Feasibility of using common Mexican ceramics as the chamber material for household ultraviolet water disinfection system.

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Abstract This study compares common lead glazed Mexican pottery with non-lead glazed pottery under ultraviolet exposure to determine whether the local ceramics can be used as household ultraviolet water disinfection system chamber. Eight common Mexican ceramic wares, four with lead glaze and four with non-lead glaze are filled with Barnstead Nanopure® water and exposed to ultraviolet light in a sealed stainless steel container. After one-week exposure, conductivity levels and lead concentrations are taken from the water in each ware. The results show the average conductivity per unit area of lead-containing ceramics is 0.57 $\mu S/cm^3$ and non-lead ones with an average of 1.66 $\mu S/cm^3$ after a week of UV exposure. The inconsistency of the conductivity of both types of ceramic ware leads to further testing for lead (Pb^{2+}) and other heavy metals in the sample water. While the samples yielded no significant amount of other metals, the calculated lead concentration per unit area for Pb-ceramics is 2.46 $\mu g/L/cm^2$ and 0.08 $\mu g/L/cm^2$ for non-Pb ceramics after a week of UV exposure. The measured lead concentration per unit area, however, for Pb-ceramics is 1.80 $\mu g/L/cm^2$, lower than the calculated one, and for non-Pb ceramics, 0.45 $\mu g/L/cm^2$, a value higher than that of calculated. All lead concentrations fall below the World Health Organization's limit of 10 micrograms per liter in drinking water. During the one-week exposure, the calculated lead concentration rises and falls sharply before leveling near the end of the one-week. This study recommends that the lead-glazed ware be exposed to ultraviolet light for two weeks before drinking the water from it. Alternatively, non-lead glazed ceramics can be used instead in regions where the less expensive lead-glazed ones are unavailable.

Introduction

Access to potable drinking water, especially in rural regions of underdeveloped countries, is extremely important in the prevention of gastro-intestinal infection and disease that claims the lives of millions of people, mostly young children, each year worldwide (WHO, 2000). In Mexico, the percentage of population with access to safe water and sanitation is considered high, with 83% and 66% respectively. However, in rural regions from 1990 to 1996, only 26% of the population has access to sanitation. To mitigate this global problem, a wide variety of water purification systems have been examined and put into practice. Despite an improvement from the 15 percentile during 1982 to 1985, the number is still alarmingly small (International Bank for Reconstruction and Development, 2000).

In the rural region of Tzintzuntzan of Mexico, a low-cost, user-friendly household photo oxidation (UV radiation) water disinfection system has been developed and implemented. Led by Lloyd Connelly and Daniel Kammen of the Renewable and Appropriate Energy Laboratory in Berkeley, California, U.S.A., this research, at its experimental stage, is testing different materials to be used as the chamber body. The experiment seeks to find the best choice based on the materials' contribution of toxins to the water during UV disinfection. Previous studies found that polyvinyl chloride (PVC) chamber leach carcinogenic compounds such as dioxins after exposure to ultraviolet light (Andrady et al., 1998). Stainless steel plates, although more durable and less reactive than plastic tubes, are expensive and hard to find in the Tzintzuntzan region. Therefore, the alternative materials examined in this study are typical Mexican ceramics made of local natural clay. Knowing the potential toxicity of the photo oxidation by-products is vital (Parkinson et al., 2001).

Pottery craft has been an integral part of Mexican culture. Since the locals are accustomed to ceramics, they are expected to synthesize it into the new water disinfection system more readily than with an unfamiliar material, such as steel plates, which is also not easy to obtain. Ceramics are often coated with a thin layer of glaze, which physically fuses into the surface of the clay and fills some of the open pores of the ceramic body, minimizing seepage (Mohamed et al., 1995). However, because lead glazes are the least expensive and the pottery community has the most experience with them, almost all the ceramics created in rural regions contains lead-based coating (Morales, personal communication). Lead poisoning has been found to occur by ingesting food that had been placed on lead-glazed ware (Matte et al., 1994; Mohamed et al., 1995). The health effects attributed to lead are damage to liver, to the nervous, reproductive, immune, and gastrointestinal systems (Manahan, 1984). Despite its danger, previous studies have demonstrated that if the glaze is fired at temperature of at least 1150ºC (or 2102ºF), then the ware is safe for food preparation and storage (Spielholtz and Kaplan, 1980). No studies have examined the effects of ultraviolet light on the ceramic glaze despite the fact that heavy metals may disintegrate from the clay matrix during exposure.

This study will examine the resilience of non-lead glaze and lead-based glaze under ultraviolet light exposure in order to examine the feasibility of using the popular lead-glaze ceramics as the water disinfection chamber material. If the lead-based glaze ceramics has no harmful leachates, it would be convenient, inexpensive, and readily available for the locals.

