OPINION ARTICLE

Pathogenic helminths in the past: Much ado about nothing

[version 1; peer review: 1 approved]

Christian Mulder

National Institute for Public Health and the Environment (RIVM), Bilthoven, 3721, The Netherlands

V1 First published: 08 Jun 2017, 6:852
<https://doi.org/10.12688/f1000research.11752.1>
Second version: 18 Jul 2017, 6:852
<https://doi.org/10.12688/f1000research.11752.2>
Latest published: 11 Aug 2017, 6:852
<https://doi.org/10.12688/f1000research.11752.3>

Abstract

Despite a long tradition on the extent to which Romanisation has improved human health, some recent studies suggest that Romanisation in general, and Roman sanitation in particular, may not have made people any healthier, given that in Roman times gastrointestinal parasites were apparently widespread, whilst in the present day such parasites rarely cause diseases. Unfortunately, this novel claim neglects the empirical evidence that worldwide infections in over 1.5 billion people are caused by ubiquitous foodborne nematodes. Therefore, many may wonder if fossil remains of soil-transmitted helminths have been reported in ancient sanitation infrastructures. Beneficial access to improved sanitation should always be prioritized, hence how can historical sanitation efforts have ever been harmful? In this short article, a strong plea for caution is given, asking for an augmented nematological record and showing that there is not any evidence against Roman sanitation, neither in the past nor in the present.

Keywords

Human diseases; Endoparasitic nematodes; Roman settlements; Fossil eggs.

Open Peer Review

Approval Status

	1	2
version 3 (revision) 11 Aug 2017		 view
version 2 (revision) 18 Jul 2017		 view
version 1 08 Jun 2017	 view	

1. **Karl J. Reinhard**, University of Nebraska, Lincoln, USA

2. **Cornelis van Tilburg**, Leiden University, Leiden, The Netherlands

Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the **Pathogens** gateway.

This article is included in the **Neglected Tropical Diseases** collection.

Corresponding author: Christian Mulder (christian.mulder@rivm.nl)

Author roles: Mulder C: Conceptualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2017 Mulder C. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Mulder C. **Pathogenic helminths in the past: Much ado about nothing [version 1; peer review: 1 approved]** F1000Research 2017, 6:852 <https://doi.org/10.12688/f1000research.11752.1>

First published: 08 Jun 2017, 6:852 <https://doi.org/10.12688/f1000research.11752.1>

In her *Nature* feature, Chelsea Wald¹ reviewed some of the conclusions by Piers D. Mitchell² and describes the fascinating rise of latrines in Mesopotamia, Greece and the Roman Empire. Both authors tried to point out that most of these sanitation facilities were not doing much for the residents' health, despite the idea that sophisticated plumbing systems, like those of ancient Rome, may have acted as a kind of control that could benefit even the poor. This debated interpretation was based on the fact that human hosts mainly acquire infective nematodes via the faecal–oral route through the soil, although unembryonated eggs can remain viable in the soil for 15 years. Helminth preservation seems to be the highest in moist anaerobic environments like latrines³; therefore, even Roman latrines, with continuous flushing and related sediments (coprolites), can become valuable for the reconstruction of past gastrointestinal infections, if evaluated correctly.

As a matter of fact, water purification will always be one of the most intriguing examples of how public health and societal health are interwoven. Amazing examples come from Roman history, where water and wastewater systems rapidly became pillars for European civilisation. The large-scale introduction by Romans of fountains into or near public buildings, together with closed aqueducts, can be seen as the very first Water Safety Plan. Interestingly, archaeologists somehow seem to be ideologically motivated to conceptualize

diseases and outbreaks in Roman times, despite the thin palynological record from ancient sanitation infrastructures around the Mediterranean Sea^{1,2} (Figure 1).

Many pathogens are reported in ancient latrines because they are intrinsically correlated to human settlements, and not to sanitation infrastructures themselves, which are supposed to reduce the risk of contact with outbreak sources. On one hand, it is true that fossil remains of roundworms, whipworms and hookworms (collectively referred to as soil-transmitted helminths) have been reported from ancient sanitation infrastructures. On the other hand, Romans were fully aware of the importance of clean water and efficient sanitation systems. Already during the short reign of Nerva in Rome (96 – 98 CE), Frontinus decided that water from different sources had to be kept separate: clean water was reserved for potable use, intermediate quality water was used for recreation and only poor quality water was sent for irrigation. Thanks to sophisticated hydraulic systems for aqueducts, cisterns, pipes, terms, baths, fountains and latrines, the capital of the Roman Empire became famous as *Roma regina aquarum*. Due to the greatest care provided to their waters for the health and security of the capital and later of the other cities, these neglected latrines became an open archaeological window not so much on Roman sanitation, but on our civilisation as a whole. Fossilized helminth

Figure 1. Multiple geographical and historical investigation bias between ancient settlements claimed to be infected in the past, and children's helminthiases in modern countries. Background map implemented with palaeoparasitological records of roundworms (*Ascaris*) and whipworms (*Trichuris*) recovered from a global selection of archaeological sites built between 200 BCE and 500 CE (Common Era)^{2,4-6,9,10}. The background map has been adapted from World Health Organization, program on Control of Neglected Tropical Diseases (gamapserver.who.int/mapLibrary/Files/Maps/STH_2011_global.png).

eggs in dung sediments from latrines are very peculiar tools to reconstruct migration routes, trades, animal domestication, diets, past outbreaks and even urban catastrophes^{4–6}.

