KKU Journal for Public Health Research | วารสารวิจัยสาธารณสุขศาสตร์ มหาวิทยาลัยขอนแก่น
Vol.11 No.2 April – June 2018 | ปีที่ 10 ฉบับที่ 4 เดือน เมษายน – มิถุนายน 2561

Original Article

Effect of Environmental Factors on Water and Excreta Temperature in Pipes with Various Materials and Configurations

Patchareeya Jaipakdee[1], RittirongJunggoth[2], SomsakPitaksanurat[3], Anthony Charles Kuster[4], PuekTantriratna[2]

Received Date:
Accepted Date:

*(1) **Corresponding author:** Master of Public Health Student in Environmental Health, Faculty of Public Health Khon Kaen University (Tel.: 086-2484158, e-mail: patchajp1993@gmail.com)*
(2) Dr., Department of Environmental Health, Faculty of Public Health, Khon Kaen University
(3) Assistant Professor, Department of Environmental Health, Faculty of Public Health, Khon Kaen University
(4) International Staff, Faculty of Public Health, Khon Kaen University

Abstract

Introduction: Environmental Factors such as light intensity, ambient temperature, and humidity can affect to the thermophilic compostion of source-separated faces at temperatures >50°C for at least one week to ensure safe sanitation. (WHO; 2006) Thus, an experiment was devised to study how to achieve these sanitizing temperatures within the pipes of various materials, exposed to ambient environmental conditions in northeast Thailand.

Aims: 1) To compare the internal temperature of four experimental materials: PVC, iron, stainless steel and aluminum in a 3x2 experimental configuration: three pipe configurations- unpainted, painted black, and painted black with parabolic reflector and two media- water and excreta; 2) To study the relationship between environmental factors, including ambient temperature, light intensity, and humidity and the internal temperature of the media.

Methods: There were two experiments from July 2017 to January 2018. The first experiment used water as a media. The second experiment used excreta as a media. Each experiment had three groups of pipes, each group with four pipes of different materials. The four pipe materials were PVC, iron, stainless steel, and aluminum. The three groups used a different configuration: unpainted, painted black, and painted black with a parabolic reflector. Each pipe was 3 inches diameter, 1 meter in length, tilted 15 degrees towards the southern horizon, and placed at a height 0.65 meters off the ground. Solar parabolic troughs were made from aluminum sheets (1.2 x 1.52 m) using shape from Surawattanawan & Limboonrung (2011). The temperature in each experimental unit was measured every hour during the daytime (09.00 to 17.00) and ambient temperature, light intensity humidity and cloud cover were collected also.

Results: With water as a media, a maximum internal temperature at 80°C was found in iron painted black with a parabolic reflector, with an average temperature at 39.8±13.2 °C (mean±S.D.). The ambient air temperature had the highest correlation with the temperature of experimental units (r = 0.51 in unpainted aluminum) followed by light intensity (r=0.22 in unpainted PVC).

With human excreta as a media, a maximum temperature at 71°C was found in aluminum painted black with a parabolic reflector, with an average temperature at 44.40±7.03°C. Light intensity had highest correlation with temperature of experimental units (r=0.27 in aluminum with parabolic reflector) follow by ambient temperature (r=0.19 in iron with parabolic reflector).

Conclusion: Solar radiation can increase temperatures of water and excreta to levels that may inactivate very strong pathogens. Iron, aluminum, and stainless steel, painted black with the addition of a parabolic reflector, could achieve temperatures higher than 65 °C in sunny weather.

Keywords: *Human Excreta, Pipes, Solar Radiation*

Introduction

A large amount of pathogens are found in human excreta (Feachem et al., 1983). Pathogens are a serious concern for managers of water resources, because excessive amounts of fecal bacteria in sewage and urban runoff have been known to indicate an increased risk of pathogen-induced illness in humans (Kay et al. 1994, Fleisher et al. 1998, Haile et al. 1999). The extent to which pathogens decrease in numbers during storage depends on factors such as pH, moisture, temperature, nutrient availability, oxygen availability, ammonia concentration and UV exposure (Peasey 2000; Schönning & Stenström, 2004; WHO, 2006; Wichuk & McCartney, 2007; Austin & Cloete, 2008; Winker et al., 2009).