Methods

Eight different ceramic potteries, obtained from local markets under the guidance of a famous local potter, Manuel Morales, of Tzintzuntzan in the State of Michoacan, Mexico, were tested as representatives of the typical glazed ceramic ware used in that rural region. Two of these potteries were broken but pieced together and tested as well, to simulate whether exposed inner clay matrix through cracks could have an affect on the water quality. All were made of the regionally common natural mix clay, barro, whose primary constituent is silica and fired at low temperature of less than 1000ºC or 1832ºF (Doremus, 1997). Four of these were coated with glazes containing lead and fired at temperature between 800 and 900ºC (or 1472 to 1652 degrees Fahrenheit). The other four pieces were glazed with non-leaded borax with firing temperature between 800 to 1050ºC (or 1472 to 1922ºF) (Morales, personal communication). Although each clay body differed slightly in color with one another because of firing temperature variation, it should not affect results since only the glaze is being exposed to the ultraviolet and in contact with the water. The characteristics of each pot, such as design and colors, are described in Table 1. All eight ceramic vessels held at least 200 mL of water. The water used in this experiment was Barnstead brand Nanopure® water, water that was purified to the nano-degree of any possible contaminant.

Pottery	Glaze type	Volume (mL)	Surface area (cm^2)	Description
White container	Pb	500	133.78	Hexagonal container with smooth glaze and colorful decoration on the outside wall
Flat tray	Pb	250	181.46	Reddish, coarse texture, with green-colored design on the inside bottom
Tall cup	Pb	350	40.72	Reddish, coarse texture, with white-colored design on outside wall
Cracked tray	Pb	350	124.69	Low tray with reddish base and green-colored design inside; coarse texture
White mug	No Pb	300	51.53	White, with smooth glaze and reddish paint-design along the outer wall
Tz. Mug	No Pb	300	54.11	Black, with smooth, glossy glaze and golden “Tzintzuntzan” written on the outside wall
Tall pitcher	No Pb	550	23.76	Reddish, coarse texture, with cream-colored and brownish design on outer wall
Cracked tray	No Pb	500	176.71	Low tray with cream-colored base and brownish design inside and out; coarse

Table 1: Detailed description of all eight pottery samples used in this study.

Hach’s benchtop sensION7 Conductivity Meter was used to measure the electrical conductivity of samples. With its four-cell electrode, the meter was able to measure between the range of 0.1 μS/cm to 200 mS/cm, while conductivity range of drinking water falls between 100 μS/cm and 1 mS/cm (Hach Company Manual of sensION7, pp. 32). Since the main ion of interest in this study is lead (Pb^{2+}), an excess of the cation will readily give a signal on the meter. To measure conductivity, the probe is placed into the sample until the slot on the end of the probe is entirely immersed. The sample is then agitated with the probe for 5 seconds to remove any bubble that may be trapped in the slot. After each measurement, the probe is rinsed with Nanopure water and dried to minimize buildup of interfering substances on the probe element. PH measures the acidity of the sample water. The higher the concentration of metals in the solution, the higher the concentration of H^+ ions that result from hydrolysis of heavy metal cations in the water, which triggers a reduction of pH equilibrium.

The 1-week water samples were also tested for other metals. A widely distributed metal in earth’s crust, chromium(VI) is readily absorbed from gastrointestinal tract and is able to penetrate cellular membranes (WHO, 1993). Since via the inhalation route, it is a carcinogen, the World Health Organization (WHO) placed a guideline value of 50 micrograms per liter on it. Therefore, the 7th-day water samples were tested for chromium(VI) by Chromium Hexavalent Extractant Method. According to WHO (1993), some studies had found aluminum to appear associated with the brain lesions characteristic of Alzheimer disease. Using the Eriochrome Cyanine R (ECR) method, this study also tested the level of Al(III) of the 7th-day samples in comparison with WHO recommendation of a concentration of aluminum of 100 to 200 micrograms per liter in drinking water. Although iron does not present a hazard to health, the taste and appearance of drinking water is usually affected below 2mg/L. Therefore, iron was also tested to observe whether the clay matrix of the ceramics was leaching materials.

The ceramic potteries are exposed to UVC light in two sealed containers that are made of plywood and lined on the inside walls with stainless steel plates of about 30-gauge thickness. One has the dimension of 31.5”x 11.75”x 9.5” and the other of dimension 32”x 11.75”x 8”. A rough diagram of the stainless steel container with pottery arrangement is shown on Diagram 1. Taller pieces of ceramics were placed in the larger box, while shorter ones were places in the other. Each container was held together by nothing but stainless steel nails. Two brass-hinges were attached to top of each box along the length of outer wall for easy access of the ceramic samples. The hinges were thus secured in place to avoid possible contamination after UV-exposure that otherwise may occur if placed inside the box. A 25W General Electric low-mercury germicidal bulb of 18 inches was attached to the ceiling of each stainless steel box. Each bulb received electrical power from ballast, of which one was made by Industrias Sola Basic in Mexico with 40W, 127V, and 60Hz; the other was a product of company, Advance, assembled in Mexico with a 40W, 120V, 60Hz capacity. The ballast could be purchased at any local hardware store.

