Stories of Waste and Value

Roots of a Circular Economy

ROOTS
Cluster of Excellence
Social, Environmental, and Cultural Connectivity in Past Societies

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» Stories of Waste and Value Roots of a Circular Economy «

Preface

In the Cluster of Excellence 'ROOTS – Social, Environmental and Cultural Connectivity in Past Societies', scholars from diverse disciplines deal with the reconstruction of past societies. Connectivities of individuals and groups, of people and the environment, of events, processes and structures are investigated from an archaeological and historical perspective. Globalisation as a worldwide process, including the associated regional effects and reactions, is of primary importance. The underlying hypothesis – the more people are connected, the lower the potential for conflict – was the starting point.

Especially in times of crises and conflicts with disrupted communication networks and transportation routes, it is even more essential to know how people reacted in changing and challenging situations in the past: not only in the recent industrial and post-industrial world but also in distant times, which provide us, so to say, with a mirror of our behaviour and our possibilities. Thus, the question is raised how hunter-gatherers, first farmers, ancient societies or early modern urban communities created their worlds.

In this respect, we decided to create a booklet series which presents information in a generally understandable way in current times of massively increasing global conflicts. With the present brochure, ROOTS continues this series, which introduces the discussions and results of our research cluster to a broader public.

This booklet is devoted to the topic of 'waste', which does not only play a crucial role in environmental protection and the sustainable use of resources in our world today, but has also always played an extremely important role in archaeologically and historically recorded societies. In contrast to numerous "manipulated" archives, which often reflect an intended world, "waste" is often harmless and can only be partially "manipulated". This is the reason why archaeologists, in particular, excavate "waste" and, by examining it, can often provide a basis for the reconstruction of past societies.

The booklet series is also conceived to stimulate discourses and commentaries on future issues from a past perspective in other media. Only those who understand the past are able to sustainably shape the present and develop lasting future perspectives. Reconstructing human behaviour in other times – and specifically in terms of the human-environment relationship – can provide a deep understanding of the past and open up opportunities for the future.

Johannes Müller
Speaker of the Cluster of Excellence ROOTS

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Konrad Ott

Treatment of Waste – Past and Present: An Introduction

Introduction

Societal metabolism with nature creates products, livelihoods, but also residuals in the form of waste. If metabolism with nature is an eternal predicament of human existence (Marx [1867] 1975, 57), there will always be waste. If a human makes a lithic tool, some lithic waste must remain. The "tool making animal" is also a waste producing animal. However, humans also reuse tools. Adam Brumm *et al*. (2019, 150) argue that there was "scavenging and reuse of stone artefacts by Lower Palaeolithic hominins". They also identify recycled artefacts and propose a terminology of how to speak about reuse, repair, recycle, and repatination in Palaeolithic times. Waste may come into existence at all stages of production and consumption: waste is a by-product. Today, in our globalised economy, artificial substances are transported all over the planet. Littering is common, be it at a public park or at coastal zones. There is even debris in outer space and centres of floating waste in the ocean. By intuition, we fear a world full of waste.

There are many historical ways to treat waste, which can and should be studied in history, sociology, and archaeology. Waste is a material companion of human life and it tells societal, cultural, economic, and even moral stories. If waste is part of the archaeological record, it can be used as a material basis for inferences about societal life. Thus, the *Reflective Turn* in ROOTS takes an interest in waste.

Analysis

The word "waste" belongs to a field of words which have similar meanings. Elements of this field are "trash", "rubbish", "litter", "garbage", *etc*. All concepts are fuzzy, because their use depends on human practices and perceptions. For sake of simplicity, I only speak of waste. The term "waste" has a meaning in ordinary language, but it also belongs to a set of economic and cultural concepts that are used in historical sciences, including archaeology.

Karl Marx ([1894] 1975, 110) spoke about "excrements of production and consumption" but did not pay much attention to the production of waste in the capitalistic mode of production. Excrements of production might be chemical residuals; excrements of consumption are faeces and rags. Marx noted that the price of raw materials sets incentives to utilise waste and he provided some examples for waste-intensive fabrication. Waste was a minor topic for Marx, as for most Marxian inspired scholars. There are few laudable exceptions. Michael Thompson first published his book *Rubbish Theory* in 1979, in which he argues that most intellectuals, including economists, are not interested in waste. We discard waste, place it outside of our dwellings and our mind-sets. Waste belongs to a minor sphere of life and persons treating waste are of minor status. My grandmother told me as a child: "If you do not do well in school, you have to work for the rubbish service".

As Thompson debates, it is not always clear what counts as waste in a given society. Waste is not an essential, but a societal way of existence. What counts as waste for a particular person (or society), may not count as waste for someone else. Excrements, including that of humans, can be seen as waste or as manure. Dumped textiles may mean clothes for the poor. Old books may be looked at as waste or as precious rarities. What is waste in urban milieus, is valuable in the countryside (organic compost, manure), especially if soils are nutrient poor (cf. Grund *et al*., this volume).

How waste is perceived, processed, organised, and regulated is a topic for historical investigations. If you study the treatment of waste you can learn much about human practices, customs, technologies, gender roles, *etc*. Waste treatment can be either anomic (irregular) or regulated and organised. In different societies, some waste may be regulated while other waste remains unregulated. As a result, different "waste-scapes" at different times and locations may be studied by historians and archaeologists. "Waste-scapes" can be seen as analogies to "sound-scapes" and "smell-scapes", which have become objects of study in cultural anthropology and social history (for sound-scapes see Schafer 1977). Some studies are collected in this volume and allow a comparison either between past societies or between the past and the present.

In principle, there are two major routes how waste might be treated. It can either be picked up and reused or it can be disposed of (= removed). If picked up, it is not treated as waste and remains within the sphere of economic production with some use value and even exchange value. If a farmer pays for manure, excrements have exchange value. On the other hand, if waste is removed, it might be burned, deposed of above or underground, channelled into rivers, lakes, and the ocean, *etc*. Removing waste can be performed either in anomic or in organised, controlled, and regulated ways. One "throws it away", and the "away" might be represented by the familiar maxim: "Out of sight, out of mind". Such maxims might be perfectly reasonable in a large natural environment, if almost all waste is organic (ashes, bones, eggshells). As I speculate, waste was not big a problem in nomadic hunting and gathering collectives. One could leave waste behind. If human collectives, however, settle down and live in larger units, as in villages or towns, treatment of waste may become organised. This "may" is not a strict "must" since collectives may also adapt to and cope with waste in their surroundings. Waste can be perceived of as a problem to be solved, but also as a given state of affairs. Problem solutions by regulation can be organised at the level of single households, production sites, and entire settlements.

A paradigm case of removing waste (dirt, dust) is the cleaning of houses, which is seen as "work" by Hannah Arendt. To Arendt *(The Human Condition),* work stands in opposition to production. Paradigm instances of work are cooking, cleaning, and doing laundry. Kitchens are rooms within which most waste occurs. There is a gender aspect in the conceptual difference of work and production. Work is often done by women, while males produce things (goods). Work, even if properly done, does not last, since humans are soon hungry again and rooms and clothing repeatedly become dirty. Waste work reoccurs as a never-ending story.

In *economic theory*, some material entity E is waste for a person P-1 if the entity E has no use value, no option value, no existence value (as an old love letter) or no exchange value. P-1 wishes to get rid of E since it stinks, disturbs, or looks ugly. Thus, E has a negative value for P-1. If there is another person P-2, for whom E is of some positive value, P-1 may pass E over to P-2 as a gift or may demand something from P-2 for E. If there is no P-2, opportunity costs will incur to P-1 to get rid of E. If treatment of waste is regulated, P-1 has to observe some legal constraints and bear the costs or must perform illegal dumping, which could be penalised.

To our moral Western minds, waste that is merely thrown away counts as *environmental pollution*. Throwing waste away is rational, but is interpreted as anti-social behaviour. Economically speaking, throwing away waste may constitute a negative external effect upon others. Under conditions of a division of labour, large-scale economies, consumerism, artificial substances, *etc*., unregulated waste treatment constitutes a tragedy, since pollution may not be just a mere aesthetic problem, but also a health problem.

In many countries and throughout history, the practice of *waste picking* is documented. Waste pickers collect, recycle, upgrade, and even sell materials, which have been thrown away by others. Quite often, women and children are among waste pickers. Waste pickers usually have a low social status. Therefore, Michael Walzer (*Spheres of Justice*, chapter on "Hard Work") regards picking and treating waste as "hard work", being defined as work which is highly important for society but has uncanny sensual features (it is smelly and dirty). Such hard work is usually badly paid and has a low status with minor social recognition.

If a person P-2 picks up a material entity E, which is waste for another person P-1, there is *ceteris paribus* and *prima facie*, a social difference in status between P-1 and P-2. The difference in rank and status is not a logical necessity, but a cultural normality. If E has no value whatsoever for P-1, but has some value for P-2, P-1 has more "wealth" than P-2. The exchange of E between P-1 and P-2 constitutes an asymmetry and inequality. Archaeology and history may investigate whether this hypothesis can be substantiated.

Waste and Environment

Waste has been a crucial topic in the environmental movement in a first wave of "social hygiene" since the 1870s and in a second wave since the 1970s. In the first wave, municipalities and representatives of social medicine wished to reduce the so-called "urban penalty", namely the risk of infectious diseases (such as cholera epidemics) as well as unhealthy and toxic working and housing conditions. The latter being a factor causing tuberculosis. This first wave was marked by successful "bio-politics" (Michel Foucault) with a focus on freshwater consumption and discharge. Foucault himself conceded that the bio-politics that accompanied industrialisation had positive effects on life expectancy and health status (Foucault 1979, 169).

A century later, the second wave had a focus on toxic and risky chemicals, which had become abundant in the post-war period (heavy metals, asbestos, and DDT, among others). It also addressed air pollution, water pollution, and chemical residuals in food. The sheer amount of waste of different kinds and different sources was (and still is) a crucial component of the "great acceleration" which characterises the full-blown Anthropocene. Yet, some waste remains invisible to most inhabitants of Western societies since it is produced, for example, in mining areas somewhere in the Global South. In the Fordist period of industrial capitalism, it was "business as usual" to externalise waste products (emissions) into the air, water, soil, forests, *etc*. Rivers became wastewater canals and the ocean became the final sink of waste. Highly toxic waste had to be deposed of in underground repositories, while "normal" waste was dumped, often illegally, or burned. Early waste burning facilities were emitters of toxic substances because the temperature of such burning was too low to destroy them. While economic theory demands the internalisation of negative external effects (polluter pays principle), economic practice made externalisation "business as usual" as long as there was no protest. In the 1970s, the models of the Club of Rome supposed that pollution would run in parallel to economic growth and, if so, waste and pollution would increase without end in the growth society.

Since the 1970s, this situation has been regarded as unsustainable. The environmental movement perceived industrial capitalism as a toxic enterprise. Waste-intense consumerism was seen as greedy, myopic, and vicious. Early environmental ethics claimed "rights against polluters" and it opposed "victimisation" via producing external effects. In the USA, so-called *eco-racism* has been criticised, which is characterised by landfills and incinerators that are built near settlements that are predominantly inhabited by African Americans and Native Americans. From an individual ethical perspective, the general maxim of deep ecology "Do not leave traces" was applied to waste according to the premise: "Minimise waste". Waste was seen as part of one's ecological footprint and it was evident that the waste production of industrial societies could not be globalised without turning the globe into a "waste-land".

The environmental motives, political protest, and bleak predictions about waste and pollution have created impacts on policy making since the 1970s. Such policies originated as prudent technocrats realised that dispersal strategies do not work indefinitely. "Dilute-and-disperse" strategies failed prominently in the case of acid rain, occurring as an adverse effect of "high-chimney"-policies. Slowly but surely, industrial societies improved waste management technologies and, by doing so, constituted new industries and business models. Capitalism operated as it always does: It transforms a problem into a business and makes a profit out of its own deficiencies. Consumers started to sort waste (glass, paper, plastic, and organic waste) and they were motivated to reduce their waste volume by price incentives. Recycling has become a new mainstream normality, although current rates could and should be increased.

Historical Lessons and Present Questions

The following remarks refer to the contributions to this volume. They try to connect the past and the present, as ROOTS hopes to do generally.

It might be the case that the maxim "Out of sight, out of mind" is a long-lasting prehistoric pattern of thought. In settlements, however, treatment of waste became a matter of concern. Waste and its treatment are part of the sedentary Neolithic way of life and economy (the so-called 'Neolithic package'). Since humans always have reasons to act, ROOTS has to ask which reasons might have governed the treatment of waste in prehistoric, ancient, medieval, and modern times. Conjectural inferences from waste may identify presumptive reasons of how to deal with waste.

Despite distance in time, one can compare strategies to deal with waste in modern times with a 4000-year-old village (Bruszczewo). As Kneisel *et al*. (this volume) argue, the strategies do not vary much. There were central places for all kinds of waste and strategies to down-use materials. The intake of waste into a lake close to Bruszczewo affected the quality of freshwater negatively, but it remains unclear whether prehistoric people had knowledge about the causal links between organic waste and stomach-affecting intestinal diseases.

In ancient times, the Roman *"cloaca maxima"* is a famous example for wastewater recharge, where wastewater was used to clean latrines. This technology was part of the overall water supply system of Rome. Ancient Rome as well as medieval Islamic cities may be seen as laboratories that dealt with (scarce) freshwater resources and wastewater (Chiarenza *et al*. 2020).

Another pattern of thought, however, is characterised by the motto "Do not waste useful items". For example, precious metals were not wasted, but reused as described by Cembrzynski and Jäcker (this volume). In modern times, there was a shift from "repairing" to "replacing", although practices of repairing and fixing always continued. Replacing, however, is closer to our post-modern lifestyles than repairing. Degrowth activists argue that we should perform a shift back to a primacy of repairing over replacing. Perhaps, it might be possible to compare "repair-cultures" throughout history.

The economy of waste is described in an instructive example in Cembrzynski and Jäcker (this volume). Under conditions of low extraction costs, lead-containing slags became waste in the production of lead in Olkusz (12^{th}-16^{th} century CE). As one had to dig deeper for lead-containing ores, extraction costs increased. Miners discovereda the old slags, a former waste by-product, and turned them into a resource. If reusing was cheaper, reusing was performed.

Kneisel and Shindo (this volume) provide another historical example on waste economy, in which deforested Northern Denmark had difficulties in reforestation and thus the recycling of timber became an efficient practice. Scarcity makes people inventive. Kneisel and Shindo foresee future markets for used timber.

In transformation periods, there are cultural experiments as well. Sharing economies and flea markets can reduce the amount of waste. Shall we revitalise exhibitions of things which have been found at waste depository sites (Diehl and Windmüller, this volume)? Shall we place things outside of our houses as take-away-gifts or do we create a new litter problem by doing so?

In our aging societies, houses have become huge storage containers of material commodities over long decades of consumerism. There is a material legacy of the post-war growth societies which is "more than just waste". Degrowth policies may profit from ceramics, leather, furniture, textiles, books, records, *etc*. that have been stored during the period of consumerism. Archaeology of modern times may discover basements and attics as discovery sites.

From the raw materials to their disposal, waste is globalised. If there are "trickling down effects" with respect to commodities, waste will end up in poorer countries. Trade with used commodities is hard or impossible to control, but such control can work as a preventive measure against the trade of future waste to the Global South. It is easy to make moral complaints about such waste trade. An innovative way to deal with such a repugnant mechanism might be to make countries of the Global South the centre of manufactures for recycling, upgrading, and export. Why should fancy and highly fashionable clothing for young adults not be created with the brands marked as "recycled from Western textile waste in Sierra Leone"? Certainly, we should call for "global post-colonial justice", as thousands of young scholars worldwide demand, but we should also think about innovative business ideas for a "green" global entrepreneurship which recycles former waste. I regard this idea as a post-colonial one.

