fully understand the contamination of groundwater with nitrate, and agriculture must also be accounted for in the study as a possible source of nitrate.

Groundwater contamination can cause major health issues, and it is often undetected in well drinking water due to lack of regular testing by homeowners. The continuous consumption of nitrate from drinking water can pose serious health effects, especially in infants (EPA, 2017). In the future, government regulations for drinking water should be applied to groundwater in areas where agricultural and industrial activities are common. Restrictions on fertilizer amounts, as well as control of waste management leachate would help to decrease nitrate levels in groundwater. Annual well water testing conducted by the Middlesex County Health Department is one way to ensure that residents could be better informed about the quality of the water being consumed on a daily basis from their groundwater wells. Educational programs should be made available in rural communities dependent on potable groundwater, in order for people to better understand nitrate and how its consumption can affect the human body. Alternate drinking water sources should also be made available for those who regularly drink groundwater and are susceptible to negative health effects from excess nitrate in well water. Globally the health and welfare of communities relying on groundwater demands more direct attention because of the threat of nitrate contamination and related health crises.

References

Peer Reviewed:

Bourke, S. A., Turchenek, J., Schmeling, E. E., Mahmood, F. N., Olson, B. M., & Hendry, M. J. (2015). Comparison of continuous core profiles and monitoring wells for assessing groundwater contamination by agricultural nitrate. *Groundwater Monitoring & Remediation, 35*(1), 110-117. doi: 10.1111/gwmr.12104

Dongmei Han, Xiaoxia Tong, Matthew J. Currell, Guoliang Cao, Menggui Jin, Changshui Tong. (2014). Evaluation of the impact of an uncontrolled landfill on surrounding groundwater quality. *Journal of Geochemical Exploration, 136*, Pages 24–39. doi:10.1016/j.gexplo.2013.09.008

El-Salam, M. M. A., & Abu-Zuid, G. I. (2015). Impact of landfill leachate on the groundwater quality: A case study in Egypt. Journal of advanced research, 6(4), 579-586.

IARC (2010). Ingested nitrate and nitrite and cyanobacterial peptide toxins. Lyon: International Agency for Research on Cancer; 1–464 (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 94).

Keeler, Bonnie & Polasky, Stephen. (2014). Land-use change and costs to rural households: a case study in groundwater nitrate contamination. *Environmental Research Letters, 9,* Pages 1-10. doi:10.1088/1748-9326/9/7/074002

Oenema, O., Boers, P. C. M., Van Eerdt, M. M., Fraters, B., Van der Meer, H. G., Roest, C. W. J., ... & Willems, W. J. (1998). Leaching of nitrate from agriculture to groundwater: the effect of policies and measures in the Netherlands. In Nitrogen, the Confer-Ns (pp. 471-478).

Spalding, R. F., & Exner, M. E. (1993). Occurrence of nitrate in groundwater—a review. Journal of environmental quality, 22(3), 392-402.

Wu, J. & Sun, Z. (2016). Evaluation of Shallow Groundwater Contamination and Associated Human Health Risk in an Alluvial Plain Impacted by Agricultural and Industrial Activities, Mid-west China. *Expo Health*, *8*(3), Pages 311-329. doi:10.1007/s12403-015-0170-x

Non-Peer Reviewed:

Environment Canada (1992). National Air Pollution Surveillance (NAPS) annual summary 1990. Ottawa (ON): Environment Canada, Environmental Protection Service (Report EPS7/AP/23).

National Primary Drinking Water Regulations. (2017, July 11). Retrieved January 17, 2018, from https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water- regulations

WHO (1985). Health hazards from nitrate in drinking-water. Report on a WHO meeting, Copenhagen, Denmark, 5–9 March 1984. Copenhagen: WHO Regional Office for Europe (Environmental Health Series, No. 1).

Appendix A

Site	Distance from Landfill (km)	Distance from Nearest Field (km) (≥ 1 Hectare)	NO_3- 10/8/17	NO_3- 10/9/17	NO_3- 10/15/17	NO_3- 11/11/17	NO_3- 11/18/17
G	0	0.4	0.5	2	0.5	0.5	0.5
O	0.14	0.1	0.5	0.5	0.5	0.5	0.5
N	0.25	0.05	0.5	0.5	2	0.5	2
J	0.469	0.09	0.5	0.5	0.5	0.5	0.5

B	0.644	1	0.5	0.5	0.5	0.5	2
E	0.983	0.1	0.5	0.5	0.5	0.5	0.5
I	1.08	0.06	0.5	0.5	0.5	0.5	0.5
K	1.11	0.01	5	5	2	2	0.5
M	1.18	0.1	2	2	2	2	0.5
C	1.22	0.1	0.5	0.5	0.5	0.5	0.5
Y	1.23	0.7	0.5	0.5	0.5	0.5	0.5
A	1.24	0.01	2	2	2	0.5	0.5
F	1.32	0.01	0.5	0.5	0.5	2	0.5
L	1.32	0.1	5	5	2	2	0.5
D	1.45	0.03	5	5	2	2	0.5
H	1.47	0.05	5	5	2	2	2
Q	3.78	1	0	0	0	0	0
X	4.11	0.6	0	0	0	0	0
R	5.52	1	0	0	0	0	0
T	6.64	0.3	0	0	0	0	0
U	7.42	0.6	0	0	0	0	0
W	7.88	0.385	0	0	0	0	0
P	10.46	0.3	0	0	0	0	0

V	11.15	2	0	0	0	0	0
S	14.31	0.9	0	0	0	0	0

Table 1. Data collected using nitrate test strips. Distances were determined using GIS mapping.

Appendix B

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	1.34375	0
Variance	1.070625	0
Observations	16	9
Hypothesized Mean Difference	0	
df	15	
t Stat	5.194691709	
P(T<=t) one-tail	5.44268E-05	
t Critical one-tail	1.753050356	
P(T<=t) two-tail	0.000108854	
t Critical two-tail	2.131449546	

Table 2. A t-test produced a p value of 0.000108854.