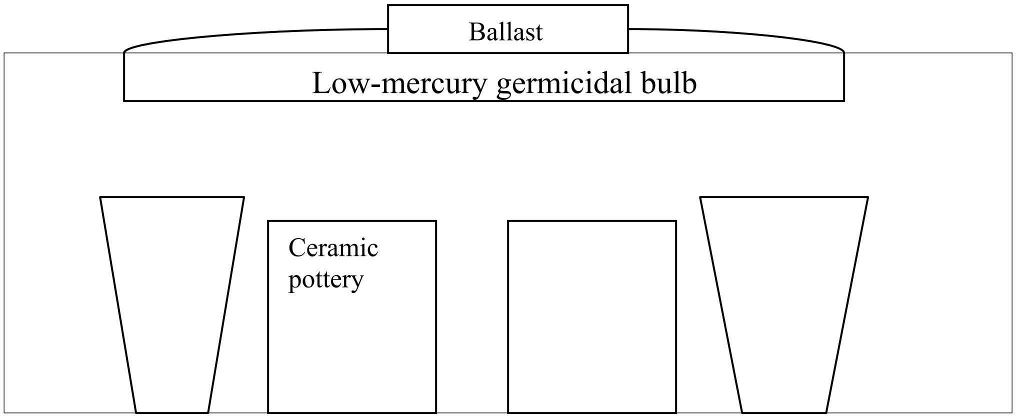
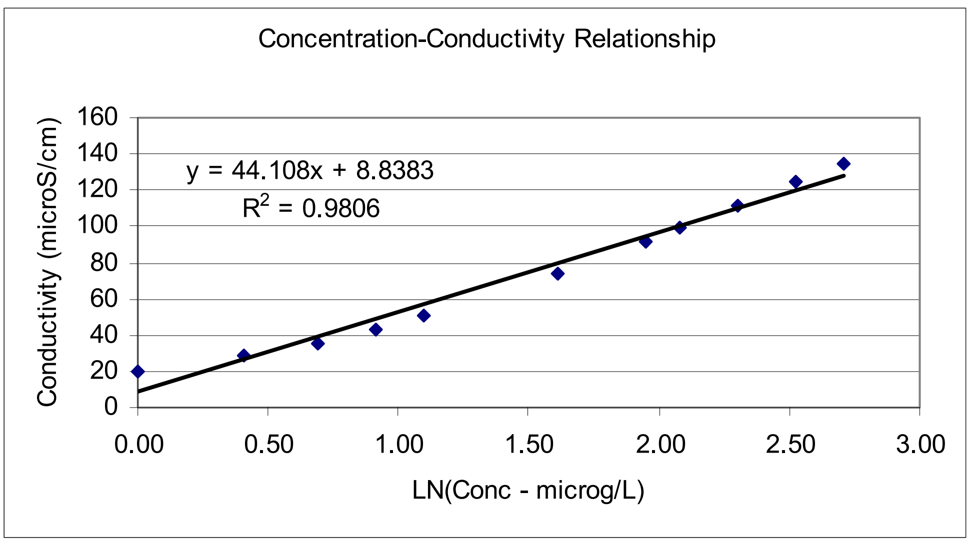


Diagram 1: The two stainless steel containers used resemble this diagram. The ceramic vessels were placed directly under the bulb along its length. The ballast was placed on top of the container.

The stainless steel boxes were washed with detergent to rid them of any oil-based residue and dust, and then cleaned with Nanopure water until no detergent remains. The box was completely air-dried before the experiment started. A stainless steel cup, purchased at a local hardware store, was cleaned and filled with 200 mL of the Nanopure water, and placed directly below the center of one UVC light bulb. Its surface area that will be exposed to the light was measured. Initial electrical conductivity and pH level of the water sample were measured and recorded. The stainless steel box was sealed before activating the UVC light to avoid seeing harmful rays. This 1-week study of stainless steel cup was done to ensure its stability. After seven days, the water sample was tested for conductivity, pH level as well as for several metals.

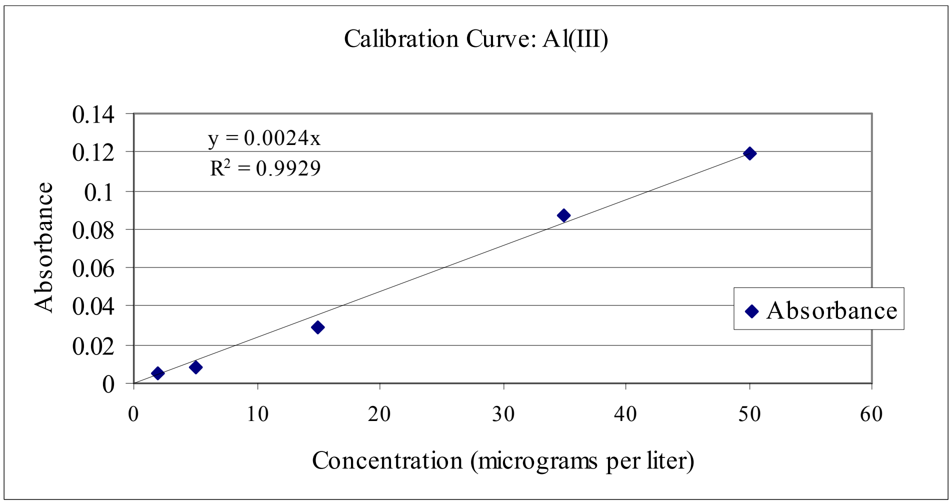
Before testing the ceramic vessels, they were rinsed with Nanopure water and let dry upside down (Mohamed et al., 1995). All eight ceramic vessels each with different volume of Nanopure water were placed directly below and along the length of the bulb, with four to each box. The initial electrical conductivity and pH level of all eight water samples were measured at day 0. The water volume was kept constant throughout the week of UV exposure to account for vaporization and same surface areas. The one-week study was done to ensure whether the level of ions leached out would decrease dramatically with successive extractions, as Spielholtz and Kaplan have found in their experiment on lead-leaching from pottery. Various factors, such as temperature and exposure time, could affect the leach ability of metals from glazed surface (Ajmal et al., 1997) and conductivity of the solution (Hach Company Manual of sensION7, pp. 23). In this study, the light bulb may raise the temperature inside the testing chamber. However, due to the fact that the ceramics are being tested for their suitability as UV disinfection chamber material, temperature is taken into consideration. Therefore, the temperature correction on the conductivity meter is not activated to simulate real-life usage of ceramics as an enclosed UV chamber.