As I have claimed, waste already emerged in sedentary collectives. Strictly speaking, there cannot be a "post-waste" society. Waste will continue to exist in the Anthropocene. Humans, however, are inventive and can engage in a practical discourse on waste, being informed by historical knowledge. We can and should proceed according to the maxim: "Reduce, refine, replace, recycle". Our patterns of recognition should shift, making the social reputation of waste managers as high as the reputation of novel writers, architects, legal scholars, physicians, professors, and priests. Post-modern societies might, for the first time in history, upgrade the social esteem of waste work. ◆

Chapter 1:

Hidden Dirt, Hidden Knowledge

↑ Taking a block sample for the micromorphology of a sod that was used to build a fortification (Vecračina, Latvia) (Photo by J. Schnee-weiß; image modified).


a
b

Lorenz Kienle, Khurram Saleem, Ulrich Schürmann

The Cognitive Value of Dirt

Materials analysis offers the fascinating possibility to explain the micro- and nanoscale features of all kinds of materials, including the functionally significant properties of minerals, artefacts and tools that are of importance to archaeology.

The analysis of materials by electron microscopic techniques allows several unique possibilities through methodological combinations to determine both the structure and chemical composition at the same sample position of an instrument. The methods used are summarised under the experimental categories of diffraction, imaging and spectroscopy, all of which represent a variety of different techniques, which have to be selected and combined carefully to answer specific material questions. The techniques are well-suited to identify traces of unintentionally included components ("dirt") in artefacts, which may play a decisive role for the material properties.

One prominent example demonstrating the potential of electron microscopy is the 4th century Roman Lycurgus Cup shown in figure 1. It is made out of composite glass and was manufactured by sophisticated production processes. The glass has unique optical properties: in direct light, it resembles jade with an opaque greenish-yellow tone, while it appears in a translucent ruby colour when the light shines through it. Freestone *et al.* (2007) suggested that the Lycurgus glass is made of soda-lime-silica type glass, similar to most other Roman and modern glasses. Trace elements of, *e.g.* gold and silver, were found as a result of more detailed analytical examinations and make up 1% of the glass, which

» The techniques are well-suited to identify traces of unintentionally included components ("dirt") in artefacts, which may play a decisive role for the material properties. «

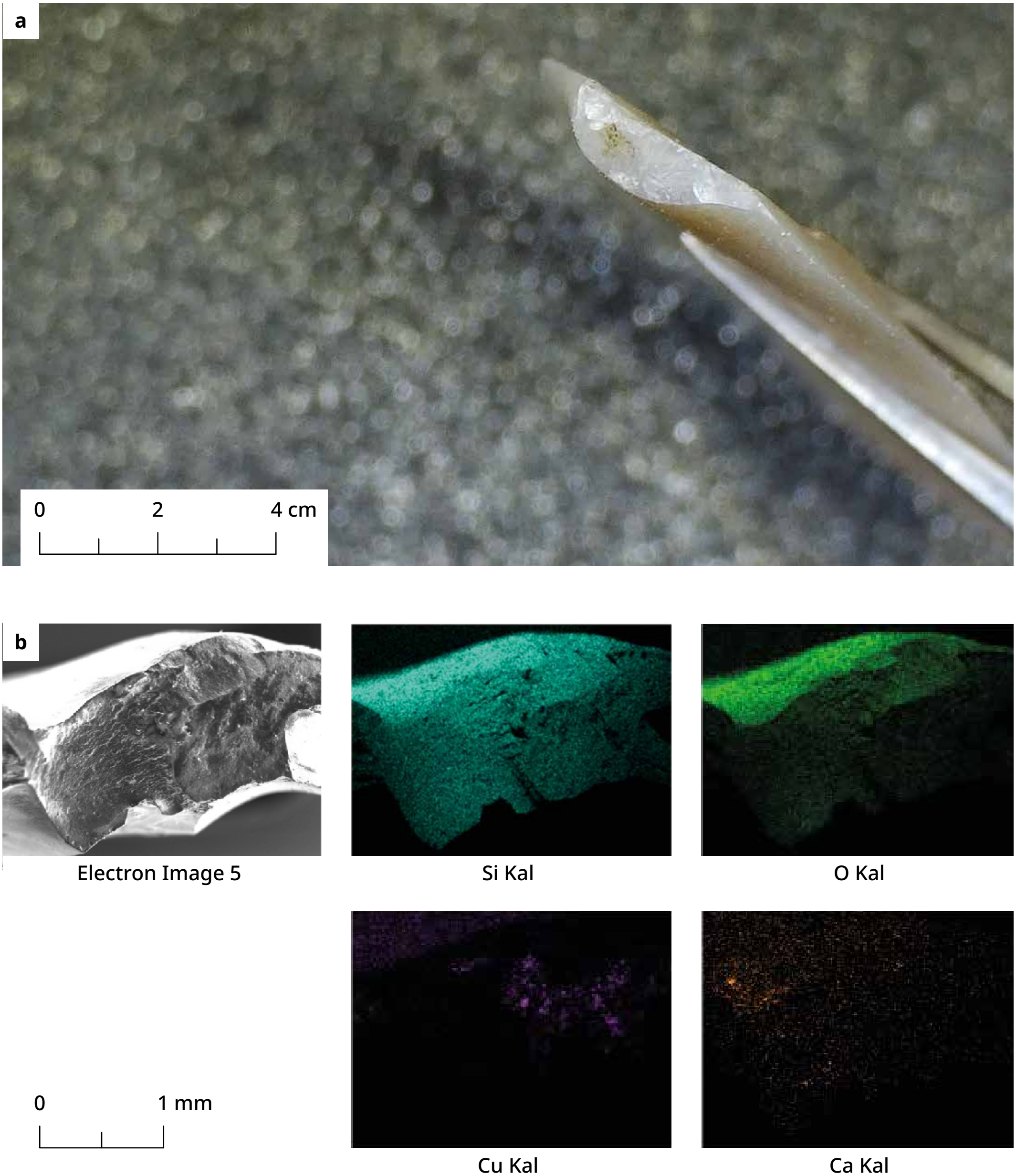
← Figure 1. The Roman Lycurgus Cup shown in: a) reflected and b) transmitted light (Source: Freestone *et al.* 2007, 270 fig. 1; image modified. https://doi.org/10.1007/BF03215599).

» Because the halides have been found to promote the colour in gold ruby glasses, it is possible that this impurity has contributed to the translucent ruby colour when the light shines through it. «

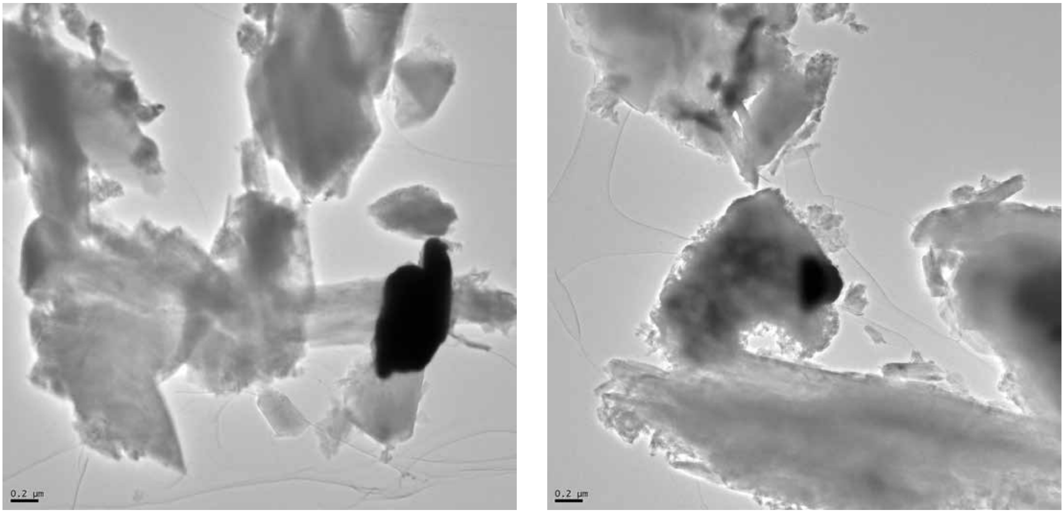
might be responsible for the complex colour and scattering. Transmission electron microscopy (TEM) was used to reveal the presence of minute particles of gold and silver alloys with 50-100 nm in diameter. Fine particles of around 15-100 nm of sodium chloride were also found in the Lycurgus Cup, which were not intentionally added in its composition. The chlorine probably derived from the mineral salts used to supply the alkali during the manufacturing process. These colourless fine particles of sodium chloride, separated from the glass solution during heat treatment, might have indirectly contributed to the optical colouration of the Lycurgus Cup. Halides are chemical compounds between elements from the 7th main group of the periodic table (so-called halogens, such as fluorine or chlorine) and elements from other groups. Because the halides have been found to promote the colour in gold ruby glasses, it is possible that this impurity has contributed to the translucent ruby colour when the light shines through it.

However, Andrey Drozdov *et al.* (2021) recently suggested that bimetallic Au and Ag nanoparticles are only responsible for the *red* colour appearance. Experimental replicas prepared by the authors showed the light absorbance by iron ions and light scattering due to the silica-rich phase as reasons for the *olive-green* colour. While the Lycurgus Cup exhibits the remarkable craftsmanship of the manufacturers, it also reveals the role of intentional or unintentional impurities in the glass during the manufacturing process of the final product that change its appearance and value.

Another field of activity for electron microscopy in archaeological contexts is an analysis of the use and production of artefacts. Our most recent examinations on flint blades may serve as a first example. The detailed analyses of flint can lead to important revelations about the production of tools from the ancient past. Copper knapping tools were not yet known in the Late Neolithic Danish material culture. Therefore, identifying copper traces on the flint artefacts by using a combination of digital microscopy and scanning electron microscopy (SEM) can help to identify the material and type of a knapping tool via its residues, as shown in figure 2. The intricate designs on the Late Neolithic flint already indicate that a copper tool was possibly used to produce them. However, our combined approach of imaging and electron spectroscopy provides elemental maps of the surface of the Late Neolithic flint blades and shows the position of copper traces unambiguously.



↑ Figure 2. Illustration of copper residues on flint surfaces. a) Digital image and b) SEM electron image and EDX elemental mapping (Analysis credit: K. Saleem; image modified).



↑ **Figure 3. TEM images of gold nanoparticles (dark contrast) in an agglomeration of silicate particles (light contrast) from anvil rock material (Analysis credit: U. Schürmann; image modified).**

The second example comes from use analysis, where traces of gold as well as copper and nickel were found on a stone in Bruszczewo, one of the few fortified Early Bronze Age sites north of the Central European Mountain Range, located in today's Poland. The TEM images of gold nanoparticles are displayed in figure 3. These residues serve as evidence of gold processing and as the first evidence of Central European gold production.

In a third example, we examined stone artefacts made from granite and flint on which traces of red pigments were found during an archaeological excavation at a Late Neolithic site in Quern-Neukirchen, located east of Flensburg. After scratching a tiny amount of material from the surface of the stone, nanometre sized particles of red chalk were extracted and analysed by means of TEM and Energy-dispersive X-ray Spectroscopy (EDX). The material of the surface, including the red colour, was analysed with TEM and EDX to prove the presence of iron oxide. Electron diffraction allows the determination of the crystal structure of particles and in this case has confirmed that they consist of iron oxide haematite, which normally does not appear in natural granite or flint. Powder from haematite has an intensive red colour and has been used in combination with clay as the colour pigment red chalk. This study thus proves the presence of hematite on a stone where it does not occur naturally in combination with the accompanying minerals, and therefore supports the assumption of deliberate use of this pigment in the Late Neolithic.

In general, "waste" in terms of surface contamination raises severe problems in material analyses, partly inhibiting a reliable determination of the chemical composition of the artefacts. To circumvent this problem, modern preparation techniques (so-called focussed ion beam milling – FIB) are applied by extracting clean slices of the material from internal parts of the artefact. Thus, in our research, we have shown how the contamination of the surface hinders the analysis of the true material of the object. The analysis of a Neolithic copper axe from 3000 BCE and ca. 1000-year-old fibulas from medie-

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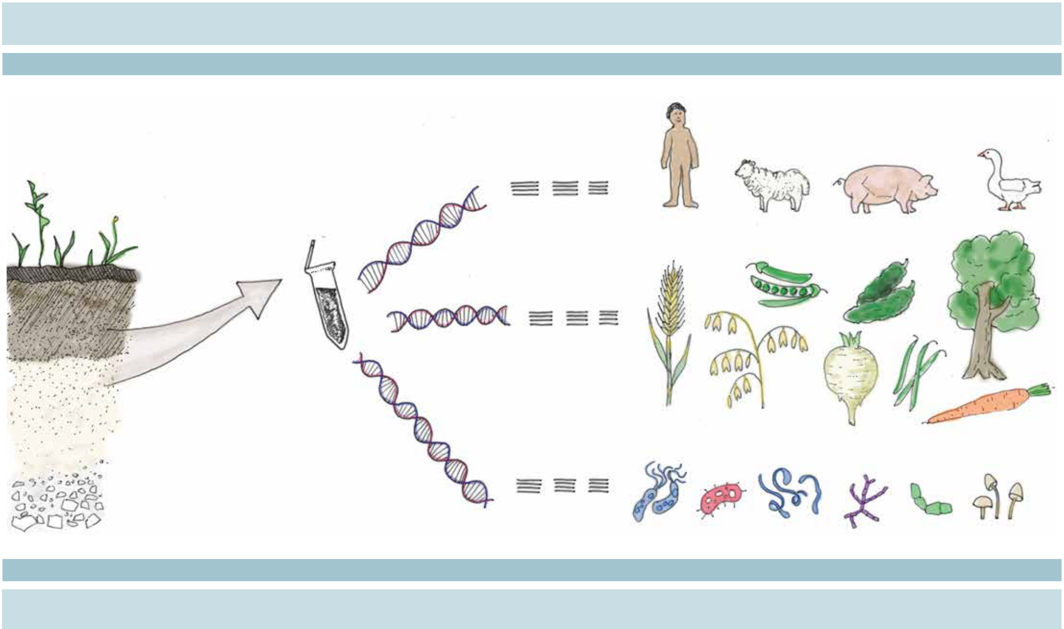
val Ostriv and East Baltic regions posed a challenge due to the surface (contamination) layer. The heavy contamination of the surface results from secondary alterations caused by environmental factors as the artefacts remained buried for hundreds of years. The analytical methods, such as SEM and TEM, generate contrasting chemical information when the chemical composition from the surface, the sub-surface and the core of the artefacts are compared. Hence, it is necessary to dig through the surface of the sample by FIB to reach the internal structure of the artefact for precise results. The contamination, on the one hand, poses a challenge for the analytical study but, on the other hand, it provides a passivating layer to help to protect the internal structure of the artefacts. In other words, the dirt crust preserves the true core. However, this contamination layer has to be penetrated to attain information about the artefacts' actual composition. Here, FIB is very helpful, using high energy ions to cut micrometre-sized layers from the material. FIB is mostly used in microelectronics, but in the search for the development of an advanced methodology of artefact analysis that does not destroy the objects by sampling, it is successfully being utilised by us in archaeology as well. An electron transparent thin slice of an artefact can be extracted from a depth of 10 μm from the surface and analysed for compositional analysis in TEM. The size of the extracted slice, which is less than 1/6th of a millimetre, is not visible to the naked eye. Thus, despite penetrating the surface of an artefact, this method fulfils the most important requirement for the study of ancient artefacts, namely their "non-destructive analysis". ◆

Jens Schneeweiß

Environmental aDNA – The Whole World in a Handful of Dirt

Genetics is changing our world. Plants are genetically modified to make them more resistant to so-called pests, i.e. undesirable organisms that would reduce the yield. Based on tiny traces of DNA (deoxyribonucleic acid) found at the scene of a crime, criminologists sometimes convict criminals years after a crime was committed. But the ancient past can also come alive in this way.



↑ Figure 1. Under appropriate conditions, traces of DNA from all kinds of organisms are preserved in the soil, which can be determined by sequencing and comparison with reference databases (Illustration by J. Schneeweiß; image modified).

The analysis of rudimentary DNA, so-called 'ancient DNA' (aDNA), can help to uncover population dynamics or kinship relationships that date back centuries or even millennia. This has led to ground-breaking findings. But even more recent dirt contains a lot of coded information. The sequencing and analysis of so-called soil or environmental DNA is a young branch of research. However, it is very promising. Everything that comes into contact with the soil – what grows on it and what decays in it – leaves more or less strong traces, which can be identified in the lab (Fig. 1).

