

V-shaped Pits in Regions of Ancient Baekje Kingdom Paleoparasitologically Confirmed as Likely Human-Waste Reservoirs

Dong Hoon Shin¹, Sang-Yuck Shim², Myeung Ju Kim³, Chang Seok Oh¹, Mi-Hyun Lee², Suk Bae Jung⁴,
Geon Il Lee⁴, Jong-Yil Chai⁵, Min Seo^{6,*}

¹Bioanthropology and Paleopathology Lab, Institute of Forensic Science, Seoul National University College of Medicine, Seoul 110-799, Korea;

²Buyeo Cultural Heritage Center, Buyeo-gun, Chungcheongnam-do 323-802, Korea; ³Department of Anatomy, Dankook University, Cheonan 330-715, Korea; ⁴Korea National University of Cultural Heritage, Buyeo-gun, Chungcheongnam-do 323-812, Korea; ⁵Department of Parasitology and Tropical Medicine, Seoul National University College of Medicine, Seoul 110-799, Korea; ⁶Department of Parasitology and Research Center for Mummy, Dankook University, Cheonan 330-715, Korea

Abstract: In a paleo-parasitological analysis of soil samples obtained from V-shaped pits dating to the ancient Baekje period in Korean history, we discovered *Ascaris lumbricoides*, *Trichuris trichiura*, and *Clonorchis sinensis* eggs. In light of the samples' seriously contaminated state, the V-shaped pits might have served as toilets, cesspits, or dung heaps. For a long period of time, researchers scouring archaeological sites in Korea have had difficulties locating such structures. In this context then, the present report is unique because similar kind of the ancient ruins must become an ideal resource for successful sampling in our forthcoming paleoparasitological studies.

Key words: *Ascaris lumbricoides*, *Trichuris trichiura*, *Clonorchis sinensis*, helminth egg, paleoparasitology, Baekje Kingdom, V-shaped pit

Effective disposal of human waste undoubtedly was instrumental to the maintenance of public health in pre-modern towns and cities. Archaeologists have shown how in the English city of York, structures such as stone-built sewers were integral to that function [1]. Presumably, effective night-soil disposal also was a top priority for contemporaneous East Asian urban dwellers [2,3]. Whereas ancient-parasite-egg contamination of soil samples taken from sewer- or toilet-like structures might be the effect of some sort of simple diffusion from outside areas, it is actually more probable that those structures had in fact been cesspits or toilets.

In fact, the remnants of some East Asian cesspits already investigated have been confirmed, by the presence of helminth eggs in soil samples, as having been used as human-waste reservoirs [4]. In East Asian agrarian societies, fertilizer in the form of night soils periodically carted away from urban sites to surrounding farms was widely used [2-4]. In the case of Korea

though, there are very few reports on historical structures that could be conjectured to have seen use as toilets or cesspits. This makes information on the sanitary status of pre-modern Korean cities particularly difficult to obtain.

Finally however, in 2004, Korean researchers located presumptive toilet structures amid the royal palace ruins of the ancient Baekje Kingdom (18 BCE-660 CE) (the *Wanggung-ri* site), from which structures they obtained soil samples found to contain a significant number of ancient helminth eggs (Fig. 1) [5]. This discovery has served to intensify the academic controversy surrounding the identification of toilets and cesspits and their probable uses in historical Korean towns and cities. In any case, it is certain that structures confirmed to have been cesspits and toilets undoubtedly will prove, and are proving to be, ideal resources for paleoparasitological studies [6]. In this light, it is expected that our current cases also will be meaningful to Korean paleoparasitologists and their investigations.

In a recent archaeological study on Buyeo, the capital of the ancient Baekje Kingdom, we found candidate cesspit and toilet ruins that yielded many soil-transmitted helminth eggs. We believe that our investigation likely will prove to be significantly revelatory on the use and maintenance of toilets and cesspits in ancient Korean towns or cities. On that basis, we

•Received 9 January 2014, revised 14 July 2014, accepted 16 August 2014.