To find the concentration of ions in the sample water, the measured conductivity levels were correlated with that of lead with a range of different known concentrations. The same was done for chromium, aluminum, and iron. Specifically, using Hach Lead Standard Solution, a known concentration of Pb would be added to a flask and its electrical conductivity taken. This process would be repeated for different concentrations of Pb solution. A lead calibration curve is created using spectrophotometer absorbance readings of known concentrations. The conductivity, natural log of concentration at micrograms per liter, and absorbance yields a linear relationship, as Graph 1 revealed. The lead concentration of water samples could be derived from the equation of the linear relationship.

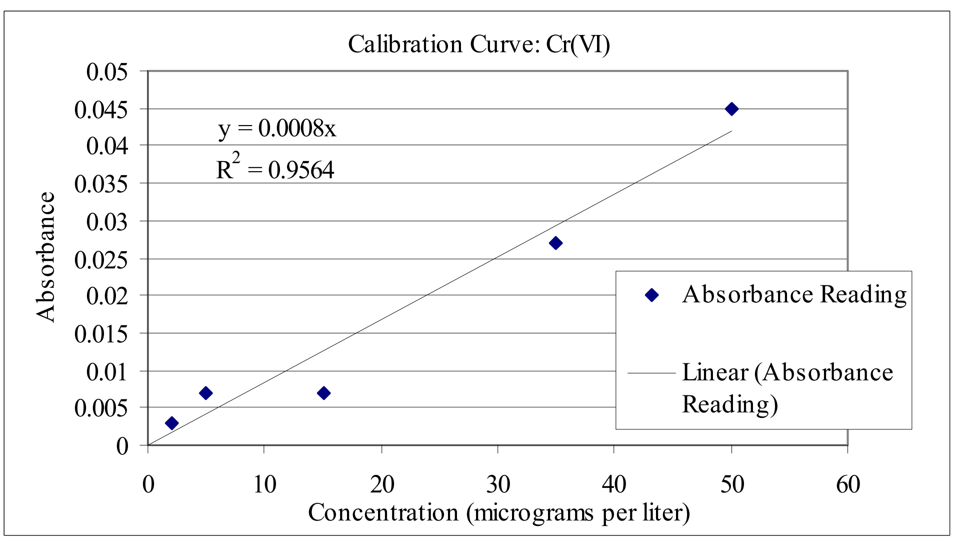


Graph 1: The correlation between conductivity and concentration of lead in water.

From the standard calibration, the concentrations could be calculated from this equation: e^((conductivity – 8.8383)/44.108). The conductivity levels of the known Pb-concentration samples were compared to that of water samples, so the concentration of ions in the samples from this correlation could be derived. If the concentration levels were above the World Health Organization (WHO) standard of heavy metals in drinking water (for lead, the limit is 10 micrograms per liter), then the samples would be placed in nitric-acid-washed polyethylene bottles for further examination of the possible presence of harmful heavy metal (lead) content using LeadTrak Fast Column Extraction Method, or Method 8317, established by the Environmental Protection Agency (EPA) for drinking water. The rate of leaching into the stagnant water was estimated with the range of testing period for each ceramic vessel. The concentrations of aluminum(III) and chromium(VI) in sample waters were measured indirectly from the absorbance reading (Graph 2 and Graph 3, respectively).



Graph 2: The correlation between concentration of aluminum(III) and its spectrometer absorbance is the standard calibration used to find the Al(III) concentrations in water samples.



Graph 3: The correlation between concentration of chromium(VI) and its spectrometer absorbance reading is the standard curve used to find the Cr(VI) concentrations in water samples.