The search for environmental DNA began in the 1990s. Genetic material was searched for almost everywhere: in soils, in water and even in the air. Initially, microbiologists isolated microbial DNA from tiny amounts of soil to see what genes and species were in the samples. However, they not only contained DNA from microorganisms that lived in them, but also genetic material from larger organisms that had been secreted, detached or excreted. These findings form the basis for highly efficient monitoring or supervision processes, *e.g.* of water bodies.

It has been known for 20 years that such old DNA residues, "dirt DNA", can survive under good conditions in the soil for thousands of years. In the meantime, research has progressed so far that, in addition to conventional macroscopic and microscopic methods of analysis, ancient ecosystems can be reconstructed much more comprehensively with the help of environmental aDNA. The possibility of sequencing genetic material from an entire genome using a little dirt was ground-breaking. This makes it possible to obtain much more information than from mitochondrial DNA (mtDNA), which has always been used in the past.

There is a saying that cesspits are the delicacies of archaeologists. The background for this is the mostly excellent preservation conditions and the high concentration of everyday waste, which lead to a great density of information. Thus, we can get very close to the everyday life of people. The rich Hanseatic city of Lübeck was a metropolis of global importance in the Middle Ages and early modern times. During the extensive excavations in Lübeck's founding quarter, among other things, about 100 cesspools and faecal pits were discovered, which give us deep insights into urban life in Lübeck at that time. They have been investigated using numerous modern analytical methods, the results of which were published in 2022 by Dirk Rieger and Patrick Flammer. One focus was on archaeoparasitology. With the help of the aDNA from the cloaca soil samples, traces of animals and plants were also analysed. A

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rapid test was developed for these analyses, which usually only allows the genus to be determined and rarely the species, but it does allow a larger number of samples to be tested.

One of the most illustrative results of Lübeck's archaeoparasite research using aDNA is a change in the cooking culture of Lübeck's merchant families in the founding quarter around the middle of the 14th century. The older soil samples contained large amounts of the fish tapeworm, which enters the host through the consumption of raw freshwater fish. This role was occupied by the cattle tapeworm in the samples after 1325, which is ingested with raw beef. The scientists therefore assume a switch from freshwater fish to beef, which they jokingly call the "sushi-tartar transition" (Rieger and Flammer 2022, 48). Various aspects come into question as causes; ultimately, they cannot be clearly named. Likewise, due to the lack of comparable studies, it cannot (yet) be said whether this observation is a Lübeck peculiarity or whether this food change is also typical for other cities of the time.

The aDNA analyses from the cesspools have confirmed the high proportion of freshwater fish in the diet of the merchants. 15 of 28 food animal species were fish that apparently came from the Wakenitz River or the monastery ponds in the surrounding area. In addition to the usual food animals, such as sheep, goats, cattle, pigs and horses, merchants also often included poultry such as chickens and geese or even pheasants in their diets.. The precise evaluation of the environmental aDNA data of the food animals did not reveal any correlation with the changeover that had been determined on the basis of tapeworms. Freshwater fish were certainly still on the menu, but the method of preparation or the origin of the fish had changed; raw meat, however, was obviously a new addition, just as meat consumption in general increased sharply, which verifies a change in the art of cooking among Lübeck merchants. This is remarkable, as modern refrigeration systems were only first developed in the course of the 20th century.

The results of the analyses allow excitingly detailed statements to be made, especially in connection with their distribution among the individual properties. Individual differences in diet, which were surprisingly varied among the wealthy citizens in the founding quarter, can partly be explained by the social position or trade connections of the people living there, who are even known by name from the written sources. For example, the *"Bergenfahrer"* (Hanseatic merchants and boatmen, who traded with Norway) ate a particularly large amount of fish, including cod. And they also had the fish tapeworm...

However, the results of the plant traces were of a very special variety. While this includes useful plants and woods, the variety of edible plants and spices is impressive, including not only the common

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native vegetables, fruits and herbs, but also numerous exotic imported kitchen plants: Grains of paradise, borage, cinnamon, coriander, lemons, saffron, turmeric, figs, almonds, nutmeg, oleaginous plants, pepper and ginger may be mentioned as examples that were common in Lübeck's founding quarter since the early 13th century. The possibilities of the combination of environmental aDNA analysis with, for example, archaeobotany are like watching colour television after listening to the radio – including the related challenges.

The example from Lübeck shows the great potential of these novel investigations. Current studies within ROOTS focus on the exploration of medieval garden land and its importance for human subsistence (Fig. 2). In this context, the analysis of environmental aDNA should provide information on the range of plants that were cultivated and on specific soil improvement measures. This work is still in progress and exciting results can be expected.

The analyses of environmental aDNA to date are still relatively limited, but development is proceeding at a rapid rate. They already show one thing very clearly: soils and sediments are still rarely tapped archives of the past that nonetheless contain overwhelming amounts of information. Ever lower costs of DNA sequencing and ever more powerful DNA databases are the key to this information, which can bring us closer to submerged worlds as if in a time machine. ◆

↑ **Figure 2. Sampling for environmental DNA analyses using sterile disposable syringes in an early modern garden soil in Bardowick, Lower Saxony (Photo by J. Schneeweiß; image modified).**

Svetlana Khamnueva-Wendt and Jens Schneeweiß

A Closer Look at Dirty Layers

A place under the open sky, sometime about 1000 years ago in Northern Europe (Fig. 1). The river is not far away, and wagon tracks in different directions indicate traders travelling overland that also pass by here. The site lies at the margin of a village, there are no buildings. Older people say that there used to be a grain field here. But now people meet here to exchange goods, to tell and listen to stories, to hear news from the world and from the surrounding villages – the first market place emerges here.

Businesses are going well, over the years a village grows around the market place. People come on foot or by ox carts, some arrive on horses. When the weather is bad, the ground softens and the carts press deep tracks into the mud. Even in good weather, walking is not always pleasurable. Many goods are sold directly from carts or makeshift stalls. Rubbish is thrown on the ground and left lying, joining food rests, excrements, and some lost things. It must have stunk to high heaven at these markets. The markets were not always a feast for the senses.

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Some ancient market places have survived in the urban environment until today. Those that were not built on are often paved over. Others emerged later in places where residential houses had previously stood. Still other market places were replaced by villages or towns with buildings, and often not even the name reflects the former market use of a place.

With conventional archaeological methods, it is not easy to prove former open spaces and their use. There are no traces of buildings that could help us. Even the tracks of wagons, which we might find if

← **Figure 1. A market place 1000 years ago (Illustration by Konrad, 7 years old, Schleswig; image modified).**

↑ **Figure 2. Sampling for micromorphology in a stony soil profile using a gypsum bandage (Photo by S. Khamnueva-Wendt; image modified).**

» Thin sections are indeed the best story tellers: they preserve detailed information about all processes that took place on a site during the whole history of its existence before, during and after the habitation period. «

we are very lucky, only shed a very small light on the past use of a site. Only rubbish can decisively help us here. Under the later buildings, the former hustle and bustle of a market can be preserved in the form of a rubbish layer or – to put it kindly – a cultural layer. With the naked eye, we do not see much: a more or less dark layer containing some archaeological find material such as shards, bones and further artefacts. However, a special method from soil science provides us with much deeper insights into the "soil archive". In so-called micromorphology, the cultural layer is viewed under the microscope.

Unlike sampling for other types of geoarchaeological analysis, the samples for micromorphological investigations are carefully carved out of the profiles into small boxes, which then contain undisturbed oriented mini-profiles that can be transported and studied separate from the field in a laboratory. The key word "undisturbed" implies that all constituents of the material are still in their original position, so that their composition and spatial relation can be examined. Depending on the properties of the deposits, the sampling can be done in small metal or plastic boxes. Or if the profile contains a lot of stones and other inclusions, special tricks, including plaster bandages, can be used to create an irregularly shaped case for the sample (Fig. 2).

In the next step, the sample is impregnated with a special resin so that it resembles a hard block that can be cut into slices, called slabs. A suitable slab is then glued onto a glass and subsequently polished to a thickness of 25-30 μm. For comparison: a human hair is 3-4 times thicker. Then the resulting sample, the thin section, is ready for investigation under a polarisation microscope. If the surface of the thin section is not covered with a special cover glass, it can be additionally investigated by other techniques, for instance, micro-XRF (X-ray florescence analysis). This provides us with the chemical elemental composition, allowing different materials to be detected.

Thin sections are indeed the best story tellers: they preserve detailed information about all processes that took place on a site during the whole history of its existence before, during and after the habitation period. One can find clues for such questions as:

- What types of soils and environmental conditions were present before the onset of habitation?
- What were the first human activities before settlement development?
- What were the main human activities during the major settlement period?
- What happened to the site after abandonment?

It is very difficult to answer these questions with conventional archaeological or geoscientific methods, especially for the first (proto)urban trading settlements in Northern Europe, where one often has to deal with two types of deposits – either with finely stratified and complex cultural layers or with nearly homogeneous, but nonetheless complex deposits, the so-called “dark earths”. The latter are dark-coloured “human-made” soil-like deposits characterised by large thickness, high organic matter content and a seemingly homogeneous structure. Such cultural deposits appear in ancient rural and urban settlements in many chronological and geographical contexts. They were formed by diverse social practices and environmental processes that are far from being conclusively investigated. Micromorphology plays a crucial role in the study of the dark earths because it makes structures and remnants of human activity visible that cannot be seen with the naked eye and in this way, it sheds light into the darkness in the truest sense of the word.

If we stay with the situation described in the beginning – the gradual development of a trading settlement – we will observe features of the corresponding landscape transformation in the thin sections. We can expect to find soil relicts indicating initial environmental conditions. Despite later disturbances, these relicts might be preserved in certain structures, like fills of animal passages, which formed long before the first human activities. The stories told by the elders may find their confirmation in thin sections due to the presence of dusty clay or silt coatings, which indicate bare soil surfaces with occasional disturbances like tillage due to crop cultivation.

Even a footprint becomes tangible: the first occurrence of humans at the site may be indicated by

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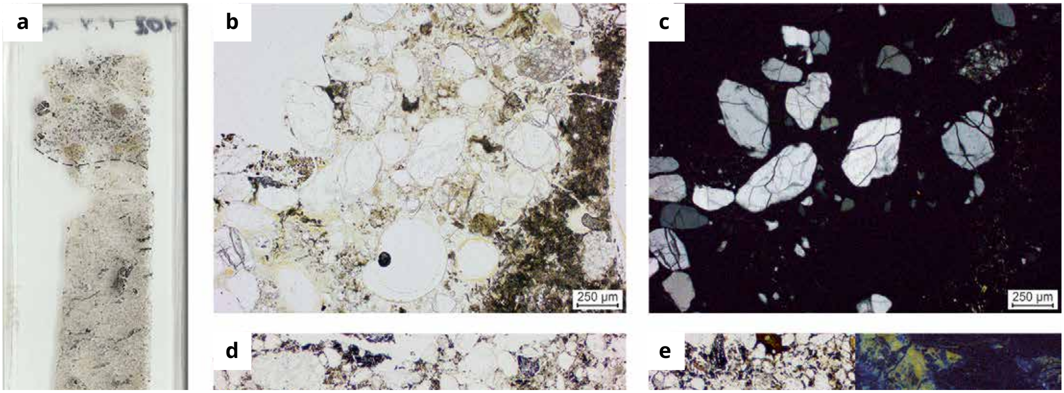
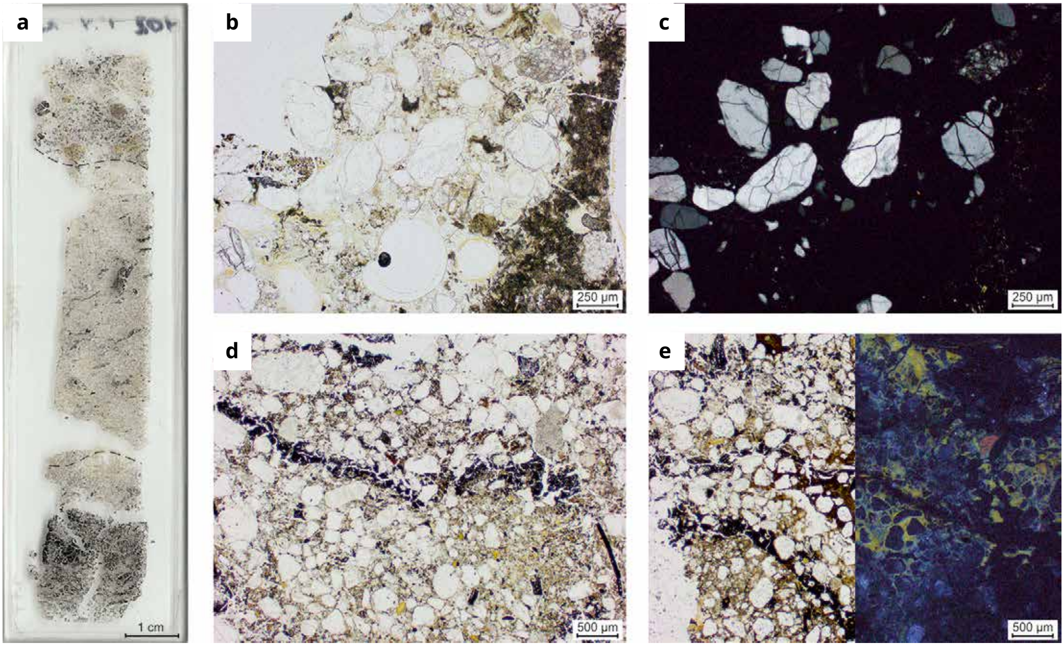


↑ **Figure 3. Photomicrographs of household waste deposits from Hedeby. a) A fish bone (yellowish arc-shaped object with spines) surrounded by charcoal, uncharred plant remains and organic material; b) phytoliths (transparent saw-like objects in the centre) embedded in herbivore excretions (Photos by S. Khamnueva-Wendt; images modified).**

trampling features, enrichment with organic material and the presence of various inclusions such as bones, wood, seeds, charcoal, or ash. Space use patterns as well as a functional differentiation between and within domestic and industrial spaces can be revealed by micromorphology, best combined with other techniques.

Coming back to our imaginary trading place, in the dark earth strata one may find micro-artefacts providing clues about the household activities, manufacture and trading activities at the site. For instance, fish bones and excrements of herbivores were identified in waste deposits in Hedeby, the most famous early medieval trading settlement in Northern Germany, pointing to the presence of households in the direct vicinity (Fig. 3a and 3b). With the help of reference materials, it is even possible to distinguish excrements of humans, pigs, sheep/goat, cattle, carnivores, rodents and chicken. While phytolith analysis of bulk samples has been recently actively used in archaeology, their direct investigation in thin sections can enable even more meaningful interpretations. Phytoliths are microscopic silicate particles that are produced by some plants (especially grasses) and remain when the organic residue has deteriorated. The study of phytoliths in thin sections provides all the contextual information. This enables an understanding of their depositional history, whether they reflect crop cultivation at a site, whether they are remains of decomposed plant mats or whether they are embedded in excrement material, which was the case in waste deposits at Hedeby (Fig. 3b).