Nematodes are the most frequently occurring invertebrates. These primitive soil organisms occupy diverse trophic levels in ecological networks and can act either as antagonists for soil-borne pests or be pathogens themselves. It can be dangerous to suggest that sanitation may not have made people any healthier, as humans can also get infected with soil nematodes by ingesting unclean vegetables or by contact with infected domestic animals. Along the aforementioned faecal–oral route, behavioral and allometric factors have been put forward in existing literature⁷, being the host-related factors linked to human size prominent. According to host–parasite regression models for mammals⁷ and assuming on average one adult body weight of 62.0 kg (corresponding to a volume of 61,400 cc), each infected human might contain up to 12,300 helminths.

Hence, it is not surprising to find helminths in sanitation systems of ancient settlements, especially if only the palaeoparasitological data for sites at which these pathogens were detected are gathered together. For instance, archaeological records of common-source outbreaks can be collated to support the idea that sanitation facilities historically linked to Romanisation have widespread helminths, although these cosmopolitan endoparasites are well-known to occur during Roman times even around the Pacific Ocean, including the New World in pre-colonial times^{5,8–10} (Figure 1). Thus, we have to realize that there would be many more helminth eggs in ancient sanitation facilities if these facilities had not been there in the past. Surprisingly, archaeologists like to invert this basic framework, and suggestive interpretation may be worse than no interpretation at all.

But even if such pathogens are identified, it remains challenging either to exclude false parasitism (incidental presence in human faeces of eggs resulting from the consumption of an infected animal^{9,11}) or to determine with certainty human outbreaks (helminth eggs might demonstrate their human origin by some circumstantial evidence only^{3,11}). Allometric rules that express parasites and

non-infected animals per square meter¹², in tandem with the several possible contamination pathways, will always lead to diseases with a high global burden¹³. Moreover, a parasitic occurrence can also be related to open water contamination, for instance from livestock grazing in upland areas causing outbreaks downstreams. This has nothing to do with any sanitation structure.

Omitting such a relevant weight of evidence in any comparison between archaeological excavations will introduce *de facto* a strong bias towards false-positive results into palaeoecological meta-analyses. In the future, to avoid interesting, but geographically misleading or even statistically speculative conclusions, one of the most intriguing hypotheses that will arise might be the investigation by microscopy of soils from archaeological sites associated either with one sanitation infrastructure or without that sanitation. In the case of Roman sanitation, due to the Hadrian's Wall bordering the northern part of the Roman Empire with all its social infrastructures, including latrines, England (entirely inside the Wall during Roman times) and Scotland (outside the Wall during Roman times) can together provide the perfect study area.

There are 2.5 billion people still living on Earth without improved sanitation facilities. A correct Big Data mining of all nematological palaeorecords¹⁴ combined with objective interpretation of, probably thin, circumstantial evidence will require great care, as the conclusion shall have implications on ongoing global control programs relating to helminthiases. On the other hand, as the taxonomic status of *Ascaris* is contentious¹⁵, palaeoecological evidence from archaeological sites in synergy with present-day molecular ecology can become an unexplored avenue to improve current control programs.

Competing interests

No competing interests were disclosed.

Grant information

The author(s) declared that no grants were involved in supporting this work.