Results

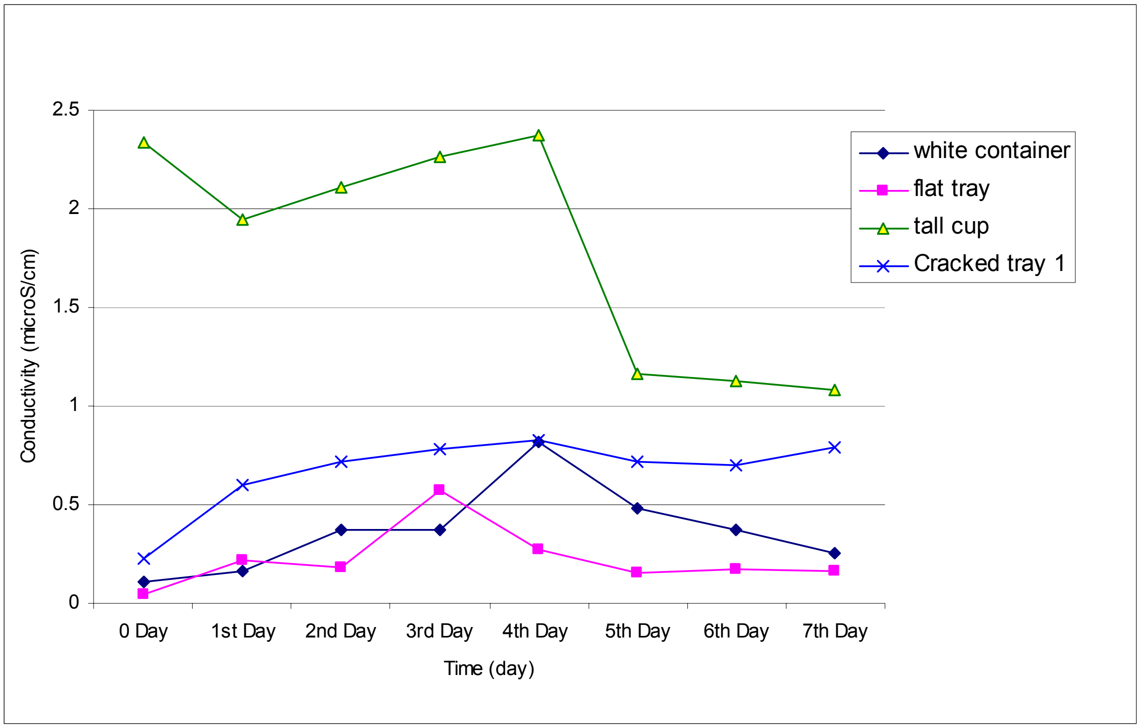
The water sample conductivity results for 1-week UVC exposure period are listed in Table 2 and Table 3, categorized according to the vessel descriptions and their glaze types. The values have been calculated with respect to surface area of each individual pottery piece. The initial conductivity reading for both types of glazed ceramics did not start out as zero. And while the Pb-glazed ceramics are thought to yield more conductive water samples, the non-Pb glazed ceramics on average is 0.59 microS/cm^3 more ionic than the other.

24Hr Period w/ UV		Conductivity per unit area (microS/cm^3)							
Ceramics	Pb	0 Day	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
white container	Pb	0.11	0.16	0.37	0.37	0.82	0.48	0.38	0.25
flat tray	Pb	0.05	0.22	0.18	0.57	0.27	0.16	0.18	0.17
tall cup	Pb	2.34	1.94	2.11	2.26	2.37	1.16	1.13	1.08
Cracked tray 1	Pb	0.23	0.60	0.72	0.78	0.83	0.72	0.70	0.79
Average =		0.68	0.73	0.85	1.00	1.07	0.63	0.60	0.57

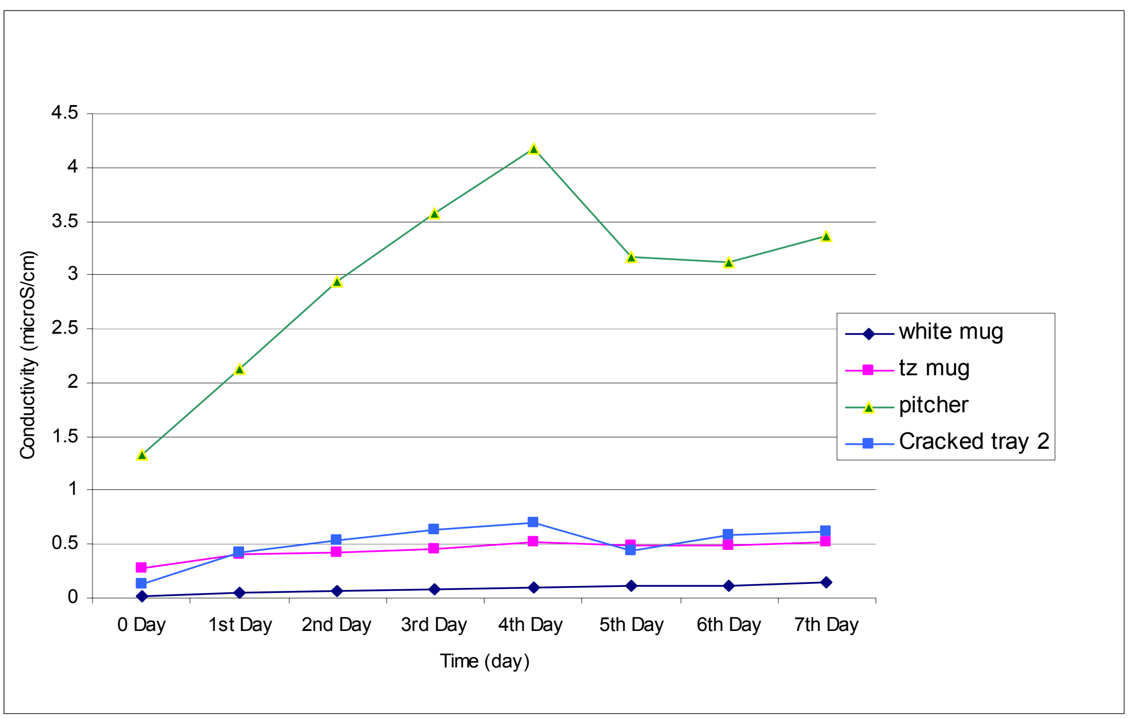
Table 2: The conductivity per unit area (microS/cm^3) for Pb-glazed ceramics over one-week period and their average.