Hedeby's character as a major trading and manufacture centre was also greatly visible in another thin section, which included three units (Fig. 4a). The lowermost charcoal-rich unit contained abundant micro-fragments of iron slags and hammerscale fragments, *i.e.* cooled sparks from forging, as well as numerous silica slags containing fissured quartz grains (Fig. 4b and 4c). Such damage on quartz cannot be the result of a usual household fire; it points to high-temperature heating in a manufacturing process. Thus, we are able to "see" a workshop of a blacksmith nearby. The following sand-dominated unit contained clear trampling features demonstrated in sub-horizontal orientation of matrix components and numerous cracks on the elongated charcoal fragments (Fig. 4d). Perhaps the "dirty" black charcoal layer was covered by sand to have a cleaner walking surface. Afterwards the use changed again, as the uppermost unit was



↑ Figure 4. Thin section 402 from Hedeby with workshop waste. a) Scan of the thin section with three visible units separated by dashed lines: a charcoal-rich layer at the base, a "trampling horizon" = sand layer with charcoal in the middle part, and a phosphate-rich layer in the upper part; b) silica slag with vesicles and fissured quartz grains in plain polarised light (PPL); c) same as b in crossed polarized light (XPL); d) trampling features in the middle sandy unit; e) strong phosphatisation features in the top unit, left part of the photo in PPL, right part of the photo in oblique incident light (OIL) (Photos by S. Khamnueva-Wendt; images modified).

enriched with phosphate, which indicates organic waste input. The phosphatisation features are well recognisable in oblique incident light, which reveals them by the bright yellowish colour (Fig. 4e). Another thin section from Hedeby revealed its entire secret not merely through microscopic examination, but through the additional use of a so-called *in situ* micro-XRF analysis (Wouters 2020). In this process, a very specific tiny spot ("micro") on the slide (*"in situ"*) is excited by X-rays. The energy released is emitted as element-specific fluorescence radiation and analysed ("X-ray fluorescence analysis"). It provides information about the material composition because it is characteristic of the different chemical elements. The thin section from Hedeby contained the rare finding of a silver/copper droplet. Coins contaminated with copper, perhaps even Arab dirhams, could have been processed here.

When seeing all these components of the cultural deposits in Hedeby under the microscope, one can vividly imagine the early medieval inhabitants of Hedeby and foreign merchants trying to make a good bargain.

Certainly, best reliable results can be achieved by a combination of different archaeological and geoscientific methods with as much sampled information as possible. Micromorphology can be a great help in unravelling the challenging palimpsest character of dark earths and other geoarchives, which record various activities occurring on the same spot through the whole lifetime of a site. ◆

Chapter 2:

Facing Stereotypes

↑ Humans intervene in nature to organise things, but the overall system remains highly complex. Agricultural landscape on the Elbe, Germany (Photo by J. Schneeweiß; image modified).

↑ Figure 1. Reconstructed plan of the 4000-year-old settlement near Bruszczewo, Poland (Illustration by S. Goetze, Kiel; image modified).

Jutta Kneisel, Janusz Czebreszuk, Wiebke Kirleis, Johannes Müller

Out of Sight is Out of Mind: Bronze Age Waste Management – Back to the Year 1800 BCE

It is summer, the beach is tempting. But instead of space for your own towel, you find rubbish on the beach that other people have left behind: Bags of chips, plastic bottles, paper towels and leftover food. It does not matter whether you want to swim in the Kiel Fjord or the Havel River; the picture is the same everywhere. Clean shores only exist where rubbish is regularly picked up by volunteers or the city administration. Is this a phenomenon of modernity, of our throwaway society or of excessive individualism according to the motto "after me, the flood"? Or can littered environments also be found in earlier human societies?

Scientists of the Cluster of Excellence ROOTS have found answers to this question during excavations of an Early Bronze Age settlement in Poland. In Bruszczewo, thanks to the good preservation conditions, it was possible to make precise statements about the waste behaviour of the population at that time, which lived almost 4000 years before us. Surprisingly, it hardly differs from our behaviour today.

An exceptionally well-preserved site

The Bronze Age settlement near the present-day village of Bruszczewo in the municipality of Kościan about 300 km west of Warsaw is built at the beginning of drastic social and economic changes. As a new alloy, bronze replaces stone tools and leads to far-reaching trade and exchange relations across Europe. In Central Europe, the so-called Únětice groups (named after a site in Bohemia) establish themselves, including the owners and manufacturers of the Nebra Sky Disk. On the eastern edge of the Únětice area lies the 1.3 ha settlement of Bruszczewo on a spur jutting into a lake. It is fortified by a massive ditch, a rampart and palisades and thus separated from the hinterland (Fig. 1). Towards the lake shore, it is closed off by two rows of parallel wattle walls and a beam construction.

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At the end of the settlement period, the water levels rise. This ensured that the remains of the Bronze Age village were sealed off from the air. As a result, organic materials have also been excellently preserved. Today, they enable us to reconstruct life in the settlement and the environment at that time in great detail in close cooperation with many scientific disciplines. For example, drill cores from the lake provide botanists with information about the pollen composition and pollution of the lake. The distribution of charred grain and its waste products, such as chaff and husks, indicates where grain processing took place and where waste was disposed of. Zoologists determine the animal bones found at the site and can thus study the distribution of individual animal species in the settlement. A woodworking site with shavings shows us the place where the poles for the wattle and daub wall on the lakeshore were prepared. Finally, the archaeologists are responsible for the "remaining rubbish".

During the excavations, a total of one tonne of pottery shards and vessel remains, as well as tools and jewellery made of wood, bone, stone, horn and bronze were recovered. The distribution of these artefacts tells us about the organisation of the craftsmen's workplaces in the settlement and whether they were used communally or associated with specific households. But it can also be used to read the "waste behaviour" of the people at that time, because all these finds, which arouse enthusiasm among archaeologists today, were thrown away as settlement waste 4000 years ago. Individual pieces, such as a bead or a small needle, may have been lost items, but the majority of what is left behind consists of discarded rubbish. Its distribution patterns in and around the settlement reveal whether it was carelessly discarded or collected, separated and recycled.

Recycled

What we mean by recycling today – the reprocessing and reuse of waste – is difficult to prove for the past. Did people regard animal bones as food waste that they reworked into tools to avoid waste accumulation? Probably not. Rather, we assume that animal bones served as raw material. The avoidance of waste with the aim of reducing waste is a modern phenomenon. However, numerous bone tools prove that bone was a valuable material that was well-suited for the production of tools or even jewellery. Thus, numerous bone points for leather processing, as well as scrapers, pins and smoothing tools for textile and pottery production and for house plastering are found in the settlement. Antlers, which were usually collected in the forests in spring or, more rarely, also came from hunting game, could be used to make hammers and hoes for working the fields. Antler and bone were also used to make jewellery pins, buttons and pendants. The discovery of bone ice skates is evidence of winter ice fun. Horns from cattle and aurochs were also used. Although the horn objects themselves are no

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↑ Figure 2. Perforated pottery sherds from the Bronze Age settlement of Dobbin, Mecklenburg-Western Pomerania (Photo by A. Heitmann, Kiel Univ.; image modified).

longer preserved, traces of cuts on the bony horn cones prove the use of horn as a valuable material. Larger bone remains were even used to build houses. They were used to wedge house pales into their pits. This was twofold cleverness, because the bone waste thus reused disappeared in a useful way and saved laborious stone gathering that could alternatively have been used to wedge the pales.

In addition to bones, the inhabitants of Bruszczewo also recycled shards. Shards of clay with rounded edges or with holes drilled through them are evidence of this at Bruszczewo and elsewhere (Fig. 2). In this way, shards of broken vessels were reworked into net sinkers, spindle whorls or game pieces. Textiles were also reused, *e.g.* in pottery production to keep the clay or the vessel moist for further processing. Textile marks on the vessels indicate that they were old, worn textiles. However, these finds form only a small part of the total inventory of finds at Bruszczewo. The vast majority of the animal bones and sherds ended up as waste.

Separated

It can be assumed that during waste disposal still usable parts, such as bones or antlers, were put aside and processed at a later time, but waste

↑ **Figure 3. The settlement of Bruszczewo on a morning in early autumn 3800 years ago. Reconstructed view according to excavation findings (Illustration by S. Goetze, Kiel; image modified).**

separation in the true sense hardly existed at that time in Bruszczewo. However, we can sometimes recognise the disposal of specific items in different places. Separate areas for animal bones from hide processing and for the disposal of large meat bones (hip, shoulder) can be detected. While the remains of fur processing (skulls and foot bones) were found in the central settlement area, the majority of the large bones was disposed of at the edge of the settlement and in the lakeshore area. Threshing remains, which accumulate immediately before food preparation, were also found in the lakeshore area and were apparently disposed of there in a targeted manner. This had the advantage that they remained moist on the shore and in the lake and were not blown through the settlement by the wind. Different work processes could therefore lead to specific waste disposal.

Gathered

The gathering of waste and rubbish can only be proven indirectly. Household waste was disposed of in the settlement in pits that were not designed as waste pits, but had previously had another use, *e.g.* as storage or stock pits. The various backfill layers of these pits prove that they remained open for a longer period of time and were gradually filled with household waste. The waste was not collected and disposed of in a specially dug pit, as we still know from the 1950s in rural areas in Germany. Instead, it was gradually disposed of in open pits that were no longer needed and filled back in this way. But not all rubbish ended up in pits, because rubbish, mostly shards and bones, was also found between the houses and on the paths. The fact that they remained there unnoticed for a longer period of time becomes clear from their small size, especially on the frequently used paths, because people moved the shards and bones repeatedly and they were gradually broken into smaller and smaller pieces (Fig. 3). Accordingly, Bronze Age people at Bruszczewo collected and disposed of only part of their rubbish. Another part ended up on the doorstep and the paths, where it was mixed with mud and other rubbish. Over time, considerable layers could accumulate in this manner, which are often particularly rich in finds. Archaeologists then speak of cultural layers.

The litter behaviour is best shown in an excavated house area on the lakeshore. There it was not possible to dig pits in the damp subsoil. The waste therefore had to be disposed of elsewhere or in a different way. At the beginning of the 18th century BCE, three houses were built below the spur near the lakeshore. They were later destroyed by fire, but not everything burned. For example, the remains of one house with beam walls survived a few centimetres high. The layers inside and outside the houses contained everything that archaeologists desire: Food remains in the form of bones and charred food, burnt and cracked pots, tools and occasionally lost pieces of jewellery – in short: rubbish (Fig. 4). However, bones and vessel remains predominated in the finds from the site and were particularly concentrated in the rear wall area of the western house. Occasionally, up to 6 kg of bone and 5 kg of pottery were found per square metre. The path between the houses was also rich in finds, with large quantities of bones and sherds lying around. At least from today's perspective, it is an unpleasant idea to have walked in the wet mud on all this rubbish when it rained.

When digging in the western house, the students found one bone next to the other. Did the in-

↓ Figure 4. The wall of the western house during the excavations. In the foreground, the bottom of a vessel lies under the overturned mud wall. Behind it, bones can be seen in the exposed section under the wall (Photo by J. Kneisel; image modified).

habitants of the house at that time simply throw the gnawed bones away or did the house burn down before the bones could be swept away? The evidence is contradictory. Dog excrement indicates that the house may have been empty for a while before it burned down and was used specifically for waste disposal. In contrast, almost completely preserved vessels and a charred grain store indicate that the house was still inhabited shortly before the fire. In the other houses, there is considerably less rubbish, but they have been heavily flooded by lake water, which might have carried out some of the waste that was originally there.

Perhaps we are simply dealing with very unhygienic living conditions. Other observations also suggest this. On a neighbouring area, an up to ten-centimetre-thick layer of dung was found along the wall of a building. Since the house was located directly on the lakeshore, a dung heap at this location is rather unlikely, although we know that the collection of dung and targeted manuring had already been practiced for a few centuries to achieve higher crop yields.

Carelessly discarded

An astonishing amount of rubbish was found among the fascines on the lakeshore. The distribution of tools, such as antler picks, hammers and bone tools, is interesting here. While functional tools and semi-finished products were found in the houses, waste and unusable, broken tools lay between the fascines and in the lake. It is easy to imagine a craftsman, annoyed, flinging the just-broken tool into the fascines and the lake.

A stroke of luck for archaeological research was a woodworking site at the fascine where wood chips, various broken boards and tools as well as a broken wheel hub had simply been left lying around. Masses of pine shavings (kindling), small burnt pine that had served as light sources, lay in the shore area. After use, they were thrown away in the damp shore area, where they have survived to this day. They were as common there as cigarette butts on the beach today. In addition, there were the aforementioned shards, bones and threshing remains – everything flew unceremoniously into the lake. Out of sight – out of mind. The archaeologists were thus faced with a picture not dissimilar to today's lakeshores. Instead of bones and pottery, now plastic, glass and butts are lying there.

Polluted

Analyses of a sediment core from the lake allow a further look at the waste behaviour 4000 years ago in Bruszczewo. Pollen, spores, algae and remains of microorganisms have been deposited in the lake sediments over the centuries. Palynologists, who research pollen grains as well as other microfossils, can identify these remains and read the deposits like annual rings on a tree. This gives them a good insight into the environment and water quality at the time. The analysis of the sediment core shows clear evidence of pollution. For example, the palynologists were able to detect high levels of blue algae (Cyanobacteria), which must have severely impaired the quality of the drinking water, at least seasonally. Alternative sources of drinking water, such as wells, did not exist in the settlement. Special fun-

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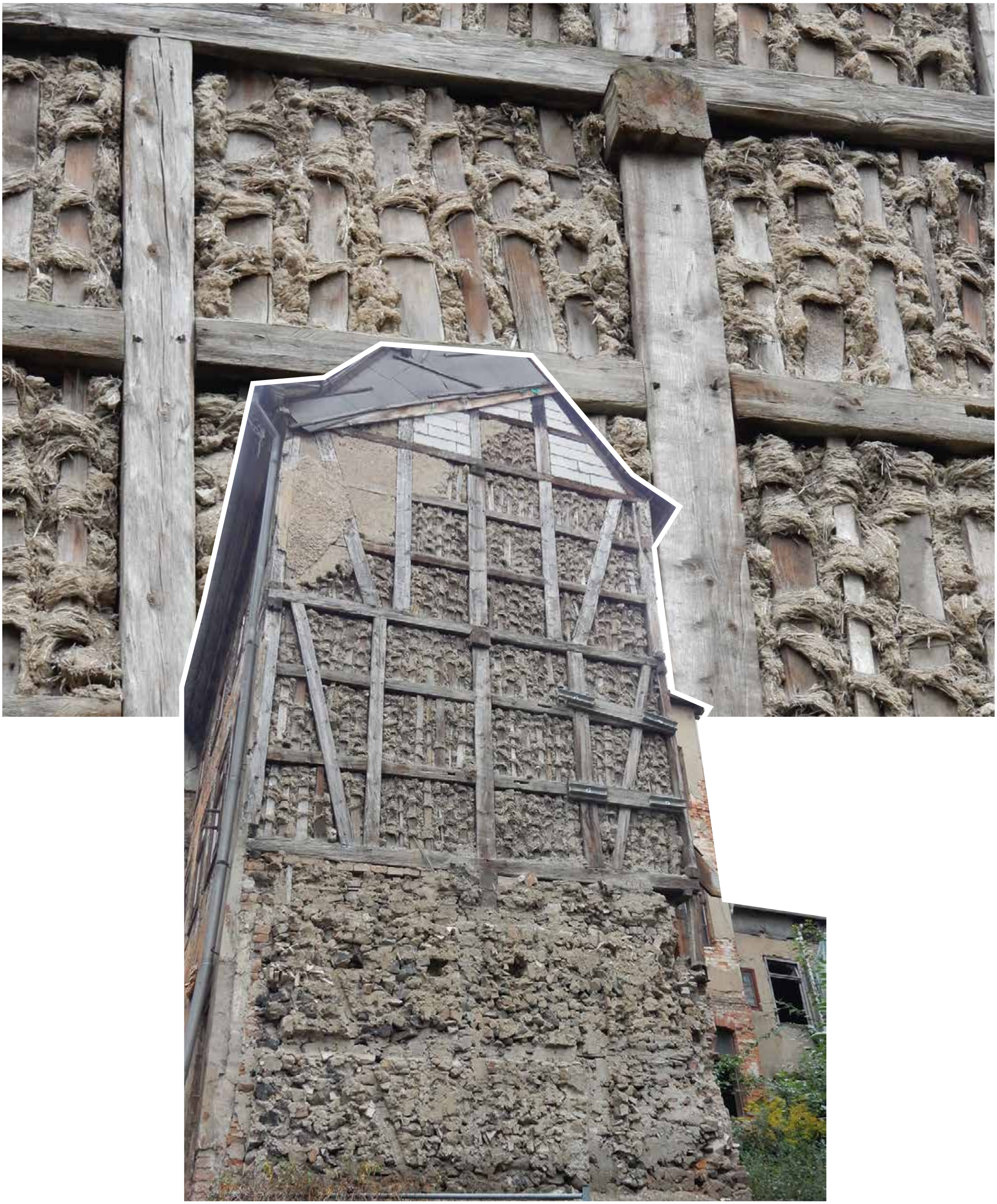
gal spores growing on dung testify to strong dung input, which promoted the growth of green and blue algae. Numerous remains of whipworm eggs also prove that animals – and probably also humans – suffered from worm infestation. Seeds of henbane, which appeared in large numbers in the settlement, speak for a parasite infestation of humans with the corresponding complaints. Henbane is a poisonous plant that has a strong intoxicating effect and was used medicinally in ancient times against pain and cramps, precisely those complaints caused by worm infestation or bad drinking water. Mistletoe, which has also been identified from pollen in the sediment profile, is known to us from ethnographic parallels as a remedy against worm infestation. Obviously, the people of that time knew how to help themselves against physical symptoms. However, they were probably not aware of the connection between the pollution of their drinking water and the diseases. Otherwise, they would have done something about it. But of course, we know from our own experience that recognising environmental pollution does not mean that something is immediately done about it.