*Corresponding author (bbbenji@naver.com)

© 2014, Korean Society for Parasitology and Tropical Medicine

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

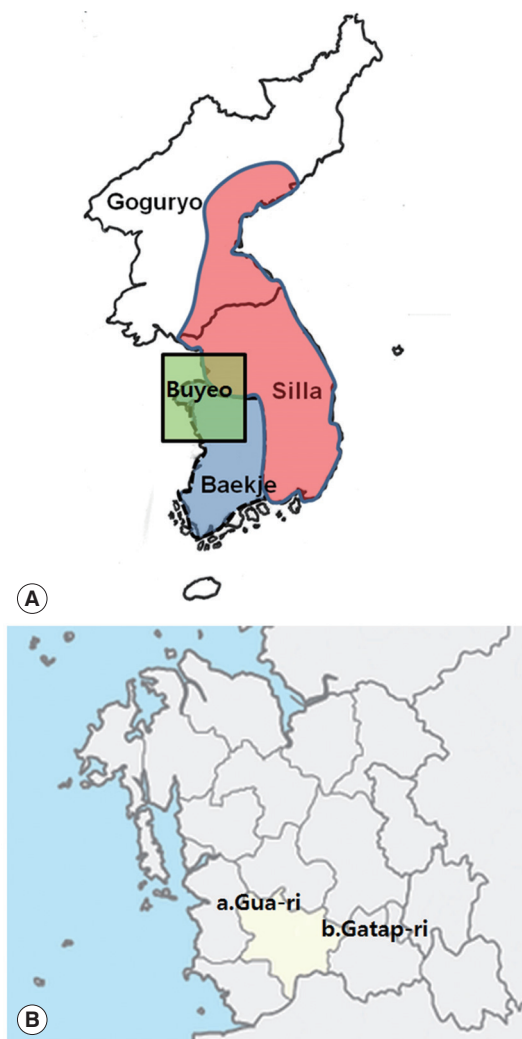


Fig. 1. (A) Ancient Korean kingdoms (Goguryo, Silla, and Baekje). (B) Magnified image of green rectangle area. a, Gua-ri; b, Gatap-ri. In both sites of 'a' and 'b', the toilets or cesspits could be identified by paleoparasitological examinations.

will report herewith.

The soil samples ($n=57$) examined in this paleoparasitological study were collected from geological strata at archaeological sites (Gua-ri 319 and Gatap-ri, Dusireoggol remains) in Buyeo, the capital of the ancient Baekje Kingdom (Fig. 1). The strata were dated to the Sabi period (6th-7th century CE). At this time, Gua-ri 319 was centrally located in a residential area of Buyeo marked by puddles and ditches. Owing to the low and moist topography there, many wooden relics could be excavated. At Gatap-ri, the Dusireoggol remains, remnants of residential areas, roads, and water-catchment facilities were excavated (Fig. 2). The number of eggs per g of feces (EPG) was calculated by multiplying 10 times to the average number of

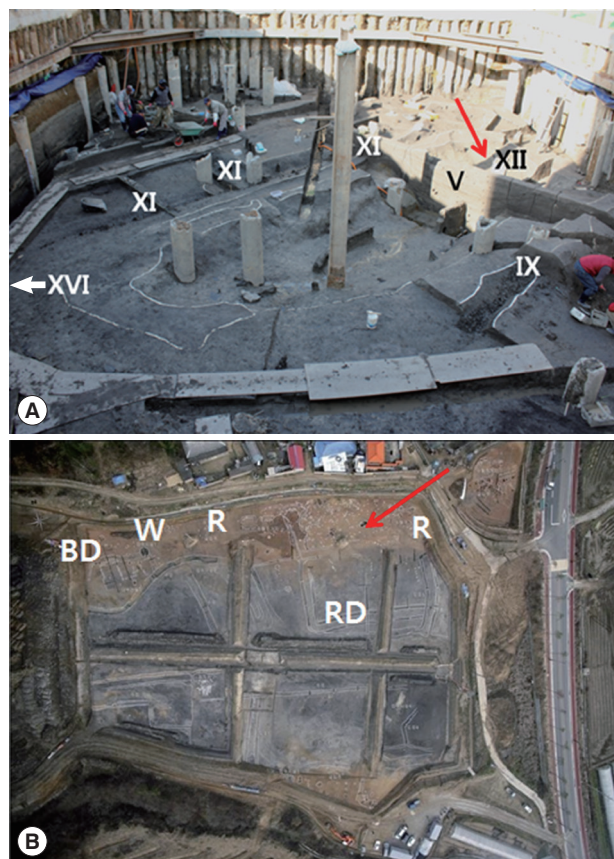


Fig. 2. (A) A photograph of Gua-ri 319 remains. Helminth eggs were recovered from the construct XII (arrow). (B) An aerial photograph on the Dusireoggol remains, Gatap-ri. BD, building; R, residential area; W, water collecting facility; RD, road. The helminth eggs were recovered from the construct suspected as the toilet (arrow).

eggs counted in soil samples considering that 10 g of soils were dissolved in 20 ml of 0.5% trisodium phosphate solution per each sample. An overall data summary is provided in Table 1.