All pathogens have threshold temperatures beyond which their viability ceases (Madigan & Martinko, 2006). The mechanism of temperature inactivation differs for different types of pathogens. Elevated temperatures irreversibly inactivate enzymes of bacteria, protozoa and helminths, thereby resulting in cellular inactivation (Madigan & Martinko, 2006; Wichuk & McCartney, 2007). For viruses, thermal inactivation occurs as a result of damage to the viral structure through denaturation of viral surface proteins (Wichuk & McCartney, 2007). In areas with higher ambient temperatures (up to 35°C), a total storage period of one year will achieve the same result, as pathogen die-off is faster at higher temperatures (Schönning & Stenström, 2004; WHO, 2006; Strauss & Blumenthal, 1990). Whereas 18 months would be needed at lower temperatures (17-20 °C). However, longer survival times of 2-3 years have been reported for Ascaris at 22-37 °C (Moe & Izurieta, 2004). Vinnerås et al. (2007) reported that 50 days of storage of faecal matter at 20°C did not reduce *Enterococcus spp.* and at 4°C *Salmonella spp*. was not reduced either. Thus, at low temperatures prolonged storage times are needed to achieve sufficient sanitation of faeces. When temperatures above 50 °C are maintained for at least one week, pathogen inactivation is achieved according to Schönning & Stenström (2004) and WHO (2006). The higher the temperature in excess of 50 °C and the longer this temperature is maintained, the better the sanitation effect. High temperatures cause protein denaturation, leading to the destruction of cells (Madigan & Martinko, 2006). Ascaris lumbricoides ova and Candida albicans were effectively killed in aerobic composting of sewage sludge at 60-70°C within 3 days (Beauford & Westerberg, 1969). The most resistant Ascaris are inactivated in 1 hour at temperatures ≥62°C, in 1 day at ≥50°C, and in 1 week at ≥ 46 (Feachem et al., 1983). Similarly, where a temperature of >50°C was maintained for more than 4 days, E. coli decreased to below the detection limit but then sometimes reappeared later in the experiment.

Most literature on the sanitation of composts report temperatures in excess of

50-55℃ as sanitizing. The higher the temperature beyond the region of 50-55°C, the shorter the time of inactivation and vice versa. It must be noted that the sanitizing temperatures (>50-55 °C) should be attained by all of the particles in the compost matrix in order for the material to be safely sanitised. Schönning & Stenström (2004) and WHO (2006)
recommend thermophilic composting of source-separated faces at temperatures >50℃ for at least one week to ensure safe sanitation. In the United States of America, the compost is regarded as hygienically safe if a minimum of 55℃ is maintained for 3 consecutive days during composting in aerated static pile or in-vessel reactors, while for windrows, temperatures greater than 55 °C should be maintained for at least 15 days with a minimum of 5 turnings during the high temperature period (USEPA, 1999).

Thus, an experiment was devised to study how to achieve these sanitizing temperatures within pipes of various materials, exposed to ambient environmental conditions in northeast Thailand. The objectives of this study were to: 1) compare internal temperature of four experimental materials: PVC, iron, stainless steel and aluminum in a 3x2 experimental configuration: three pipe configurations - unpainted, painted black, and painted black with parabolic reflector and two media- water and excreta; 2) study of the relationship between environmental factors, including ambient temperature, light intensity, and humidity and the internal temperature of the media.

Purpose

To Study of the relationship between environmental factors: ambient temperature, light intensity and humidity affecting the temperature and compare internal temperature of 4 Experimental Materials: PVC Iron Stainless and Aluminum in 3 Experimental series: Unpainted painted black and parabolic with water and excreta as intermediate.