The pollution of the water in Bruszczewo can well be attributed to the fact that people carelessly disposed of their waste in the lake and gave animals free access to the lake, allowing excrement and manure to enter the water. It is striking that the significant pollution in Lake Bruszczewo only occurred during the Early Bronze Age settlement between 2100-1650 BCE. During subsequent settlement phases, such as the Later Bronze Age (1000-700 BCE) or the early Middle Ages, there is no evidence of such pollution of the lake. It is possible that the connection between littering and eutrophication was recognised and the lake was prevented from tipping over. Obviously, later inhabitants of the area dealt with their waste differently.

Can we learn from the past?

Bruszczewo shows: The waste behaviour of people 4000 years ago is not much different from our behaviour. The motto "out of sight, out of mind" still applies, both on a small and a large scale. Admittedly, today we are aware of the cause-effect patterns, as a result of which a change in the way we deal with waste has long been taking hold. Especially in individual living areas, a lot has changed in the last 4000 years. Waste separation and recycling today are attempts to reduce the amount of waste. But landfills and an excessive application of manure to the fields contribute to environmental pollution just as much as the disposal of waste in the lake did back then. The problem has merely shifted. Targeted recycling can only be proven in a few cases in the distant past. Instead, much leftover waste was considered a raw material that was still available in sufficient quantities to be used when needed. The aim was not so much to avoid waste as to use all available resources, because the procurement of raw materials was laborious. A look at the past teaches us that it is not the waste that is the problem for man and his environment, but how we deal with it, our waste behaviour. Separated waste helps to conserve resources and provides valuable materials for the future. Maybe the next time you clean, use an old T-shirt instead of a new microfibre cloth? ◆



Benjamin Claaßen

From Weeds to Construction Material: Rye in Germany

Rye is more popular in Germany than anywhere else in the world. Nowadays, this cereal grain can mostly be found in bakeries. Bread and buns made from rye act as a traditional and rustic alternative to plain wheat bread. For many, the characteristic rye-sourdough is a welcome change to the common yeast-based pastries. In addition to bakeries and supermarkets, rye became a staple for feed in livestock farming.

With its massive popularity in Germany, it is no surprise that the Central European country is the leading producer of rye. But even outside of Germany, rye-based products and pastries are becoming increasingly popular. But what makes rye such an important agricultural crop?

People tend to put the things that surround them into different categories and label them. This is also true for plants. Domesticated plants of high economical value and importance for sustenance, *e.g.* rye, are called *agricultural crops.* Plants that we do not think of as particularly useful are called *weeds*.

Weeds lack any apparent value and are not regarded as useful at all, sometimes they even cause economical damage. They grow rampant in cultivated gardens and fields, suppressing and overgrowing more delicate crops. Their removal is cost and labour intensive and their growth robs the soil of important nutrients and valuable water. In summary, nobody in their right mind would try to cultivate such weeds.

← Figure 1. a) So-called *'Wellerhölzer'* in open compartments of a half-timbered house; b) the straw material used to wrap the timbers is clearly visible (Photo by F. Schlütz, Kiel Univ.; image modified).

Historically, botanists tried to classify plants according to their morphology and traits. Based on features, such as number or shape of their petals, people tried to draw conclusions about the phylogenetic relationships of all plants known to man. With the emergence of molecular methods of identification, it later became possible to test and sometimes correct the proposed relationship on the basis of genetic sequences.

The classification of plants as crops and weeds is anything but scientific. It lacks any molecular or morphological rationale and is solely based on our human perspective. While we have very good reasons to label highly important agricultural crops as useful, we dismiss any plant not obviously useful to humans as weeds. But is this reasonable? Is this fair?

Today, we undoubtedly regard rye as an important crop. After all, we put a lot of effort and resources into its cultivation. But has rye always been this important crop that we know and cherish?

Success story of a weed

The predecessor of rye that we know today probably originated from an area which now makes up parts of Armenia and Eastern Turkey. Rye arrived in Europe around 4000 BCE, some 6000 years ago, and then gradually spread across the continent over the next 4000 years. By the Middle Ages, rye became the most popular cereal grain in Germany and parts of Central Europe.

From the wild to the fields

When rye came to Europe, it was a very different plant than the crop that we know today. While it already had some of its current features and traits, these were not as developed and its full potential still remained undiscovered. Rye found its place in fields of wheat for a long time.

While it thrived for millennia in close proximity to wheat, wild rye was exposed to the controlled conditions on the wheat fields and rye that was found on these fields was thus very well-adapted to the growing conditions of wheat. Presumably, this was also how farmers learned of the desirable traits of rye and its potential as a cultivar. Soon the agricultural significance of the weed started to rise. The traits that made rye especially important were its resistance to frost and its modest demands for nutrients. As a result, the former 'weeds' became more interesting from an agricultural point of view.

The rising popularity of rye resulted in a change in perception about the plant starting around the beginning of the Common Era (CE). The former weed that hampered the production of wheat became one of the most important and desired crops of medieval Europe. Its robustness and versatility led to the great importance of rye.

Rye as a construction material

At its prime, rye was more than just grains and livestock feed. People used the cereal as material for the construction of the, then common, half-timbered houses. Rye straw was one of the most common materials for so-called *'Wellerhölzer'*, also referred to as *'Lehmwickel'*. These are wooden boards, often oak, which are wrapped in straw and clay. They were used to fill the gaps, so-called *'Gefache'*, in the wooden framework of houses, before they were plastered with clay (Fig. 1). In addition, *'Wellerhölzer'* were also used as insulation material in ceilings.

They were made by cutting straw to size and soaking it in a mix of water and clay. Following that, the boards were wrapped in the straw and additional clay was added. *'Wellerhölzer'* were mainly used in the construction of half-timbered houses. While any type of straw could potentially be used to produce *'Wellerhölzer',* people usually used cut and threshed rye, because it was readily available as a by-product of the large-scale cultivation of rye.

Its unusual role as a resource for construction material underlines the special importance of rye for the people of the Middle Ages, who found alternative uses for the cereal than just food in the form of material for housing and created a remarkable example of adding value to a seemingly useless by-product of food production. In this regard, and because of the agricultural techniques of its time, rye, the former weed, rose in significance as a crop in the Middle Ages.

A matter of perspective

From its origins in Western Asia to the fields of today, rye has undergone a considerable domestication process (Fig. 2). Adaptation to the conditions of European wheat fields and extensive selective

» Weeds lack any apparent value and are not regarded as useful at all, sometimes they even cause economical damage. Nobody in their right mind would try to cultivate such weeds. «

↑ Figure 2. Winter rye *(Secale cereale)* in modern agricultural cultivation (Photo © R. Graß, Kiel Univ.; image modified. Retrieved from: https://www.pflanzenbau.uni-kiel.de).

breeding for many generations cumulated and further enhanced its numerous agriculturally important traits.

Together with the plant, the human perception of the plant has changed. From the unwanted weed competing with bread wheat on the fields, to the most important cereal crop, providing not only food for the people, but also shelter from the cold and rain, rye has undergone a complete makeover.

With the changing of the times, our perspective changed too. And it is still changing today. In Germany, rye is still very popular. But just like half-timbered houses are no longer the dominant structures in our cities, rye has lost some of its glory. With the decline of half-timbered houses, rye has lost its former significance as a building material. Moreover, modern agricultural methods allow for the cultivation of a wide variety of cereals. Frost resistance and robustness of rye are no longer enough. Furthermore, international trade makes almost every imaginable agricultural product available, the whole year round. While rye is no longer the important cereal it used to be, it remains exciting to find out which current weeds will become 'the next rye'. ◆

Dana Zentgraf and Jens Schneeweiß

Turning Soil, Changing Perspectives – How Modern Sustainability Concepts and Past Ways of Life Meet in the Garden

The German Federal Environment Agency (Umweltbundesamt (UBA)) informs that: "Leaves, green waste, twigs and roots of bushes or other small trees as well as lawn cuttings are considered as garden waste". (Source: https://www.umweltbundesamt.de/umwelttipps-fuer-den-alltag/garten-freizeit/gartenabfaelle#gewusst-wie). Furthermore: "It is advisable to compost this waste directly on the premises."

At first, this seems to be a platitude. However, when considering trends in garden landscaping that have been established predominantly in the suburbs of the western world in the post-war era, the significance of the claim becomes obvious: gardens made of gravel and homogenous lawns have become common models for landscaping. Both designs are supposed to be functional as well as appealing to the eye; their care can be achieved with minimal technical equipment including lawn mowers, industrial fertilisers and pesticides (Fig. 1). Nonetheless, the disadvantage of these gardens are the repercussions that they have on the ecology such as a lack of biodiversity, soil compaction and frequent use of fertilisers.

In contrast, garden waste disturbs the sterile order of plots of land. It is therefore often disposed of at recycling centres and not composted on site as recommended by the German Federal Environment Agency.

This practice stands in significant contrast to the value and care of fertile soil as one of the oldest motives of human cultural activity. It thus appears reasonable that with the advent of the environmental movements in the 1970s, questions regarding possibilities of alternative forms of garden landscaping and agriculture have arisen and have since also entered the realm of recreational gardens.

← Figure 1. A garden ideal that is often aspired to: bedding plants that are aligned along straight edges and English lawns need a lot of care if they are to remain accurate (Photo by M. Zentgraf, Berlin; image modified).

With the awareness of the ecological crisis, people are increasingly searching for possibilities to enhance and adapt their own scope of actions. These questions belong to the area of practical philosophy and affect an individual's way of life and accordingly the shaping of communities: What can I personally do to contribute to the preservation of the planet? Which principles should I follow? How can I act responsibly and be actively involved in processes of change? As a reaction to these reflexions, many people are trying to reorganise their everyday life, for example, by engaging in sustainable gardening. In accordance with a strong sense for sustainability, gardens are increasingly being cultivated without commercial products and solely with the use of home-grown fertilisers and organic care products. The recommendation of the German Federal Environment Agency (UBA) marks a shift in the understanding of gardens as a static concept towards a dynamic circular system.

The growing tendency towards a circular garden economy bears witness to a shifted perception of gardens. Circular economies respect the natural dynamics of gardens (Fig. 2). Although garden products are inherently human and thus strongly influenced by cultivation practices – such as paradisical oases in deserts – garden components are invariably dependent on the seasons, regional ecologies and the worldwide climate. The ancient Greek philosopher Heraclitus (520-460 BCE) remarked that one can never descend into the same river twice; in analogy, the same applies to gardens. The morning garden covered with dew is different to the one covered with blossoms that only open up during the day and turn towards the sun – which draws the flower clock of the Swedish natural scientist Carl de Linné (1707-1778) to mind. The circular garden is concerned with the character of the dynamic of gardens and purposely draws energy from the alternating circumstances and sequences during a garden year.

What does this mean for the waste household of gardens? A circular garden economy is based on the principle that everything a garden yields should stay in the garden and only very little should be substituted externally. Following this guideline, green and vegetable waste or dung are used for composting and fertilisation of the patches and trees. Instead of industrial fertiliser, muck from stinging nettles or horsetail and mixed crops are used in the patches. Regarding the tools, decorations and amenities of humans, it is advised to make use of durable products and to avoid synthetic materials so that little waste is produced. This approach is rooted in the vegetative phases of plants: during times of abun-

» A circular garden economy is based on the principle that everything a garden yields should stay in the garden and only very little should be substituted externally. Following this guideline, green and vegetable waste or dung are used for composting and fertilisation of the patches and trees. «

↑ Figure 2. Compost is the basis of the circular garden. In the course of the year, waste is collected in a circular garden, which is transformed into valuable compost by insects, snails and microorganisms. Without compost there is no cycle! (Photo by M. Zentgraf, Berlin; image modified).

dant green waste, the same are collected and properly composted for reuse or directly applied to the patches as surface mulch.

Refraining from the use of industrial products required that the pioneers of circular gardens search for alternative techniques that were implemented in the past. This is why they draw on pre-industrial methods for the preservation of the soil, methods of past generations. Among them, we can find, first and foremost, the composting and reuse of waste, ashes and plant residues: "As countryfolk knew, odoriferous manure made for plentiful harvests", as mentioned in the study *Aroma. The Cultural History of Smell* (1994, 57) by Constance Classen, David Howes and Anthony Synnott. This idea is experiencing

» What has been considered as useless waste in the recent past, is now being considered as useful and important after receiving a re-evaluation within the context of circular gardens. «

↑ **Figure 3. Archaeological excavation in Bardowick, Lower Saxony. The remains of medieval pits (foreground) are covered by a garden soil *(hortisol)* up to 1 m thick, which has developed over the last 800 years. It is clearly visible in the excavation border (Photo by J. Schneeweiß; image modified).**

a revival, which means: what has been considered as useless waste in the recent past, is now being considered as useful and important after receiving a re-evaluation within the context of circular gardens.

What is currently even being considered as a movement against the capitalist consumerist society of post war times and found its way into the cultural practices of gardening, had long been common practice in gardening and landscaping, which becomes evident through archaeological research: people's own gardens have played an important, if not essential, role for humans at different times and places. In many places, it still does today. The example of medieval Europe shows that in relatively short periods of time of no more than two to three centuries the traces of settlements can accumulate in early urban as well as in rural contexts. Often, we are dealing with huge black layers of earth, whose remarkably dark colour results from a high percentage of charcoal and humus. The thickness of the layers bears witness to the fact that the soil was supplied with significant amounts of organic material and that it has been broken up regularly. In most cases, this soil cultivation becomes recognisable through a mixed structure meaning a lack of a distinctive, visible layering. A particularly active soil life additionally supports this. Nowadays, we can assume that people in the Middle Ages were aware of the value of fertile soil and that they knew how to positively influence this. Literary sources passed

» Namely, an unintentional side effect of the application of waste in gardening is that we simultaneously transport information via minerals, nutrients and artefacts.

Thereby, the soils enable conclusions about the activities and 'waste management' of past populations. The soil itself becomes a witness of the past, an archive of cultural history with an individual composition and various characteristics. «

down from antiquity onwards describe soil cultivation in detail and list different individual fertilisers for plants and cultivation methods with the help of donkey, cattle or chicken dung as well as human faeces. Thus, husbandry was not only necessary for the meat production of farms but also played a vital role in the cultivation of fruits and vegetables during premodern times (as well as in modern bio-dynamic farming concepts).

Soil sciences have classified this type of soil: the *hortisol* (= garden soil) was declared soil of the year in 2017 (Fig. 3). Anthropological waste, like shards, charcoal or bones, are a component of its pedological characteristics, which renders it anthropogenic. From an archaeological perspective, these 'waste' objects can be regarded as valuable finds. Accordingly, we speak of 'cultural layers' that may also contain residues of tools, coins and jewellery.