24Hr Period w/ UV		Conductivity per unit area (microS/cm^3)							
Ceramics	Pb	0 Day	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
white mug	no Pb	0.02	0.05	0.07	0.08	0.10	0.11	0.11	0.14
tz mug	no Pb	0.28	0.40	0.42	0.46	0.51	0.48	0.49	0.53
pitcher	no Pb	1.33	2.13	2.93	3.58	4.18	3.17	3.12	3.36
Cracked tray 2	no Pb	0.13	0.42	0.54	0.63	0.69	0.43	0.58	0.62
Average =		0.44	0.75	0.99	1.19	1.37	1.05	1.07	1.16

Table 3: The conductivity per unit area (microS/cm^3) for NonPb-glazed ceramics over one-week period and their average.



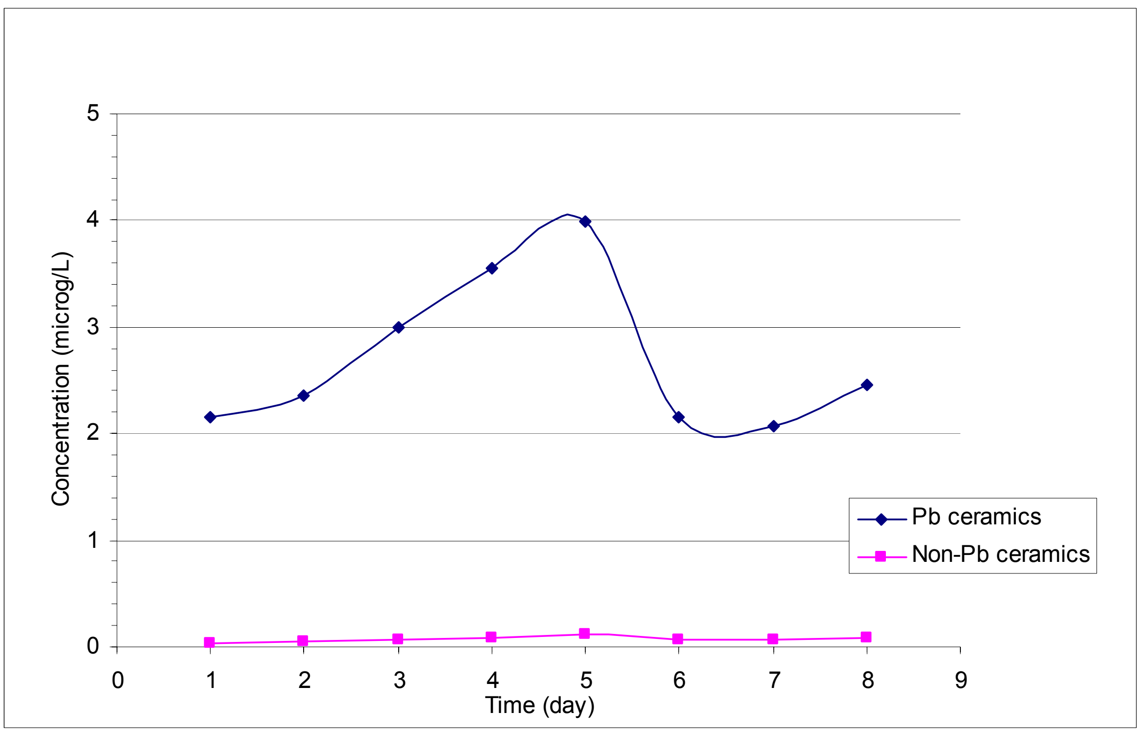
Graph 4: The conductivity per unit area (microS/cm^3) for lead-glazed ceramics over 1-week exposure period.



Graph 5: Conductivity per unit area (microS/cm^3) for non-lead ceramics over a week of exposure.

In comparison, the water in non-lead glazed ceramics fluctuates less and is less ionic than the lead-glazed ceramics (Graph 4 and Graph 5). Both glaze-types of broken trays yield the highest conductivity throughout the exposure period, with an initially high conductance as well. The non-lead coated ceramics have all slightly increased in conductivity, implying a decline in water quality. All data seem to peak near the middle of the exposure time and then decline to a much lower level of conductivity (Graph 4 and Graph 5). The pitcher (Graph 5) exhibits extreme conductivity compared to its non-lead ceramic counterparts. The possible reasons for its deviation are discussed in the following section.

The average calculated lead concentrations for lead and non-lead ceramics (Graph 6) are based on the calibration curve (Graph 1). Although the graph seems to show a major discrepancy between lead and non-lead ceramics, the concentrations are so small that the difference is considered statistically insignificant. Analysis by paired t-test yields a P-value of 0.2129.



Graph 6: Calculated lead concentration per unit area (micrograms/L/cm^3) of both types of ceramics over one week UV exposure.