Method and materials

- **Study site**

This study was conducted at open space near by the wastewater treatment system in Khon Kaen University. (16°27’24.45”N 102°48’56.20”E)

- **Experimental design**

There were two experiments. The first experiment used water as a media (from July 18, 2017 to August 22, 2017). The second experiment used excreta as a media (November 6, 2017 to January 17, 2018). Each experiment had three groups of pipes, each group with four pipes of different materials. The four pipe materials were PVC, iron, stainless steel, and aluminum. The three groups used a different configuration: unpainted, painted black, and painted black with a parabolic reflector, as shown in Figure 1a-c. Each pipe was 3 inches in diameter, 1 meter in length, tilted 15 degrees towards the southern horizon, placed at a height 0.65 meters off the ground. The experiment group of painted black were painted black with aerosol paint spray matted. The experiment group of painted black with a parabolic reflector were made from aluminum sheets (1.2 x 1.52 m) using shape from Surawattanawan & Limboonrung (2011). Pipes were also painted black with aerosol paint spray matted.

- **Data collection**

Ambient air temperature and relative humidity were collected using Thermo Hygrometer; light intensity was collected using Heavy Duty Light Meter with PC Interface 407026; and internal temperature in each experimental unit was recorded using a thermometer. Each pipe was measured 3 sections, which is bottom, middle and top. (All data were collected every hour during day time (09.00 to 17.00).

- **Statistical analysis**

Descriptive statistics include the minimum-maximum, mean, standard deviation frequency and proportion of ambient temperature, light intensity, humidity, and temperature, were computed in Microsoft Excel. The Pearson Correlation coefficient was computed between each environmental factor and the internal temperature independently. Differences among internal temperature in each pipe material were tested for statistical significance using Kruskal-Wallis ANOVA (non-parametric test) because the assumption of normality was met using significance level of 0.05 with STATA 10 software.

Results

- **Ambient environmental conditions**

Environmental conditions among the two experiments (using water and using excreta) were similar, as shown in Table 1. Ambient air temperatures generally ranged from 22 to 48°C in both experiments. Light intensity was slightly higher in the water experiment, with a much higher maximum. However, these high values were outliers. Humidity was also low during the excreta experiment, which is expected, since this experiment was conducted during raining season (July-August) and dry season (September-January)

- **Comparison of Internal temperatures among materials**

In experiment 1, using water as a media, iron painted black with the parabolic reflector had the highest internal temperature (mean 39.8°C), followed by stainless steel (38.8°C), aluminum (38.6°C), and PVC (36.6°C). Results are shown in Table 2a. Iron pipes also had the highest intneral temperatures for painted black and unpainted. In general, Iron > Stainless Steel > Aluminum > PVC. And Parabolic > Painted Black > Unpainted.

In experiment 2, using excreta as a media, the internal temperatures were higher than water, as shown in Table 2b. Aluminum with the parabolic reflector had the highest internal temperature (mean 44.4°C), followed by iron (42.8°C), stainless steel (42.1°C), and PVC (41.3°C). Similarly, painted black was higher than unpainted. However, in unpainted pipes, iron was notably higher in temperature than stainless steel and aluminum.

- **Correlation of environmental factors to internal temperature**

In experiment 1, using water as a media, ambient air temperature correlated the most with internal temperature of unpainted pipes among all materials at a moderate level (Pearson's r=0.041 in iron and 0.51 in aluminum), as shown in Table 3a. Correlations were similar among the painted and parabolic configurations (Tables 3b and 3c).

On the other hand, in experiment 2, using excreta as a media, light intensity correlated the most with internal temperature of pipes, but at a weak level (Pearson's r= 0.05 in PVC to 0.19 in iron). Correlations were similar among painted and parabolic configurations (Tables 3b and 3c).

- **Testing differences in temperature among pipes**

The different materials had statistically different internal temperatures ($p<0.001$) for all experiments (unpainted, painted, parabolic and water and excreta). Test statistics and p-values are reported in Tables 2a and 2b.

Discussion

It should be noted that excreta achieved higher temperatures than water. While the two medias were tested at different times (during raining season and dry season) and thus had different environmental conditions, the air temperature and light intensity were similar during the two experiments. Therefore, this result may be because excreta absorbs more solar radiation and retains more heat with its solids, compared to water.