At Gua-ri 319, we collected samples ($n=56$) at 5 different points, some of which were inside of a V-shaped pit. At Gatap-ri, only 1 sample was obtained from a V-shaped pit. The samples were taken using conical tubes (Falcon Plastics, Los Angeles, California, USA) driven into the soil strata. Surface-soil samples for use as negative controls also were taken.

Back at our laboratory, a contamination-minimization protocol entailing the wearing sterilized gloves, head caps, and masks was followed. The samples were re-hydrated in 0.5% trisodium phosphate solution [7,8] and observed in 10 μ l quantities 20 times (total per sample: 200 μ l) under light-microscopy (Olympus, Tokyo, Japan). Egg-size measurements were taken from 10 eggs, and the number of helminth eggs per

gram (EPG) was estimated. Since 10 g of soil was dissolved in 20 ml of 0.5% trisodium phosphate solution per sample, the EPG was calculated by dividing the average number of eggs counted in each sample by 10.

Table 1. V-shaped pit examined by paleoparasitological technique

Sites	Excavated by	Period	Area in sites	Number of Samples
Gua-ri 319	Buyeo Cultural Heritage Center	Baekje	XII (V-shaped pit)	14
			XI	11
			XVI	13
			V	6
			IX	12
Gatap-ri	Korea National University of Cultural Heritage	Baekje	V-shaped pit	1
Total				57

Among the Gua-ri 319 samples, eggs were found only in those taken from the V-shaped pit (area XII; no eggs were found in areas XI, XVI, V, or IX). Their morphologies and sizes, typical of *Ascaris lumbricoides*, *Trichuris trichiura*, and *Clonorchis sinensis*, respectively, identified them as such. Significantly, the egg-bearing samples representing the Gatap-ri site, in the same Buyeo area, also were obtained from a V-shaped pit, and the species were the same; *A. lumbricoides*, *T. trichiura*, and *C. sinensis* (Fig. 3). The average egg dimensions and EPG for each site’s samples are summarized in Table 2.

A previous series of paleoparasitological studies showed how historical high-population-density towns and cities in East Asia removed human waste. For each spatial and temporal span of historical development, the pattern of night-soil removal appeared to differ [2,3,5]. In another study, paleoparasitologists investigating the Neolithic Jomon period in Japan