Ceramics	Pb	Calculated Pb Concentration per unit area(microg/L/cm^2) 0 Day	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
white container	Pb	0.01	0.01	0.02	0.02	0.07	0.03	0.02	0.01
flat tray	Pb	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01
tall cup	Pb	7.07	4.92	5.75	6.62	7.33	2.39	2.32	2.21
Cracked tray 1	Pb	1.57	4.51	6.23	7.50	8.55	6.20	5.96	7.60
Average=		2.16	2.36	3.00	3.55	3.99	2.16	2.08	2.46
white mug	no Pb	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
tz mug	no Pb	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
pitcher	no Pb	0.07	0.11	0.17	0.24	0.33	0.19	0.18	0.21
Cracked tray 2	no Pb	0.01	0.03	0.04	0.06	0.07	0.03	0.05	0.06
Average=		0.03	0.04	0.06	0.08	0.11	0.07	0.07	0.08
SS cup	no Pb	0.87	0.89	0.92	0.93	0.98	0.99	1.00	1.02

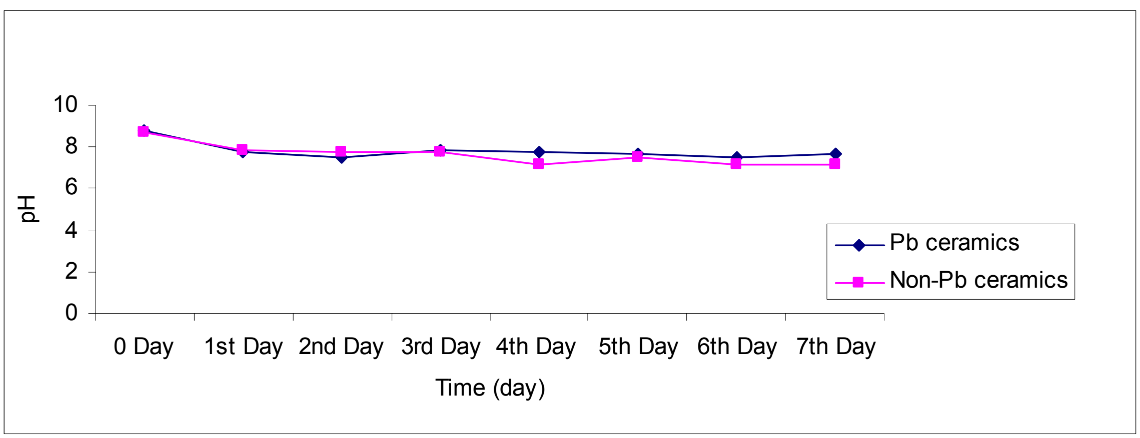
Table 4: Calculated Pb concentration per unit area for lead and non-lead ceramics as well as the stainless steel cup.

Since the conductivity does not reveal whether all the ions in the sample water are metals, it is assumed that the level detected is the maximum amount of metals that can occur in the water. Only when this number exceeds the World Health Organization (WHO) limit of 10 micrograms per liter for lead in drinking water should there be a rise in concern of water quality. The assumed lead concentrations per unit area for the 1-week period are calculated from the calibration curve and listed above (Table 4). The data seems trivial for major health concerns. However, the stainless steel cup, which was thought to be the sturdiest, was showing a fluctuation in conductivity and thus, the purity of its water was questionable (Table 4).

Pottery	Pb	ΔpH	Fe (mg/L)	Cr(VI) (microg/L)	Al(III) (microg/L)
white container	Pb	-1.47	0.06	0	0
flat tray	Pb	-1.5	0.32	2.5	0
tall cup	Pb	-2.59	0.23	1.25	0
Cracked tray 1	Pb	-2.25	0	0	0
white mug	no	-0.66	0	0	0
tz mug	no	-1.36	0	0	0
pitcher	no	-0.32	0.4	73.75	4.2
Cracked tray 2	no	-0.98	0.025	0	0
Stainless steel	no	-1.95	0	1.25	0

Table 5: the 7-day water samples yielded trace amount of measured metals. Only the pitcher exceeded the WHO recommendation of 50 micrograms per liter. Other ceramics were strong in their clay matrix.

After 7-day UVC exposure, the water samples were stored in polyethylene bottles overnight and tested for concentrations of lead, chromium(VI), aluminum(III), and iron via their specific methods (Table 5). Also included in Table 5 are the overall changes in pH values of all samples between day 0 and day 7. The average pH, however, did not fluctuate to a great extent throughout the seven-day period (Graph 7). The difference between pH value of lead and non-lead ceramics was insignificant.



Graph 7: A comparison of the average pH values of lead and non-lead ceramics over 7 days. The difference is insignificant.

Discussion

The fluctuating conductivity measurements of all samples, especially of the lead-glazed ceramics, imply change in water quality after the ceramic surface is exposed to UVC light. In this study, the difference between the lead and the non-lead ceramics is not statistically significant. However, the calculated concentrations of lead in all eight water samples fall under the WHO limit of 10 micrograms per liter of lead in drinking-water. After 7 days of UVC exposure, the water samples only contained trace amounts of iron, aluminum(III), and chromium(VI), of which none came close to the WHO limits except the non-lead pitcher that yielded 23.75 micrograms per liter over the limit. The results of this study show that overall pH of the samples decreased by an average of 1, an insignificant difference.

Studies have developed techniques for calculating concentrations of heavy metals by electrical conductivity method (Kayyal and Mohamed, 1997). This study tries to correlate conductivity of a water sample to the possible metals that might be present in the water inside a disinfection chamber. The ceramics and glaze, however, are made of many different forms of natural minerals and metals, including lead. A possible mixture of cations and other anions in the water samples might skew the conductivity readings. While this study was a preliminary look at whether ceramic glazes could withstand ultraviolet light, the main objective was to examine possible leachates from the ceramics. Conductivity, pH, and some direct concentrations of other metals could substantiate the assessment.