Another observation is that aluminum had a higher temperature for excreta compared to iron, which was the opposite for water. Therefore, when choosing a pipe material where the goal is to increase temperature, it is important to choose the material based on the media inside the pipe. Additionally, comparisons among pipes were similar (e.g., iron was consistently higher than aluminum in all water experiments). However, with excreta, one outlier existed. For unpainted pipes, iron was hotter than aluminum in excreta. Whereas, aluminum was hotter than iron for painted configurations. This result is likely because iron, unpainted, is darker in color than the other materials. Therefore, color of the pipe, as demonstrated among painting and different materials, is very important in achieving solar absorbance.

The temperature was increased by the conduction process in which heat energy is transmitted through collisions between neighboring atoms or molecules. Conduction occurs more readily in solids and liquids, where the particles are closer together (UCAR, 2019). The painted black with a parabolic reflector as a line focus collector can achieve the highest temperature (higher than 65 °C) which using shape from Surawattanawan & Limboonrung (2011) that can achieve the highest temperature approximately 60°C. Similarly to a study of the factors that affect the efficiency of hot water systems by Padakan & Radagan (2010) which control water flow rate at 0.0083 can increase the temperature to 78°C. All things considered, that the painted black with a parabolic reflector can increase the temperature over 60°C.

The temperatures achieved inside the pipe likely could achieve some level of pathogen inactivation. *Ascaris lumbricoides ova* and *Candida albicans* were effectively killed in aerobic composting of sewage sludge at 60-70°C within 3 days. (Beauford & Westerberg, 1969) The most resistant Ascaris are 1 hour at ≧62°C, 1 day at ≥ 50 °C, and 1 week at ≧46 (Feachem et al., 1983) where a temperature of >50°C was maintained for more than 4 days, E. coli decreased to below the detection limit but then sometimes reappeared later in the experiment. At higher temperatures pathogen die-off is faster. Temperatures greater than these thresholds were achieved. However, it should be noted that the excreta was not moving through the pipes in the experiment. Thus, it would be important to maintain the excreta in contact with solar radiation for long periods of time to achieve the temperatures found in this experiment.

There are some differences between water intermediate and human excreta intermediate because human excreta had sludge to higher thermal capacity (Houdkova et al., 2007). The degree of thermal inactivation of pathogens is a function of both the temperature and time of exposure (Feachem et al., 1983; de Bertoldi, 1998; Wichuk & McCartney, 2007). Several authors have studied the temperature-time relationships that result in a safely sanitized compost.

Conclusion

Solar radiation can increase temperatures of water and excreta to levels that may inactivate very strong pathogens. Iron, aluminum, and stainless steel, painted black with the addition of a parabolic reflector, could achieve temperatures higher than 65°C. PVC pipe material had much lower temperatures than the metals. Holding excreta in painted black with a parabolic reflector may be a way to inactivate pathogens found in human excreta.

Acknolwedgements

This research is funded by the project of the sanitation system to eliminate infected liver under Fluke Free Thailand, many thanks to Professor Thidarut Boonmars and committee. Thank you also to faculty at the Department of Environmental Health

Occupational Health and Safety, at the Faculty of Public Health of Khon Kaen University. Also, thanks to Environmental Health Branch Senior Public Health Khonkaen University that makes this study so well done, thank you.

References

Austin, L. M., & Cloete, T. E. (2008). Safety aspects of handling and using fecal material from urine-diversion toilets: A field investigation. **Water Environment Research, 80**(4), 308-315.

Beauford, B. W., & Westerberg, S. C. (1969). Survival of human pathogens in composted sewage. **Applied Microbiology, 18**, 994-1001.

de Bertoldi, M. (1998). Composting in the European Union. **BioCycle, 39**, 74-75.

Echaubard, P., León, T., Suwanatrai, K., Chaiyos, J., Kim, C. S., Mallory, F. F., et al. (2017). Experimental and modelling investigations of Opisthorchis viverrini miracidia transmission over time and across temperatures: Implications for control. **International Journal for Parasitology, 47**(5), 257-70.