Usually, we quite literally trample all over the ground and soil and we do not understand its relation to past human interventions. However, the *anthrosols* – meaning the black soils that can be traced back to human activity – have undergone a re-evaluation in the scientific discourse. Namely, an unintentional side effect of the application of waste in gardening is that we simultaneously transport information via minerals, nutrients and artefacts. Thereby, the soils enable conclusions about the activities and 'waste management' of past populations. The soil itself becomes a witness of the past, an ar-

» In the same way as our perception of modern gardens changes the way in which we view soil as a dynamic system, anthropogenic soils are increasingly becoming the focus of historical sciences. «

chive of cultural history with an individual composition and various characteristics. Within historical-archaeological research, dark garden soils constitute a recent and growing field that started with decorative gardens but increasingly includes common kitchen gardens as well. In this context, it is no more the archaeological finds that are the focus of attention but rather the archival function of the soil and its fertility that has grown over centuries. Formerly a physical ground, the soil itself acts as evidence (Fig. 4). Such soil functions as a source of knowledge that offers information about the past as well as an object of science at the centre of an investigation. Not completely scientifically tangible, the soil evolves into an epistemic object. The material consistency of old garden soils is not affected by this new attention, however, they become something different, namely scientific objects under investigation promising insights into human activities. This is made possible through chemical, physical, macro- and microscopic analyses that have long advanced to the extended methodology of modern archaeology.

In the same way as our perception of modern gardens changes the way in which we view soil as a dynamic system, anthropogenic soils are increasingly becoming the focus of historical sciences. While these layers have long been regarded as containers of archaeological finds, additional information can be gathered and decoded from these valuable archives. The growing popular interest in human-environmental relations and their historicity additionally supports the exploration of the – definitely ambivalent – past relationship between humans and their waste.

It is remarkable that the realisation of the archival function of soils and the growing interest to investigate them coincides with a dramatic decline of preserved soils, not only the *anthrosols*. The effort to

↑ Figure 4. Geoarchaeologists sampling a garden soil *(hortisol)* in Bardowick, Lower Saxony. The analyses are supposed to provide information about subsistence farming and garden use since the 13th century (Photo by J. Schneeweiß; image modified).

preserve and protect soils that grew over centuries is thus at the same time a sign of their destruction. Accordingly, attempts are made to counteract the process of decrease with recovery:

"The garden waste collected by councils can be processed into valuable compost in central composting facilities. [...] The produced compost is often being offered to citizens, for example in the form of potting soil." (Source: https://www.umweltbundesamt.de/umwelttipps-fuer-den-alltag/garten-freizeit/garten-abfaelle#hintergrund).

According to the German Federal Environment Agency, this rounds up the regional circular system. This definitely holds true and certainly promotes a more sustainable lifestyle in the sense of a circular economy. However, in the same manner, the local and regional history archived in the soils is being completely destroyed. This means that archives are being lost comparable to the smelting of old gold coins to produce new jewellery. Only the recognition of the soil as having both cultural and natural history value as well as biodiversity worth protecting can eventually lead to its preservation. ◆

Chapter 3:

Use. Reuse. Refuse

↑ Antique capital of a column that was converted into the base of a hand rotary mill (Ulpia Sarmizegetusa, Romania) (Photo by P. Thomas, Deutsches Bergbau-Museum Bochum; image modified).

↑ **Figure 1. Public fountain in Pompeii, Italy (Photo by N. Lamare, 2012; image modified. With permission of the Ministero della Cultura - Parco Archeologico di Pompei. Prohibition of reproduction or duplication by any means).**

Nicolas Lamare, Max Grund, Guillermo Torres

"Water, Water Everywhere, ... nor Any Drop to Drink"? Water Waste, Reuse, and Quality in Ancient and Medieval Times

Water supply and wasting water: Beyond stereotypes

"With so many indispensable structures carrying so many waters you may compare the idle pyramids or the other useless, although famous, works of the Greeks!" Frontinus, to whom we owe this statement, was the *curator aquarum*, the head of Rome's water department in the 1st century CE. The treatise he wrote, "On the Water Supply of the City of Rome" *(De Aquaeductu Urbis Romae)*, provides us with valuable information on water management in antiquity. This famous quotation sums up the importance that the Romans attached to the water that supplied the many other cities of their empire, very often by means of aqueduct lines, sometimes overground and passing over aqueduct-bridges, the silhouettes of which still mark today's Mediterranean landscape. Associated with the great baths of Rome and the provinces, but also with the small or large fountains well-known in the streets of Pompeii and Herculaneum (Fig. 1), they contributed to the creation of a picture of a Roman civilisation of water and became synonymous with sumptuary expenditure or Roman subsistence.

Note: Quote in the title after "The Rime of the Ancient Mariner" by S.T. Coleridge (1798).

» These discoveries are important, since they indicate that the Romans were not only careful not to waste water, but might also have been aware of the need to store it. «

↑ Figure 2. Well catchments were essential for the water supply. Picture from Boccaccio, *The Decameron*, trans. by Laurent de Premierfait, 15th century; image modified (Source: Bibliothèque nationale de France, Bibliothèque de l'Arsenal, MS 5070 fol. 182r; gallica.bnf.fr / BnF. https://gallica.bnf.fr/ark:/12148/btv1b7100018t/f377.image).

Recent research has shown, however, that aqueducts could indeed be sealed shut by means of metal valves that redirected water to large public cisterns that probably filled up during the night. Apart from Italy, remains of such systems have been identified from France to Jordan and from the Netherlands to Tunisia. These discoveries are important, since they indicate that the Romans were not only careful not to waste water, but might also have been aware of the need to store it, in case of shortage or irregularity of flow from the spring. This concern continued, and perhaps increased, in late antiquity (ca. 4th-6th century CE) as evidenced by the Yerebatan Sarnıcı, one of the great underground cisterns of Istanbul, which was then the new capital of the empire known as Constantinople.

The supply of drinking and untreated water was also crucial for European medieval cities with their high population densities. While in the early stages of city development, the use of river water and maybe wells sufficed the needs of the inhabitants, these systems reached their limits as the cities grew. If there was no clean river water and the wells were soiled, often due to latrines in their neighbourhood, other solutions had to be found. The use of wood and lead discharge lines for water supply was one of the most common methods, even if they were associated with difficulties. Water was intercepted at

➜ Figure 3. The "Schöner Brunnen" of Nuremberg, 14th century, Rijksmuseum Amsterdam; image modified (Photo by F. Schmidt, 1895. Source: Rijksmuseum, https://www.rijksmuseum.nl/nl/collectie/RP-F-F18284; © Creative Commons public domain CC0 1.0. https://creativecommons.org/publicdomain/zero/1.0/).

➘ Figure 4. Roman tap, Rome, Museo della Civilità Romana; image modified (Photo: Le plombier du désert. Source: Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Robinet_d%27arr%C3%AAt_%C3%A0_boisseau_romain_en_bronze.jpg; CC BY-SA 4.0. https://creativecommons.org/licenses/by-sa/4.0/deed.en).

clean rivers or springs (Fig. 2), brought to the cities by wooden pipes and was made available in public fountains. Within the city, it was possible to use lead lines to produce more pressure for the fountains. In times missing a *Pax Romana*, the supply of water for cities from outside was as vulnerable as never before, which is one of the reasons why the exact courses of water lines were kept secret and known only by a few. It was still quite easy to cut off the cities from these crucial supplies.

Fountains were not just necessary for urban life, but were often built in a monumental way, as seen in the Roman imperial period and later times. One of the most stunning examples of medieval representative fountains is the "Schöner Brunnen" of Nuremberg, built in the late 14th century (Fig. 3). The fountain itself was supplied by two discharge lines. From these sorts of fountains, various stages of use, reuse and discharge of the water were common.

Uses and reuses: the multiple lives of water

The flow of water in the Roman aqueducts could be controlled, yet other means were also used at the scale of the users. Numerous taps (Fig. 4), very similar to ours, allowed the water to be cut off in public fountains or baths. More utilitarian valves hidden from view were operated to open or cut off the flow of water to small garden fountains in the houses of the wealthy elite, as in the Casa del Torello di Bronzo in Pompeii. However, taps were not found at the extremity of each pipe: the water from the public fountains certainly flowed throughout the day and simply overflowed from the basin onto the road. This clear water had its purpose though. By flowing towards the sewers, Frontinus specifies that it prevented the stagnation of waste water in these channels. Moreover, this clear water called *aqua caduca* or *otiosa, i.e.* water that has fallen or is unused, had a special legal status: no one could appropriate it except for bathhouses and fullers, whose tanning and dyeing activities required large quantities of water. Wastewater was also reused, the main example being for latrines. These public toilets consisted of a bench with holes with a continuous stream flowing underneath (Fig. 5). In Rome as in the provinces, most of these latrines were associated with public baths: the water that was evacuated or discharged from the basins was redirected to the latrines to flush them.

In the Middle Ages, the unused and surplus water of bigger fountains was not simply drained into the sewers or a river and thus wasted. It was collected and led into other discharge lines. One of the very best examples is the hydraulic network of late medieval Nuremberg described by Endres Tucher in his *Baumeisterbuch der Stadt Nürnberg* (Fig. 6). These discharge lines with collected, reused water sup-

↓ Figure 5. Public toilets, Dougga (anc. Thugga), Tunisia, ca. 2nd century CE (Photo by N. Lamare, 2009; image modified).

plied other subordinated fountains in other parts of the city. So, the freshest water was offered by the most representative fountain. It was once again collected and used to supply other fountains or subordinated fishponds. The described system is just one example of different cascades of fountains and water supply points, which guaranteed the availability of water throughout a city. In nearly every medieval city with discharge lines, surplus water of the first fountain was collected and led into subordinated supply points. Even when it was not usable as drinking water after the first or second fountain, it was often led into basins or sewers to make it accessible for cleaning or craft use. At the end of this network, it was led into the rivers or town moats. However, even at this ending point it was still often in use, as a proper way to dispose of refuse or faeces. In sum, the water, which was led into the cities with some expenditure, was used in its different stages of quality before it was disposed of and therefore led out of the city again. Even when overflowing fountains look like a waste of the surplus water at first sight, this surplus water was still used in the next stages before final disposal.

➜ Figure 6. The water of the running wells always had several stages of use. Picture from Book of Hours, Use of Rome (the 'Golf Book'), Bruges, ca. 1540; British Library, Add MS 24098, fol. 21v; image modified (Source: British Library. https://imagesonline.bl.uk/asset/12650/).

» Smell, taste, colour, appearance and temperature were features taken into account to examine water quality. «

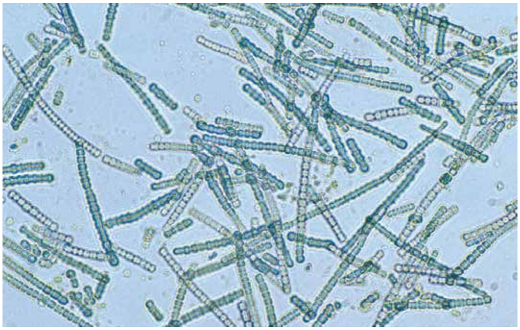
Water quality assessment: past and present views

The notion of clean or waste water must itself be characterised as it corresponds to the criteria and knowledge of each period.

The Romans used water from various sources: rainwater collected in cisterns, underground water reached by wells, river water or spring water that could be conveyed by aqueducts. There are some diverging views, but on the whole, ancient authors state that rainwater was preferred for drinking: this is indicated by Vitruvius in his treatise on architecture *(De Architectura)* written around 15 BCE during the reign of Emperor Augustus. Accordingly, the clarity of the water and the absence of algae were generally trusted. Pliny the Elder in his *Natural History* (lat. *Naturalis historia*), an encyclopaedia written around 77 CE, mentioned another selection criterion: instead of “stagnant and lazy” waters *(stagnantes pigrasque)*, running waters *(quae profluunt)* were preferred for drinking, *i.e.* water from rivers and streams, but also from aqueducts and fountains.

Different qualities of water were used for different purposes. Water filtration was common: grids were placed at the arrival of aqueducts to prevent larger debris from passing through, whereas settling basins allowed residues to settle. We know of cisterns, such as those at Dar Saniat near Carthage in modern Tunisia, which contained settling basins: as the water decanted, it became purer and each quality of water was used for different purposes, washing and irrigation, bathing, and drinking. Frontinus mentioned the construction of an aqueduct in Rome by Emperor Augustus, which distributed poor water quality, but this was intended for gardens and *naumachia*, water spectacles, which did not require clean water to be employed. Thus, smell, taste, colour, appearance and temperature were features taken into account to examine water quality, as we can learn from Vitruvius. Even the ancient Greeks were not indifferent to the quality of water. It is clear from the works of Hippocrates (5^{th}-4^{th} century BCE) that they were aware of the danger to animal and human health posed by water sources near mining areas.

Despite the great efforts made for water reuse, waste management, including waste water and personal hygiene, represented a major risk for public health. Romans, for example, lacked toilet paper, and instead used wool, moss or sponges for cleaning. Public toilets were crowded and hand washing was non-existent or inadequate. Private toilets usu-



← Figure 7. A blue-green algae species – *Cylindrospermum* sp. – under magnification at the Adelaide laboratories of CSIRO Land and Water, 1993; image modified (Source: Willem van Aken, CSIRO. https://en.m.wikipedia.org/wiki/File:CSIRO_ScienceImage_4203_A_bluegreen_algae_species_Cylindrospermum_sp_under_magnification.jpg; © CC BY 3.0. https://creativecommons.org/licenses/by/3.0/deed.en).

ally lacked running water and were commonly located in or partially separated from the kitchens. Such practices and environments stimulate the growth and dissemination of infectious diseases, particularly water-borne diseases. The observation of water with the naked eye obviously had its limits. Studies have revealed the presence of various microorganisms such as *cyanobacteria* (Fig. 7), *chlorophyta* and *bacillariophyta* in several fountains in today's cities of Italy and Spain. Hippocrates already reported individuals suffering from different kinds of intestinal diseases. Infectious diseases, such as cholera, dysentery, tuberculosis, typhoid fever, influenza, yellow fever and malaria, were among the repeated outbreaks linked to water-borne diseases when public water supplies and waste-disposal systems were inadequate or non-existent. Archaeological evidence has suggested that methods, such as tanks, sieves, filters as well as boiling water, were used during antiquity to assure water quality. The use of boiled water was widely recommended, however, was not always feasible due to ecological or economic issues. Inequalities of demand related to firewood and other combustibles were among the limitations preventing the use of this method in an extensive manner. Other studies carried out on skeletons have revealed lead poisoning in Roman populations: a direct consequence of lead use as the main component of pipes designed to distribute water under pressure in the cities.

As in antiquity, grids and settling basins were also known in the Middle Ages to enable the provision of clean water for artificial water supply. The already described urban water supply networks of wells and drains enabled the use of all qualities of water, sometimes also as a combination of different systems, *e.g.* for gardening and bathing purposes or channels for artisanal needs. People in the Middle Ages made a clear distinction between pure, clean water and water of other qualities. Spring water was particularly preferred. The provision of clean drinking water was associated with similar problems as in antiquity; the lead pipelines could also result in poisoning. Smelly or obviously polluted water was not used in most cases, certainly not for drinking. But even apparently clean, crystal-clear water could be dangerous. In times when bacteria and other pathogens were still unknown, the associated risks could hardly be avoided. ◆

Paweł Cembrzyński and Marie Jäcker

Use and Reuse of Lead in the Middle Ages – A Biography of Lead

Introduction

Living in times of abundance, we are used to throwing things away and buying new ones. Most of our items are made of new raw materials. It is cheaper than recycling old resources. However, this practice has only been the norm for a short period of history. The pre-modern past was characterised by a scarcity of resources – reusing materials was a natural need.

In the Middle Ages, metals were quite common but much more expensive. Thus, many everyday items were made of wood, wicker, clay, textile or leather. Costs of metals varied depending on the type: iron was quite easily accessible, but there was a shortage of lead or copper, not to mention silver and gold. Metals reached high prices because of extraction costs. Specialised knowledge, raw materials (construction timber, iron for tools, ropes, charcoal for furnaces), and costs of transportation from often distant places were required. Metals were therefore precious and could not be wasted. Their lavish use was considered a sign of great wealth. In contrast to today's consumption habits of constantly replacing old things with new ones, people in the Middle Ages often repaired things. Broken items were reused as raw material for other objects. Metals are relatively easy to rework. As a result, they circulated constantly in the medieval economy, changing shapes, places and owners.