The non-lead pitcher yielded an abnormally high conductivity and thus, a high lead concentration, compared to the other non-lead ceramic vessels. Several possibilities could explain this ambiguity. The pitcher may very well be lead-glazed, since fired at low temperature, the lead and non-lead ones are not easy to differentiate, especially with painted decorations on them. Another reason is that the surface area reached by ultraviolet light is larger than expected, causing more deterioration of the ceramic walls than the rest. The pitcher may be porous, due to the lack of chemical bonding between clay and glaze, and thus introducing contaminants into the water.

The statistically insignificant result of lead concentration per unit area for all samples could indicate that there were no difference between lead and non-lead glazed potteries, so lead-glazed wares were safe to use chamber material. On the other hand, the result could simply imply that non-lead glazed wares were just as unreliable as the lead-glazed ones. However, since all the concentration levels obtained fell below the WHO limits, the lead ceramic glazes might strengthen their retention ability of metals under proper firing (Mohamed et al., 1995) and none would leach out. Furthermore, some of the ceramic vessels studied here were decorated with green compounds. Glazes from tableware should not be colored with copper compounds because of their ability to increase the lead solubility in the glaze (Hamilton, 1977). Studies have found that the amount of lead leached out decreased with each successive leaching (Mohamed et al., 1995). Thus, this study proposes that ceramics is a good candidate as chamber material; users need only to run the water through the chamber and exposed to ultraviolet light for a period of a week to two weeks before drinking from it so the leachates will be excreted.

A reduction of pH values between the initial and the final samples of all ceramic potteries might suggest that the cations were leaching into the waters faster than they could be neutralized. The remaining H^+ ions in solution would cause a reduction in pH (Kayyal and Mohamed, 1997). However, not all cations are hazardous metals. Therefore, a slight change in the pH of the samples has little significant denotation.

The broken trays were used to represent exposed clay parts that might appear when firing slightly cracks the ceramics during construction. The results, however, did not show any increase in conductivity or concentration amount of the metals tested. The release of lead from a glaze is an ion-exchange reaction (Mohamed et al., 1995). Therefore, less clay matrix exposed would restrict the degree of ion-exchange that might occur.

The lack of aluminum(III), iron(II) and chromium(VI) found in the 7-day samples was a indication of the rigidity of clay body. If contaminants did escape from the clay, they were in trace amounts. The iron(II) stayed at a level undetectable by taste under WHO recommendation. Except the finding of chromium(VI) in the pitcher, which required further examinations, the rest of the data were satisfactorily insignificant.

In Mexico, a total of 43% of all households lies below the poverty line in 1996, and rural area comprises of 53% of the total households below the poverty line (Agency for International Development, 1999). A 1995 survey done by the International Bank for Reconstruction and Development shows that 42.5% of Mexican population earns below $2 a day and 17% earns less then a dollar per day. While the other assemblages of UV water disinfection system may cost a bit more, the labor cost will not be relevant since the system is taught to and assembled by the individual. The present design of water disinfection system requires electricity for the ultraviolet light, but the availability of power in rural regions of Mexico is still uncertain.

Although the percentage of population with access to safe water and sanitation is considered high, with 83% and 66% respectively, in rural regions, only 26% of the population has access to sanitation from 1990 to 1996. Despite an improvement from the 15 percentile during 1982 to 1985, the number is still alarmingly small (International Bank for Reconstruction and Development, 2000). In urban areas, 91% of its population access to safe water (International Bank for Reconstruction and Development, 2000). Access to safe water during 1990 to 1996 (83% of population), compared to 1982-1985 (82% of population), has improved little. This figure further confirms the importance of inexpensive, clean water access, especially in the rural regions of Mexico, where half of all households lie below international poverty line.

Since the locals are accustomed to ceramic-making, they are expected to synthesize it into the water disinfection system more readily than with an unfamiliar material. This will make the disinfection system more adaptable and more readily acceptable to the rural residence. Insofar, the information makes the integration of ceramics into water disinfection system for rural Mexico plausible, but ceramics does have its ill effects.

A number of pervasive health problems such as discomfort in kidney region of back, respiratory infections, parasites, diarrhea, and seizures in children (Hibbert et al., 1999) have been associated with lead exposure. In villages, most homes serve both as dwellings and as pottery-making facilities, leading to high Pb levels in food, soil, and indoor atmosphere. The problem is especially heightened in children, who are more active and thus inhale larger portion of the lead content around the home. The pottery production process usually occurs in the presence of, and sometimes even with the help of, children (Hibbert et al., 1999). Contamination, however, can be prevented in several ways. To minimize exposure, workers can wear masks and gloves during pottery making and do so in a safe distance from children and food preparation area. A change in behavioral habits can also greatly reduce the exposure risk. As Hibbert et al. have observed, the pottery kilns sometimes serve as a source of heat and light for social gathering or mealtime, and a lack of running water and thus lack of regular hygiene exacerbates the exposure problem. Communication and public education is the key to prevention. Therefore, the author recommends implement of water disinfection system accompanied by education on ceramic production safety issues. Pottery production should slowly phase into using non-lead glazes for water disinfection chamber material. In the meantime, public education will be the key to minimize health risk in pottery-making villages. In the long run, a dramatic policy may be required to mitigate it.

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