Feachem, R. G., Bradley, D. J., Garelick, H., & Mara, D. D. (1983). **Sanitation and disease: Health aspects of excreta and wastewater management, World Bank studies in water supply and sanitation.** New York: John Wiley and Sons.

Fleisher, J. M., Kay, D., Wyer D., & Godfree, A. F. (1998). Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage. **International Journal of Epidemiology, 27**, 722-726.

Gantzer, C., Gaspard, P., Galvez, L., Huyard, A., Dumouthier, N., & Schwartzbrod, J. (2001). Monitoring of bacterial and parasitological contamination during various treatment of sludge. **Water Research, 35**(16), 3763-3770.

Haile, R. W., Witte, J. S., Gold, M., Cressey, R., McGee, C., Millikan, R. C., et al. (1999). The health effects of swimming in ocean water contaminated by storm drain runoff. **Epidemiology, 10**, 355-363.

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1998). **Applied statistics for the behavioral sciences** (4th ed.). Boston: Houghton Mifflin.

Kay, D., Fleisher, J. M., Godfree, A. F., Jones, F., Salmon, R. L., Shore, R., et al. (1994). Predicting likelihood of gastroenteritis from sea bathing: Results from randomized exposure. **Lancet, 344**, 905-909

Houdkova, L., Boran, J., Elsäßer, T., & Stehlik, P. (2007). Importance of experimental measurements and simulations for “sludge-to-energy” systems. **Computational Methods and Experimental Measurements XIII**, 465-474.

Madigan, T. M., & Martinko, M. J. (2006). **Brock biology of microorganisms.** 11th ed. Upper Saddle River, NJ: Pearson Prentice-Hall.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. **Journal of Water and Health,** (Suppl 04), 41-57.

Morishita, K., Komiya, Y., & Matsubayshi, H. (1972). **Process of medical parasitology in Japan.** Tokyo: Megureo Paraitological Museum.

Niwagaba, C. B. (2009). **Treatment technologies for human faeces and urine**. Retrieved October 25, 2017, from http://pub.epsilon.slu.se/2177/1/niwagaba_c_091123.pdf

Peasey, A. (2000). **Health aspects of dry sanitation with waste reuse.** Leicestershire, UK: Loughborough University.

Surawattanawan, P., & Limboonrung, T. (2011) **Mathematical modeling and the design of solar parabolic trough.** Retrieved October 25, 2017, from http://www.acat.or.th/download/acat_or_th/journal-16/16%20-%2012.pdf

Padakan, R., & Radagan, S. (2010). A study of the factors that affect the efficiency of hot water systems. **Engineering Journal Kasetsart, 22**(70), 96-109.

Schönning, C., Stenström, T. A. (2004). **Guidelines for the safe use of urine and faeces in ecological sanitation.** Sweden: Stockholm Environment Institute.

Shuval, H. I., Gunnerson, C. G., & Julins, D. S. (1981). **Night–soil composting: Propriate technology for water supply and sanitation volume 10.** Washington, DC: World Bank.

Strauss, M., & Blumenthal, U. J. (1990). **Human waste in agriculture and aquaculture: Utilization practices and health perspectives.** Switzerland: International Reference Center for Waste Disposal.

USEPA. (1999). **Control of pathogens and vector attraction in sewage sludge.** Cincinnati, OH: United States Environmental Protection Agency, Office of Research and Development, National Risk Management Laboratory, Center for environmental Research Information,

University of Corporation for Atmosheric Research [UCAR]. 2019. **Conduction.** Retrieved June 18, 2019, from https://scied.ucar.edu/conduction

Vinnerås, B., & Jönsson, H. (2007). **Handling systems for reuse of urine and faecal matter from urban areas.** Sweden: Department of Agricultural Engineering, Sveriges Lantbruksuniversitet.

World Health Organization [WHO]. (2016). **Soil-transmitted helminth infection.** Retrieved October 25, 2017, from http://www.who.int/mediacentre/factsheets/fs366/en/

World Health Organization [WHO]. (2006). **Guidelines for the safe use of wastewater, excreta and greywater: Volume 4, excreta and greywater use in agriculture.** Geneva: The Organization.