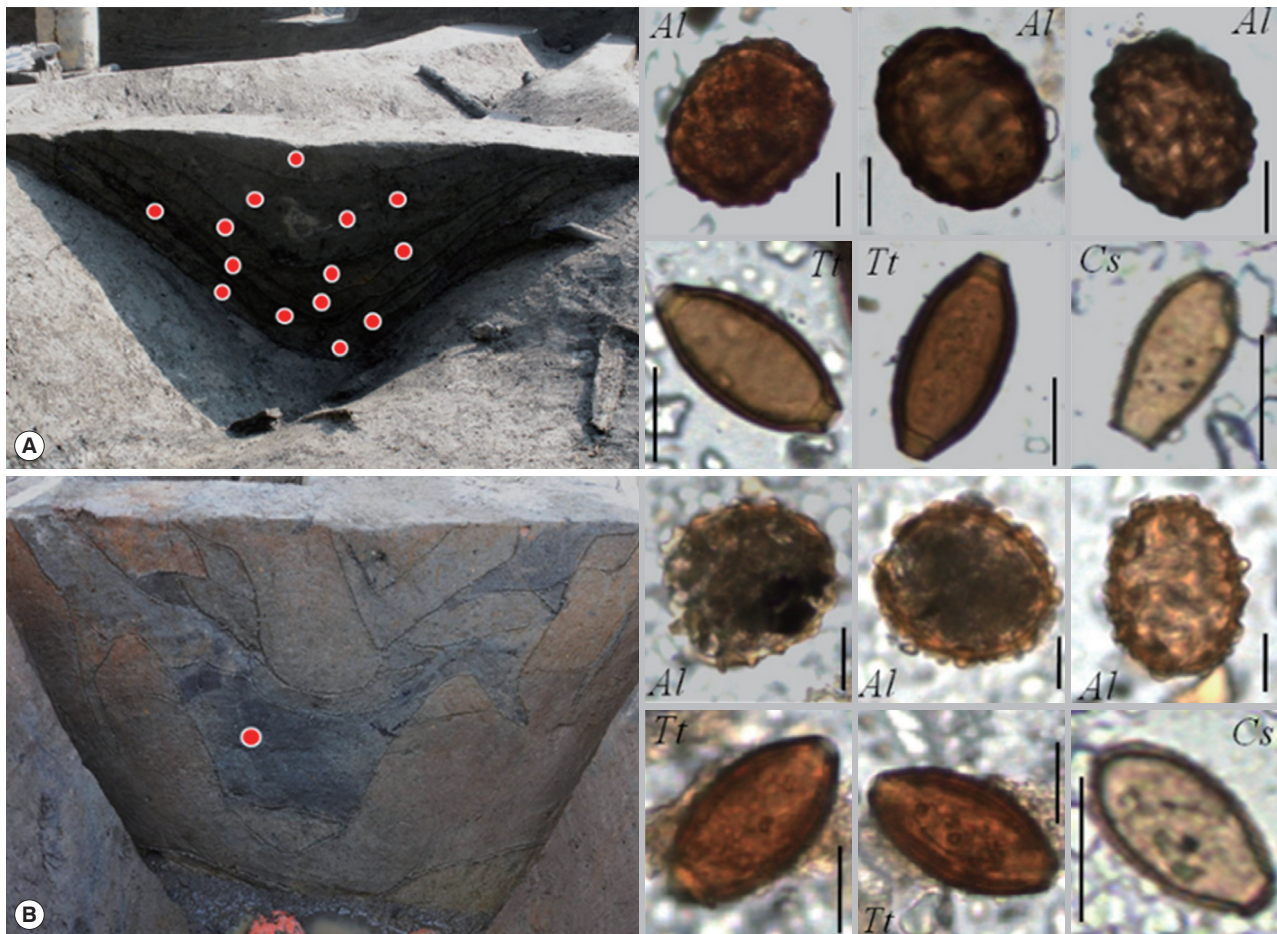


Fig. 3. Helminth egg discovery in the samples from Gua-ri (A) and Gatap-ri (B) sites in Buyeo. (A) Gua-ri site, the construct XII. V-shaped pit could be identified. Sampling points are marked by dots. In every sample examined, *Ascaris*, *Trichuris*, or *Clonorchis* eggs were discovered. (B) In Gatap-ri site, V-shaped pit was also discovered. The sampling point is marked by red dot. We also discovered *Ascaris*, *Trichuris*, and *Clonorchis* eggs. Scale bars in each egg plate=20 µm.

Table 2. Informations on ancient parasite positive samples

Sites	Discovered eggs	Average size (μm) ^a	EPG ^b
Gua-ri 319	<i>Ascaris lumbricoides</i>	61.4 (53-73) × 47.5 (45-50)	33
	<i>Trichuris trichiura</i>	51.3 (48-55) × 25.6 (25-28)	21
	<i>Clonorchis sinensis</i>	28.9 × 15.2 ^c	0.3
Gatap-ri 90	<i>Ascaris lumbricoides</i>	73.4 (64-79) × 51.2 (47-60)	130
	<i>Trichuris trichiura</i>	55.0 (52-55) × 28.2 (27-30)	50
	<i>Clonorchis sinensis</i>	29.7 (29.7) × 16.1 (15-17)	30

^aThe average size was calculated on 10 eggs so far as circumstances permit.

^bEPG was calculated by multiplying 10 times to the average number of eggs counted in soil samples considering that 10 g of soils were dissolved in 20 ml of 0.5% trisodium phosphate solution per each sample.

^cOnly 1 egg of *C. sinensis* was recovered from this sample.

found many human coprolites in a shell midden, indicating that those pre-agrarian people used that site and others like it as toilets, dung heaps, or night-soil reservoirs [4]. In time though, the use of toilets, even flushing toilets, came to predominate in East Asia as in other areas of the ancient civilized world [9,10], as confirmed by archaeological investigations [4]. Besides flushing toilets, a tradition of cesspit toilets was also developed in East Asia. Cesspit toilets served farmers as reservoirs for the night soils they commonly utilized as a fertilizer. Once the cesspits became full, their contents were carried away to nearby farmlands. In fact, the use of cesspit toilets in a traditional Japanese society has been verified by archaeological investigations [4].