References

- Wald C: **The secret history of ancient toilets.** *Nature*. 2016; **533**(7604): 456–458. [PubMed Abstract](#) | [Publisher Full Text](#)
- Mitchell PD: **Human parasites in the Roman World: health consequences of conquering an empire.** *Parasitology*. 2017; **144**(1): 48–58. [PubMed Abstract](#) | [Publisher Full Text](#)
- Moore PD: **Life seen from a medieval latrine.** *Nature*. 1981; **294**: 614. [Reference Source](#)
- Araújo A, Reinhard KJ, Ferreira LF, et al.: **Parasites as probes for prehistoric human migrations?** *Trends Parasitol.* 2008; **24**(3): 112–115. [PubMed Abstract](#) | [Publisher Full Text](#)
- Reinhard KJ: **Archaeoparasitology in North America.** *Am J Phys Anthropol.* 1990; **82**(2): 145–163. [PubMed Abstract](#) | [Publisher Full Text](#)
- Reinhard KJ, Confalonieri UE, Herrmann B, et al.: **Recovery of parasite remains from coprolites and latrines: Aspects of paleoparasitological technique.** *Homo*. 1986; **37**(4): 217–239. [Reference Source](#)
- George-Nascimento M, Munoz G, Marquet PA, et al.: **Testing the energetic equivalence rule with helminth endoparasites of vertebrates.** *Ecol Lett.* 2004; **7**(7): 527–531. [Publisher Full Text](#)
- Mejia R, Vicuña Y, Broncano N, et al.: **A novel, multi-parallel, real-time polymerase chain reaction approach for eight gastrointestinal parasites provides improved diagnostic capabilities to resource-limited at-risk populations.** *Am J Trop Med Hyg.* 2013; **88**(6): 1041–1047. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Gonçalves ML, Araújo A, Ferreira LF: **Human intestinal parasites in the past: new findings and a review.** *Mem Inst Oswaldo Cruz.* 2003; **98**(Suppl 1): 103–118. [PubMed Abstract](#) | [Publisher Full Text](#)
- Leles D, Reinhard K, Fugassa MH, et al.: **A parasitological paradox: Why is ascarid infection so rare in the prehistoric Americas?** *J Archaeol Sci.* 2010; **37**(7): 1510–1520. [Publisher Full Text](#)
- Brinkkemper O, van Haaster H: **Eggs of intestinal parasites whipworm (*Trichuris*)**

- and mawworm (*Ascaris*): Non-pollen palynomorphs in archaeological samples. *Rev Palaeobot Palynol.* 2012; **186**: 16–21.
[Publisher Full Text](#)
12. Hechinger RF: **Parasites help find universal ecological rules.** *Proc Natl Acad Sci U S A.* 2015; **112**(6): 1656–1657.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
13. Bethony J, Brooker S, Albonico M, *et al.*: **Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm.** *Lancet.* 2006; **367**(9521): 1521–1532.
[PubMed Abstract](#) | [Publisher Full Text](#)
14. Dallas T: **helminthR: an R interface to the London Natural History Museum's Host–Parasite Database.** *Ecography.* 2016; **39**(4): 391–393.
[Publisher Full Text](#)
15. Søe MJ, Kapel CM, Nejsum P: **Ascaris from Humans and Pigs Appear to Be Reproductively Isolated Species.** *PLoS Negl Trop Dis.* 2016; **10**(9): e0004855.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Open Peer Review

Current Peer Review Status:

Version 1

Reviewer Report 17 July 2017

<https://doi.org/10.5256/f1000research.12694.r23627>

© 2017 Reinhard K. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Karl J. Reinhard

School of Natural Resources, University of Nebraska, Lincoln, NE, USA

Christian Mulder's "Pathogenic helminths in the past: Much ado about nothing" reveals some basic problems with the research presented by Piers Mitchell in "Human parasites in the Roman World: health consequences of conquering an empire. Parasitology". The critique recognizes that the conclusions of the study are overblown and points to errors in methods and theory. I read Mitchell's work and concur with Mulder. Mitchell does not approach the problem from the perspective of the science of archaeology nor the science of parasitology. Mulder suggests that Mitchell did not control for false parasitism through spread of eggs through the environment. In the science of archaeology, as applied to parasitology, concentrations of parasite eggs per ml or gr are calculated by researchers. These calculations document the distribution of eggs through strata within pits and across ancient village landscapes. This leads to statistical identification of transmission points. When these archaeological egg accumulations are verified as fecal deposits via ancillary pollen and seed analysis, then fecal contamination "hot spots" are defined. Dating of these points can lead to very solid information about emergence and control of geohelminths. This has been demonstrated archaeologically by the references of Fisher and Trigg's work below. Secondly, the geohelminth life cycle of ascarids seems to be misunderstood by Mitchell who asserted that people could have been infected in Roman baths.

I have a paper that has just been published addressing rigor in archaeological parasitology. This highlights the sort of issues such as false parasitism noted by Mulder.

I believe that Mulder is spot on with regard to Mitchell's assertion. I strongly recommend this work for indexing and I would hope that Mulder includes references to the work by Fisher's team and Trigg's team. The work by Trigg is in press and can be obtained via Heather Trigg or Steve Mrozowski.

Useful References:

- Fisher et al. (2007)¹
- Trigg et al. (2017)²

- Reinhard (2017)³

References

1. Fisher CL, Reinhard K, Kirk M, DiVirgilio J: Privies and Parasites: The Archaeology of Health Conditions in Albany, New York. *Historical Archaeology*. 2007. 172-197
2. Trigg HB, Jacobucci SA, Mrozowski SA, Steinberg JM: Archaeological Parasites as Indicators of Environmental Change in Urbanizing Landscapes: Implications for Health and Social Status. *American Antiquity*. 2017. 1-19
3. Reinhard K: Reestablishing rigor in archaeological parasitology. *International Journal of Paleopathology*. 2017. [Publisher Full Text](#)

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Partly

Are arguments sufficiently supported by evidence from the published literature?

Yes

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Archaeoparasitology, palynology, paleoparasitology, paleonutrition, archaeobotany, palynology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research