World Health Organization [WHO]. (2002). **Sanitation.** Retrieved October 25, 2017, from http://www.who.int/water_sanitation_health/hygiene/emergencies/em2002chap8.pdf

Wichuk, K. M., & McCartney, D. (2007). A review of the effectiveness of current time temperature regulations on pathogen inactivation during composting. **Journal of Environmental Engineering Science, 6**, 573-586.

Winker, M., Vinnerås, B., Muskolus, A., Arnold, U., & Clemens, J. (2009). Fertiliser products from new sanitation systems**: Their potential values and risks. Bioresource Technology, 100**(18), 4090-4096.

Table 1 Ambient Environmental Conditions

	Water	Excreta
Air temperature		
Mean (S.D.)	34.3±6.4	32.3±4.5
Min-Max	22-48	22-48.4
Humidity		
Mean (S.D.)	64.6±22.2	43.7±13.7
Min-Max	24.7-99.8	14-70
Light intensity (LUX)		
Mean (S.D.)	7,812.2±5,497.2	6,960.3±2,559.2
Min-Max	1,044-34,300	1,340–15,500

Table 2a Comparing of temperatures of experimental series with 4 experimental materials: PVC, Iron, stainless and aluminum water intermediate

	PVC	Iron	Stainless	Aluminum	x^2	*p-value*
Unpainted					160.111	0.0001
Mean (S.D.)	32.4±5.9	34.8±7.6	33.3±6.3	32.4±5.5		
Min-Max	22-45	22-53	22-46	22-45		
Hours accumulate of temp. above 45˚C	2	14	4	2		
% Hours accumulate of temp. above 45˚C	1.5	10.8	3.1	1.5		
Painted black					22.512	0.0001
Mean (S.D.)	34.4±7.2	35.1±7.5	35±7.3	34.8±7.4		
Min-Max	22-53	22-53	22-51	22-53		
Hours accumulate of temp. above 45 ˚C	10	15	11	11		
% Hours accumulate of temp. above 45˚C	7.7	11.5	8.5	8.5		
Parabolic					36.566	0.0001
Mean (S.D.)	36.6±9.7	39.8±13.2	38.8±12.1	38.6±12		
Min-Max	22-59	22-80	22-72.5	22-74		
Hours accumulate of temp. above 45 ˚C	22	29	26	24		
% Hours accumulate of temp. above 45˚C	16.9	22.3	20	18.5		

Table 2b Comparing of temperatures of experimental series with 4 experimental materials: PVC, Iron, stainless and aluminum with excreta intermediate

	PVC	Iron	Stainless	Aluminum	x^2	*p-value*
Unpainted					100.56	0.0001
Mean (S.D.)	37.0±3.9	41.4±4.6	38.1±4.9	36.4±4.6		
Min-Max	22-49	24-60	24-56	20-53		
Hours accumulate of temp. above 45 ˚C	21	127	33	17		
% Hours accumulate of temp. above 45˚C	6.7	40.4	10.5	5.4		
Painted black					20.526	0.0001
Mean (S.D.)	40.5±3.9	41.9±4	41.6±5.4	42.6±6.0		
Min-Max	24-58	25-60	23-56	25-59		

Table 2b Comparing of temperatures of experimental series with 4 experimental materials: PVC, Iron, stainless and aluminum with excreta intermediate (cont.)

	PVC	Iron	Stainless	Aluminum	χ^2	*p-value*
Hours accumulate of temp. above 45 °C	76	127	103	128		
% Hours accumulate of temp. above 45 °C	24.2	40.4	32.8	40.8		
Parabolic					32.435	0.0001
Mean (S.D.)	41.3±5.4	42.8±5.2	42.1±4.9	44.4±7.0		
Min-Max	25-65	27-71	24-69	25.5-71		
Hours accumulate of temp. above 45 °C	95	135	133	154		
% Hours accumulate of temp. above 45 °C	30.3	43	42.4	49		