» The pre-modern past was characterised by a scarcity of resources – reusing materials was a natural need. «

← Figure 1. Galena – silver-bearing lead ore. Mechernich, Eifel, Germany (Photo by N. Nezafati. Source: Collection of the Deutsches Bergbau-Museum Bochum; image modified).

↑ **Figure 2. A lead ingot (693 kg) from 14th century Olkusz discovered on the Krakow market square. Deposit in the Muzeum Historyczne Miasta Krakowa (Source: © Muzeum Historyczne Miasta Krakowa; image modified).**

In this context, one of the most interesting materials is lead. It is a heavy metal with a very low melting point (327.5 °C). Thanks to this attribute, it can be melted with little effort. It is also soft and can be shaped easily. Furthermore, it is quite resistant to external conditions, such as temperature fluctuations and moisture, and thus is durable and lasts for a long time. In the Middle Ages, lead was accessible in several places in Europe, for example, in Britain, Poland, Czechia or Germany, and played an important role in many medieval crafts in the pre-modern world. The process of production and use of lead tells a fascinating story of metal circulation in the Middle Ages. Here, we will shortly describe the bi-

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ography of lead from its origins in ore veins to the streets of Polish towns and rooftops of English cathedrals showing different ways of using and reusing lead.

How lead was produced – mines in Olkusz

One of the most important mining regions in medieval Central Europe was in Southern Poland near a town called Olkusz. Since the 12th century CE, lead was the main product of these mines. The production scale did not grow continuously, but varied over time from a few hundred tons per year at the production peak in the 14th century to 2500 tonnes per year in the 16th century, the next and largest production peak. The mines supplied mostly Central European markets. Lead appeared in ores containing metals like iron, zinc or some silver (Fig. 1).

Miners extracted the ore in underground mines. On the surface, they crumbled and sorted it to choose the best parts. In the next step, the ore was roasted on an open fire to remove other minerals. The roasting of good quality ore immediately produced pure lead. If the lead was still contaminated it was smelted in furnaces. In both cases, melted lead was then formed into bars. An exceptional example dating to the 14th century was found in Krakow (Poland) on a market square and weighs almost 700 kg (Fig. 2). These kinds of bars served for large scale and long-distance trade.

The production process left a lot of waste. During the sorting of the ore, miners threw not only useless but also pieces of poor-quality ore onto heaps. Smelting them required too much effort and resources. A similar situation concerns another type of waste: slags. Every stage of roasting and smelting

» They improved smelting techniques that enabled a cheaper processing of slags. The reuse of old waste could be carried out several times along with technological developments or the need of even the poorest to find a source of income, no matter how small. Supposed waste had a use value. «

← Figure 3. Different types of furnaces used for lead smelting (Source: Agricola 1556. *De Re Metallica*; image modified).

produced slags as a by-product (Fig. 3). It contained many unwanted minerals and metals (like iron) but also lead. Miners threw them on large heaps near furnaces. However, this waste was profitable for others. In Olkusz, a change in the perception of mining waste occurred at the end of the 15th century with a mining crisis caused by the over-exploitation of the rich ores in shallow deposits. Digging deeper, below the water table, was very expensive due to the costs of drainage by special machines. Miners started to look for other sources of lead, which they found in the slags. They improved smelting techniques that enabled a cheaper processing of slags. The reuse of old waste could be carried out several times along with technological developments or the need of even the poorest to find a source of income, no matter how small. Supposed waste had a use value.

Lead slags were not only used as a source of metal. These hard and heavy stones were perfect for building street surfaces. In pre-modern towns, streets were often muddy due to wandering animals, the movement of carts and the practice of dumping waste on the roads. To solve this problem, towns invested in solid street paving. Archaeological excavations in Olkusz revealed a sequence of street surfaces made of slag and crumbled rock dated from the late Middle Ages to the modern period. They were still hard centuries later so that archaeologists had to use jack-hammers to excavate them.

The highest use of lead – Exeter Cathedral

The Middle Ages were deeply influenced by religion which made the houses of worship – churches and cathedrals – one of the most important medieval building operations, literally towering above everything else. A church or a cathedral was much more than just a place of worship. It was God's home on earth and the more impressive in size, complexity and height a cathedral was, the closer it brought the faithful – and probably above all the builders, the bishops and church leaders – to God himself. Therefore, enormous effort and materials were put into building churches and especially cathedrals that were also the seat of the bishop and the symbol of a whole diocese. One of the building materials was lead. It was not only used as a covering for the roofs of cathedrals, but also used to connect architectural elements made of stone, for water pipes and gutters as well as a component of glass frames for windows. The historical sources and well-preserved cathedrals from England exhibit how lead was used in such big investments.

Exeter Cathedral was mainly built between ca. 1280 and 1350. It has the longest vaulted ceiling in Europe and thus a large roof had to be covered with lead. The amount of lead that was required was not a major problem. England had rich deposits of lead, one of them was in Devonshire, close to Exeter. We can trace the supply of lead for Exeter Cathedral thanks to accounts registering how much money was spent on materials and on the workforce. As noted there, despite being sufficiently available, lead was quite expensive, even more so because huge amounts were needed for an entire roof. One cartload of lead was approximately worth the yearly salary of a mason at the top of the pay list. The costs increased even further due to the fact that the heavy material had to be transported to the building site. But the enormous costs remained visible, since if an entire roof of a cathedral was covered with lead, this became a symbol for the wealth of its religious builders (Fig. 4). The handling of the lead was the task of a plumber or a glazier (when it was used for glass windows), who were fairly constantly employed with their assistants. In Exeter, they even had their own workshop close to the cathedral.

It was due to its high costs, the difficulty of transport and the presence of the plumbers that lead was often reused. By looking into the accounts, we can learn how the workers actually went about re-using lead. During the busy summer days, when the majority of workers was on the building site, the plumbers and their assistants smelted the lead to produce gutters, pipes or sheets that were put onto the roof. Litharge was a by-product of this process, which we find in the sources under the name 'lead ash'. The 'lead ash' was then reused and through the accounts we learn how it was done.

First of all, the master plumber Thomas and his assistant were paid to go with the men to the River Exe to supervise the washing and smelting of the 'lead ash'. The workers were paid to wash the lead, something they probably did with the help of coarse sieves to get rid of stones and lumps by making use of the flow of the river. They were assisted by a smith, who probably re-smelted all litharge. We can see that the knowledge of experts was required for the recycling process. From a historical perspective, the whole recycling process is also interesting because it was usually done on one or two days and

» One cartload of lead was approximately worth the yearly salary of a mason at the top of the pay list. «

↑ **Figure 4. Lead roof of Exeter Cathedral, view from the North Tower to the South Tower (Photo © T. Pestridge, Exeter Cathedral; image modified).**

due to the fact that the workers were not at the actual building site where there was a well for water, they were also provided with drinks – the cost of which we can see in the building accounts. Over the period of 50 years, the recycling of lead by washing and founding 'lead ash' took place every now and then, but probably regularly when enough 'lead ash' was gathered so that a few days of working at the river were useful.

This example of the reuse of lead at construction sites of medieval cathedrals does not only show us how it was actually done but also that it was worth the effort of carrying the 'lead ashes' to the river, having supervision for the technical process, paying a smith and the workers and taking care of their well-being by providing drinks. It becomes clear that lead was a costly material to be recycled and we can see how new things can be made for future use even from the ashes of a product.

Further uses of lead

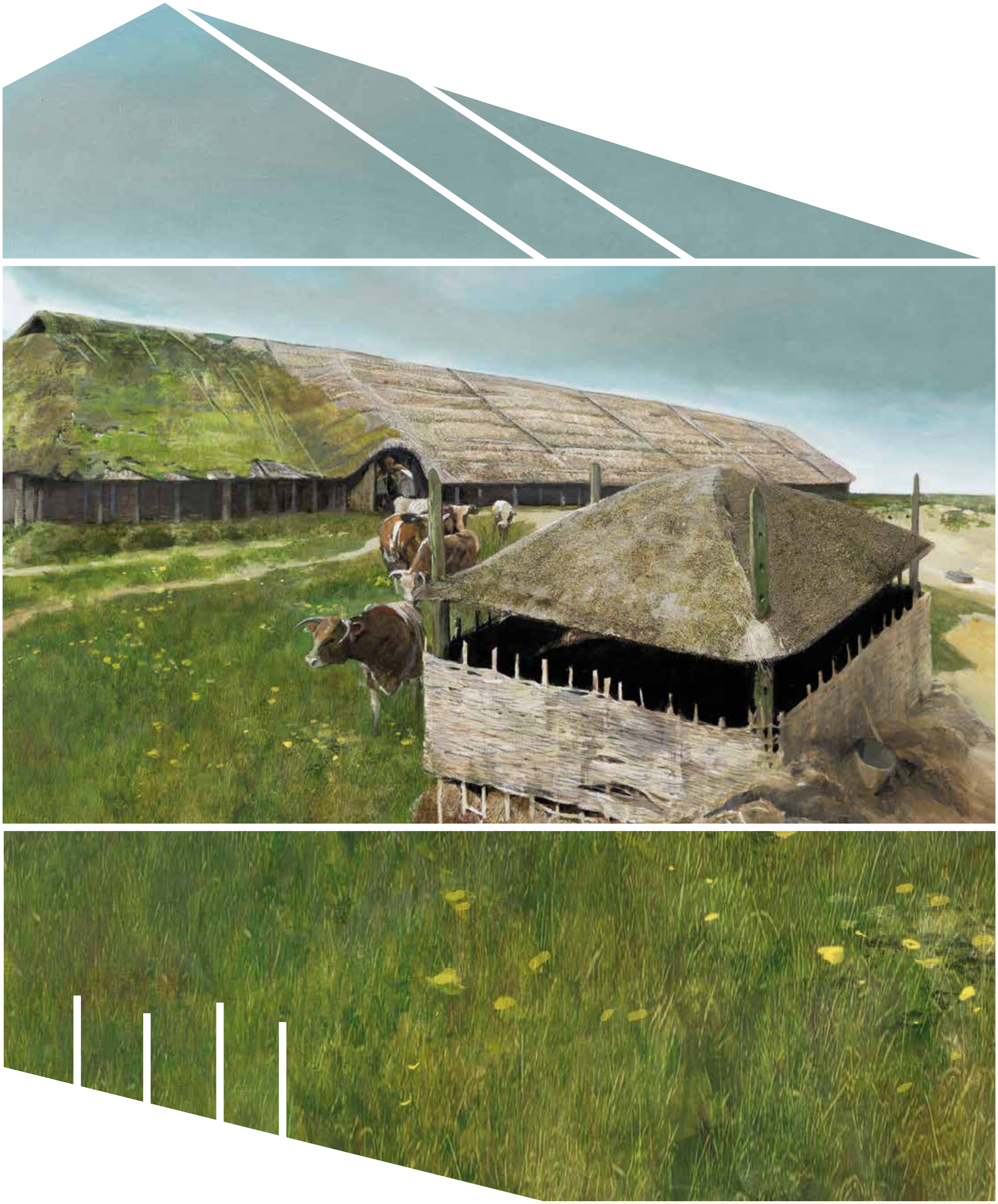
Beyond its use in the building industry, lead had various further applications, for example, for the production of weights, seals, badges, printing types and as a component in metallurgical processes, glazing pottery and tiles and in the production of glass. All roofs, windows, pipes and gutters as well as other lead items were potential sources of cheap, reusable material for next generations. Small-scale daily reuse is illustrated, for instance, by the use of recycled lead for seals attached to fabrics. They contained information about the producer and were a guarantee for the origin of a textile. After being sold, the seals were melted and new seals were made.

» Lead circulated for very long periods of time and it is still circulating. Its reuse and recycling show us that a circular economy of one material can even cross the thresholds of centuries since the lead which we see on cathedrals and churches today is sometimes still from medieval times. «

Reuse could also be observed on a larger scale like selling whole pipelines for purposes of war. Documents from late medieval England indicate that it was common among artisans (plumbers, glazers) to possess 'old lead' or to even be partly paid in such material. The scale of use and reuse is hard to estimate because not all transactions with lead were registered, although a good example of the scale of reuse is the situation that occurred in the 16th century. During the Reformation in England, many cloisters were secularised and became the property of the king. The lead that was on their roofs was immediately melted and sold (probably to supplement the king's budget). A huge amount of metal flooded the European market, changing supply lines and causing a crisis in other mining regions.

The long life of lead

Lead circulated for very long periods of time and it is still circulating. Its reuse and recycling show us that a circular economy of one material can cross the thresholds of centuries since the lead which we see on cathedrals and churches today is sometimes still from medieval times. In recent years, England has experienced a series of thefts where lead has been stolen from the roofs of churches and cathedrals because the price for lead has risen. By reselling what has been stolen, large quantities of medieval lead entered the market again and thus are part of the modern-day cycle. Lead has always been subject to circulation and has often changed its shape during this process answering the needs of the time. The historical examples from Polish mines or English cathedrals also both show that the motivation behind reuse seems to be purely economic, because it was simply cheaper than procuring new raw material. ◆



Jutta Kneisel and Lisa Shindo

Timber Recycling – or: How to Get People to Recycle?

Introduction

When timber is no longer used, it can be reused in a new structure, modified to give it a new function or burned. If it is too damaged to be reused or burned, insects, fungi and micro-organisms take care of decomposing it. The organic matter thus extracted is then assimilated by the roots of living plants and contributes to their growth. In the case of trees, this helps, among other things, to produce wood in the trunk, branches and roots. It is therefore a real cycle in which old timbers can produce, after some time, new timbers. Here nature recycles.

The following article deals with the question "How to make people recycle". Two case studies will be used to shed light on the way people recycle. What is the intention behind recycling, why did people recycle in the Bronze Age 3400 years ago? What drives people in the Alps today to reuse old wood? Both case studies are about the recycling of timber for house construction. Studies of houses in the French Alps provide rich material for dendrologists, scientists who study wood. In contrast, we know of only few prehistoric sites with good wood preservation. The Bjerre site in Northern Jutland from the Older Bronze Age (1700-1100 BCE) is one of them. Let us take a look at the motivation of residents there to recycle.

Case study: Bronze Age Northern Jutland

The Nordic Bronze Age is characterised by monumental burial mounds and aisled houses combining living quarters and stables. The northwest region of the Jutland Peninsula stands out for its particularly high density of burial mounds and well-preserved settlement structures. The Thy region, located to the northwest of the Limfjord, has been exemplarily studied by Danish archaeologists in an international cooperation project. Both the burial mounds and the construction of the longhouses have a considerable impact on the landscape. For an average barrow, 2-3 ha of grass sods (fertile arable land) are needed to create the mound. The small hamlet units usually consist of a longhouse and possibly one or two other storage buildings. The construction of longhouses, reaching sizes of up to 420 m² floor space, requires considerable amounts of timber. The basic framework of these three-aisled houses is built from massive posts. The walls consist of smaller posts and wattle and daub, which is plastered with clay (Fig. 1). The stabling of livestock in one half of the building began in the Older Bronze Age. It is interesting to note that the size of the houses increased

← Figure 1. Older Bronze Age farmstead (1700-1100 BCE) in Northern Europe, image modified (Image by K. Wilson, Ridderkerk, Netherlands).

↑ Figure 2. An alpine house (at 1900 m altitude) for a single family, dating back to at least the 18th century. Different types of timber construction were used for the upper floors: half-timbering and *Blockbau* (Photo by L. Shindo; image modified).

in the course of the Older Bronze Age up to about 1100 BCE. It was not until the Younger Bronze Age that the size of the houses decreased significantly, and at the same time monumental burial structures were abandoned and simple urn burials were preferred.

Case study: Medieval and modern times in the Western Alps

Remains of buildings from different times can be found in the mountainous regions of the southern French Alps. We find some ruins of temporary accommodations at high altitudes and standing buildings for permanent housing at lower altitudes. In the higher altitudes, only the bases of the stone walls are conserved. Some of these sites have been used over the long-term, at least during the Middle Bronze Age and the medieval period. But here, we focus on the lower elevation sites from medieval times and the modern period that have good timber preservation.