Meanwhile, similar reports on human-waste reservoirs in Korea have been few. However, in 2004, as noted above, Korean researchers finally found toilet-like structures at the Wang-gung-ri site, the location of the ruins of the Baekje Kingdom's Royal Palace. One such presumptive toilet was a 10.8 m (length) × 1.8 m (width) × 3.4 m (depth) pit. Also evident, significantly, was a sewage canal connecting the toilets to the Royal Palace perimeter grounds [5]. Parasitological examinations of sediments sampled from those structures, in this seminal Korean paleoparasitological investigations, revealed many *Ascaris*, *Trichuris*, and *Clonorchis* eggs.

In much the same way, the current study also could prove to be very meaningful to concerned researchers. We discovered many of the same species (*Ascaris*, *Trichuris*, and *Clonorchis*) of helminth eggs in soil samples obtained from the V-shaped pits unearthed at the Gua-ri and Gatap-ri sites in Buyeo. Unfortunately, however, final determination of their exact purpose must remain unconfirmed for now, pending the accumulation of more information, historical and otherwise, on ancient Ko-

rean towns and cities. Historical studies from other countries, however, are suggestive. In both ancient Rome and medieval London, for example, there were a number of latrines, cesspits, dung heaps and gutters wherein human waste was accumulated [11]. Likewise, it is entirely possible that the V-shaped pits investigated in the present study were used as cesspits, reservoirs, or dung heaps for the night soils of the Baekje people. We note that even in this politico-cultural center of that ancient Korean kingdom, there might well have been many such structures.

Our study established the presence of ancient helminth eggs (*A. lumbricoides*, *T. trichiura*, and *C. sinensis*) in soil samples obtained from V-shaped pits in Buyeo, the capital of the ancient Baekje Kingdom. Our overall results indicate that these pits might have been used as human-waste reservoirs. Whereas this is indeed a significant finding, we must also admit that the number of cesspits or toilets reported thus far for historical Korean towns or cities remains very small. Identifying and studying additional archaeological structures that once functioned as toilets or cesspits in historical Korean towns and cities, particularly those representing a variety of temporal and spatial ranges undoubtedly will facilitate the locating and collecting of ideal paleoparasitological samples.

ACKNOWLEDGMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (no. 2013R1A1A 2009688). SYS and MHL worked for Guari-319 site; GIL and SBJ worked for Gatap-ri as archaeologists. MJK and CSO worked for sampling in the fields; MS, JYC and DHS did parasitological examinations and paper writing.

CONFLICT OF INTEREST

We have no conflict of interest related to this work.

REFERENCES

1. Addyman PV. The archaeology of public health at York, England. *World Archaeol* 1989; 21: 244-264.
2. Ki HC, Bae JH, Shin DH. Historical study on factors inducing soil-transmitted helminth infection among people of old Seoul City during Joseon Dynasty. *Korean J Med Hist* 2013; 22: 89-132.
3. Kim MJ, Ki HC, Kim S, Chai JY, Seo M, Oh CS, Shin DH. Para-

- sitic infection patterns as correlated with urban-rural recycling of night soils in Korea and other East Asian countries: the archaeological and historical evidence. *Korean Studies* 2014 (in press).
4. Matsui A, Kanehara M, Kanehara M. Palaeoparasitology in Japan-discovery of toilet features. *Mem Inst Oswaldo Cruz* 2003; 98(suppl 1): 127-136.
 5. Buyeo National Research Institute of Cultural Heritage. The Achievement and Significance of Excavation on the Wanggungni Site in Iksan, Buyeo. 2009 (a monograph).
 6. Seo M, Oh CS, Chai JY, Lee SJ, Park JB, Lee BH, Park JH, Cho GH, Hong DW, Park HU, Shin DH. The influence of differential burial preservation on the recovery of helminth eggs in soil samples from Korean medieval tombs. *J Parasitol* 2010; 96: 366-370.
 7. Callen EO, Cameron TWM. A prehistoric diet as revealed in coprolites. *New Scientist* 1960; 8: 35-40.
 8. Criscione CD, Anderson JD, Sudimack D, Peng W, Jha B, Williams-Blanger S, Anderson TJ. Disentangling hybridization and host colonization in parasitic roundworms of humans and pigs. *Proc Biol Sci* 2007; 274: 2669-2677.
 9. Vuorinen HS. Toilets and health throughout history, The 3rd International Dry Toilet Conference. Tampere, Finland. 2009.
 10. Vuorinen HS, Juuti PS, Katko TS. History of water and health from ancient civilization to modern times. *Water Sci Technol* 2007; 7: 49-57.
 11. Taylor C. The disposal of human waste: a comparison between Ancient Rome and Medieval London. *Past Imperfect* 2005; 11: 53-72.