Table 3a Correlation coefficient (r) of unpainted experimental series

	PVC		Iron		Stainless		Aluminum	
	Water	Excreta	Water	Excreta	Water	Excreta	Water	Excreta
ambient temperature	0.4169**	0.0971	0.4061**	0.1402	0.4645**	0.0525	0.5112***	0.0992
light intensity	0.2254	0.0450	0.1652	0.1862	0.2055	0.0983	0.1625	0.0111
humidity	-0.0463	-0.0119	-0.0530	-0.0643	-0.0389	-0.0523	-0.0032	-0.0020

***0.50 to 0.70 (-0.50 to -0.70) Moderate correlation
**0.30 to 0.50 (-0.30 to -0.50) Low correlation
0.00 to 0.30 (0.00 to -0.30) Little if any correlation

Table 3b Correlation coefficient (r) of painted black experimental series

	PVC		Iron		Stainless		Aluminum	
	Water	Excreta	Water	Excreta	Water	Excreta	Water	Excreta
ambient temperature	0.4552**	0.0919	0.4010**	0.1546	0.4066**	0.1764	0.4154**	0.1396
light intensity	0.1712	0.2499	0.1230	0.0688	0.0971	0.1420	0.1357	0.1430
humidity	-0.0164	-0.0605	-0.0450	-0.0219	-0.0640	-0.0326	-0.0785	0.0673

***0.50 to 0.70 (-0.50 to -0.70) Moderate correlation
**0.30 to 0.50 (-0.30 to -0.50) Low correlation
0.00 to 0.30 (0.00 to -0.30) Little if any correlation

Table 3c Correlation coefficient (r) of parabolic experimental series

	PVC		Iron		Stainless		Aluminum	
	Water	Excreta	Water	Excreta	Water	Excreta	Water	Excreta
ambient temperature	0.4249**	0.0680	0.2978*	0.1856	0.3248**	0.0627	0.3560**	0.0066
light intensity	0.1371	0.2312	0.1034	0.2124	0.0831	0.2053	0.0860	0.2738
humidity	-0.1027	0.1487	-0.0037	0.1480	-0.0283	0.1625	-0.0515	0.1396

***0.50 to 0.70 (-0.50 to -0.70) Moderate correlation
**0.30 to 0.50 (-0.30 to -0.50) Low correlation
0.00 to 0.30 (0.00 to -0.30) Little if any correlation

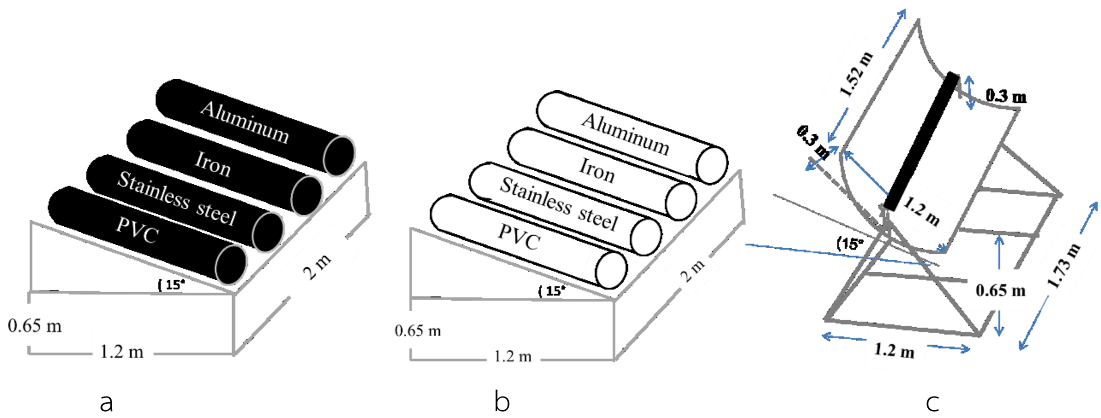

Figure 1 Experimental series: a) Unpainted, b) painted black and c) painted black with a parabolic reflector (Adapted from Surawattanawan & Limboonrung, 2011)