These permanent villages or small hamlets feature permanently inhabited houses. The settlements are very compact in order to save space for farmland. However, all the houses have an impressive volume: far from being a sign of wealth or a large family, the dimensions are explained by the harsh climate: the longer the winter, the more fodder must be stored in the highest floors of these houses to feed the livestock in the stables (Fig. 2).

Rural homes have the same functions: to house a family and its livestock, to preserve crops and food, to allow the work of each season to be carried out (including the care of livestock), and to enable the preparation of meals and dairy products. The climate makes it necessary to bring together all the functions of the farm and the family home under one roof: a common stable (where one eats

← **Figure 3. An example of a very elaborate ceiling from the 16th century in the living room of a house at 930 m altitude (Photo by L. Shindo; image modified).**

and sleeps with the livestock), the kitchen, a cellar and the barn constitute a unitary building. Generally, these houses do not have any outbuildings as the large amount of snow in winter would make daily movements between the house and its outbuildings very difficult. For this reason, the ground floor is insulated from the cold by masonry walls at least 50 cm thick, while on the upper floors the wood barn is always very well-ventilated to allow the harvest to dry out and thus eliminate any risk of fermentation. Wood lightness enables the creation of these many openings and its resilience allows different construction methods to be considered: trusses, a type of French ceilings, half-timbering, ceilings with joists, and *"Blockbau"*, which is a method of wood stacking with the beams joined together at their ends. The choice of construction method is often linked to the local wood resource. A *Blockbau* wall, for example, requires more wood than a timber-framed wall. But a wealthy owner can always import a lot of wood and have a luxurious structure built to make his house stand out (Fig. 3).

Timber under analysis

In prehistoric buildings in Denmark as well as in medieval and modern Alpine farmhouses, there is a lot of wood (Fig. 4): structural elements of buildings (beams, posts, wattle, truss, *etc.*), finishing work (doors, windows, staircase steps, *etc*.) and furniture (table, tableware, benches, shelfs, ladders, *etc.*). In this article, however, we will focus on structural elements. Whereas for the alpine area we can refer back to complete building structures, for the Bronze Age there are no raised building structures. For this, we have to depend on special preservation conditions in the soil. The Bjerre site in the North Jutland region of Denmark *(Nordjylland)* has such good preservation conditions. Dune-covering and rising

↑ **Figure 4. An Early Bronze Age house (1800-1650 BCE) from the inside (Illustration by S. Goetze, Kiel; image modified).**

water levels ensured that the wooden posts were preserved in the ground over the millennia.

How to recycle timber?

All wood in good condition can be reused. During the modern period, in construction quotations concerning wooden parts, it is sometimes common to find a written mention of wood as “use of new wood”. This means that, inversely, it was possible to employ reused timber! For example, in the Alps we found a weathered wooden tile, that, since it was still mechanically strong enough, became a flooring element inside the house (Fig. 5) with the same shape, but a different function. A decorated ceiling beam from an old-fashioned ceiling was cut to fit into a roof structure – here with a different shape and a different function. Additionally, large poles were cut into finer and more numerous poles with a different shape, but the same function.

For buildings from prehistoric times in archaeology, it is more difficult to identify reused wood. It only works with good wood sustainment. However, there are several clues to prove this practice: beams, for example, that were used in a timber wall and have connection points on the back, such as mortises or notches without an active function, were clearly reused. Scientific methods for material dating, such as dendrochronology, can also highlight a timber that is older than the others within a homogeneous whole, probably indicating reuse.

Moreover, wood species identification can be used to identify non-local wood species. Imported timbers may have been brought in by humans, providing evidence of exchange and mobility prac-

↑ Figure 5. a) A roof board has been reused in an interior floor (the white scale on the board measures 20 cm). b) This farm is located at an altitude of 1390 m. These alpine roof boards are very recognisable because they have two gutters on each long side to facilitate snow drainage (Photo by L. Shindo; image modified).

tices between different regions. For example, when many coniferous species growing in the mountains are used in lowland buildings, this means that they have been imported by wood traders, often because the timber resource in the lowlands is not sufficient to meet demands. Timbers may also have been brought in naturally by water, particularly after heavy rainfall; this, however, probably did not occur on an economically lucrative scale. Water transport also played a role in the Bronze Age. For example, Bronze Age houses are usually built from solid oak posts, but the Bjerre house has many unusual structures. The wall posts are partly built from branches that are crooked. Two of these wall posts are determined to be *Larix* (larch), a non-native species of wood that was only native to the Alpine region or Siberia at the time. Driftwood is one explanation for this unusual post. Even today, stranded Siberian larches lie ashore on Scandinavian coasts. Parts of the roof-supporting posts were cut from a single massive oak trunk, dating to the Stone Age. Since such massive logs are no longer known from the Bronze Age, it is assumed that a log found in the bog was recycled.

» In the Bronze Age, recycling was a necessity if one wanted to maintain the socially fashionable architectural style. «

↑ **Figure 6. Forestless heather landscape, Northwest Denmark, with Bronze Age barrows. The landscape may have already looked like this at the end of the barrow phase (1300-1100 BCE) (Photo by J. Kneisel; image modified).**

Why did they recycle?

In the Bronze Age, recycling was a necessity if one wanted to maintain the socially fashionable architectural style. The landscape of Northwest Denmark was already largely treeless at this time, much like it is today (Fig. 6). This is documented by pollen studies that reconstruct the vegetation history. Massive deforestation for the extraction of timber, the construction of grave mounds and the creation of farmland produced a treeless landscape. Strong westerly winds still make reforestation difficult today. The increasing size of the houses required huge amounts of timber, which was obviously no longer available in Bjerre. The numerous unsuitable woods used for construction, such as birch, aspen or willow, are evidence of this. The people of the time knew how to help themselves and recycled bog oak and driftwood. Thus, recycling arose from the need to maintain a certain style of building, according to one's own social understanding, and the lack of suitable timber.

During medieval and modern periods, there were several reasons why timber was considered more as a material to be reused than as a waste product. Felling a tree and cutting it up takes time and energy, and it is easier to reuse a beam that is already available than to prepare a new one. Indeed, at the latest since medieval and modern times, prior to felling a tree, the owner's permission was required and sometimes a notary was needed to draw up an official document. Then, it was necessary to choose the tree with the desired dimensions, cut it down,

» Felling a tree and cutting it up takes time and energy, and it is easier to reuse a beam that is already available than to prepare a new one. «

remove the branches, take it out of the forest and bring it to the construction site. In contrast, the use of reemployed timbers does not, to our knowledge, give rise to the drafting of official documents. There must have been oral agreements with owners, or perhaps people helped themselves freely in abandoned buildings, since this was faster and cheaper.

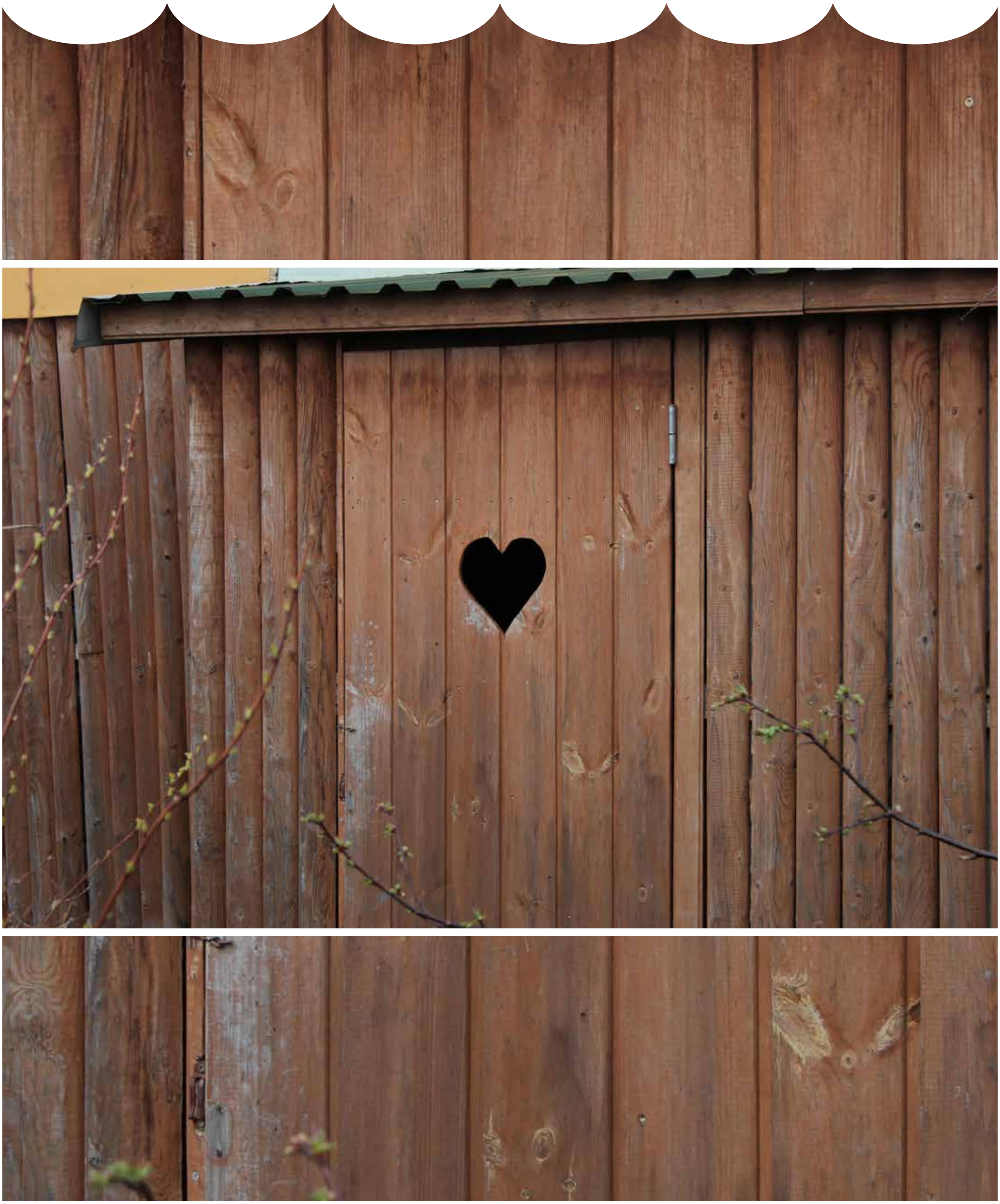
Therefore, historically, ecological concerns did not motivate the reuse of timbers and no mention of such in the textual sources has ever been identified.

Nowadays, there are companies that sell old timber, salvaged from restored or destroyed houses. This old timber is sought after because it is not only needed in the restoration of historic buildings, but also because it also adds character to a new house as a spolia. Moreover, there is also a popular belief that the old timber, which is already several decades or hundreds of years old, is more resistant than today's timber that often originates from young, fast-growing trees. The key words "sale of old wood" typed into your internet browser will give you an idea of the extent of this market.

Conclusion

Both case studies illustrate what drives people to recycle. While in the Alpine region recycling can essentially be traced back to an avoidance of extra labour, which is becoming a fashion in modern times, in the Bronze Age, the lack of suitable building material to build the steadily growing houses motivated timber recycling. However, the environmental factor plays a role in both case studies. In the Alpine region, it is economically unreasonable to always cut new trees, whereas in Denmark mismanagement led to a shortage of wood. How, then, do you get people to recycle? The lack or scarcity of raw materials and their associated increase in value (higher prices) is probably the most significant factor, which also applies in our modern world. The recycling of computer scrap and mobile phones for rare raw materials is just one example. But the social necessity or social value of recycling is also an important point. It can no longer be verified whether people in the Bronze Age, who built the Bjerre house, thought it was "cool" to use bog oak or driftwood. But they were certainly happy to have found these woods to build their big houses. In the Alps (and elsewhere), in contrast, the use of old wood has become fashionable for both economic and environmental reasons as well as to create a connection to the 'good old days', providing prestige and symbolising 'reliable values'.

What can we learn from this for *our* future? Make recycling a fashion or a value for social status and do not call it recycling. ◆



Max Grund, Bente Majchczack, Jens Schneeweiß

Shit Happens – Dealing with Faeces in the Middle Ages

When the pressure's on, we retreat to the quiet lavatory and flush everything away cleanly afterwards. Today, the outhouse and the chamber pot have the aura of a curiosity. For our parents' and grandparents' generation, however, they were still commonplace (Fig. 1). While we sit on the water closet as a matter of course, the finite nature of water as a resource is increasingly being recognised, especially after the dry years of 2018, 2019 and 2022. But the value of faeces and urine as natural resources, in contrast, remains underestimated because they pose dangers at the same time.

With a glass full of faeces at the lectern, Bill Gates called for a global toilet revolution on 6 November 2018 in Beijing at the *Reinvented Toilet Expo*, a trade fair for innovative toilet technology that does not require sewers. His goal is to fight disease on a global scale, but also to conserve resources and recyclables – concerns that were already important to humanity many centuries ago.

On the countryside, domestic waste, like faeces, always had a value. In an economy based on animal husbandry and agriculture, recycling was not a problem but vital. In the coastal region of Northern Germany, for example, the agricultural production unit from the Bronze Age to the early modern period consisted of a farm with a residential byre-house, in which humans and animals lived door to door. The manure was driven out of the byre and the slurry was drained away from the house via gutters for

← Figure 1. The heart in the door has become an international symbol for the outhouse, the love of the simple job. Here is an example from Latvia (Photo by J. Schneeweiß; image modified).

↑ **Figure 2. Soil profile of a *Plaggenesch* soil from Goting on the island of Föhr (district of North Frisia, Germany). The stratigraphic sequence shows the sandy Pleistocene sand at the bottom, followed by a bleached horizon with archaeological features and finds dating from the Neolithic through the Pre-Roman Iron Age. On top of this follows an 80 cm thick plaggic anthrosoil with several chronological horizons containing features of the Roman Iron Age, the Migration Period and the Early Middle Ages (Photo by B. Majchczack; image modified).**

rapid seepage into drainage ditches. To prevent the slurry from flowing into the living quarters on higher ground, the houses were built along a slight slope. Latrines or cesspits were completely unnecessary; sewage and faeces were simply put in the byre or on the dung heap. This dung was of great value, especially where there were nutrient-poor soils that required fertilisation. On the sandy soils of the high-lying Geest, the *Plaggenesch* economy offered a solution from the pre-Roman Iron Age onwards. On unused heath areas, the top humus layer of soil was removed. These “plaggen” were then enriched with manure and slurry to be spread on the arable land afterwards. Repeatedly over the centuries, the so-called “Esch soils” grew into metre-thick humus layers (Fig. 2). Ceramic shards, charcoal particles and ashes show that common household waste was also included in this special kind of soil improvement. *Plaggenesch* farming reached a climax from the 10th century onwards in the High Middle Ages with the perpetual cultivation of rye. Only through this special form of fertilisation was it possible to cultivate the same areas with rye year after year.

But how and where did the people defecate who inhabited the vast forested areas southeast of the Baltic Sea, which we commonly associate with the Slavs? They too kept livestock and grew crops, but they had no stables. Instead, the livestock grazed in the forest. Without stables, there was no manure, so there was no fertiliser. Archaeobotanical analyses prove that they utilised and also cultivated crops. But we do not know exactly where and to what extent. How did they deal with the faeces of animals as well as those of humans? Were they understood as valuable raw materials for soil melioration? Empirically gained experience shows that a deep black colour of the cultural layers is typical especially for Slavic settlements in East Central Europe. A high charcoal content is responsible for this colouration. Investigations revealed that the soil also contains faeces from humans and animals. This is very similar to the famous *Terra preta do índio* (“black Indian soil”) from the Amazon region, which is considered a prime example of historically sustainable agriculture there and formed the basis of a complex civilisation until the arrival of the Spanish conquistadors. The legendary El Dorado may have been a culture of arable farmers. The high yield potential of the soil, which was actually very poor in nutrients, was achieved there by transformation with faeces and charcoal, which were collected and then purposefully added to the soil. Faeces provide the important

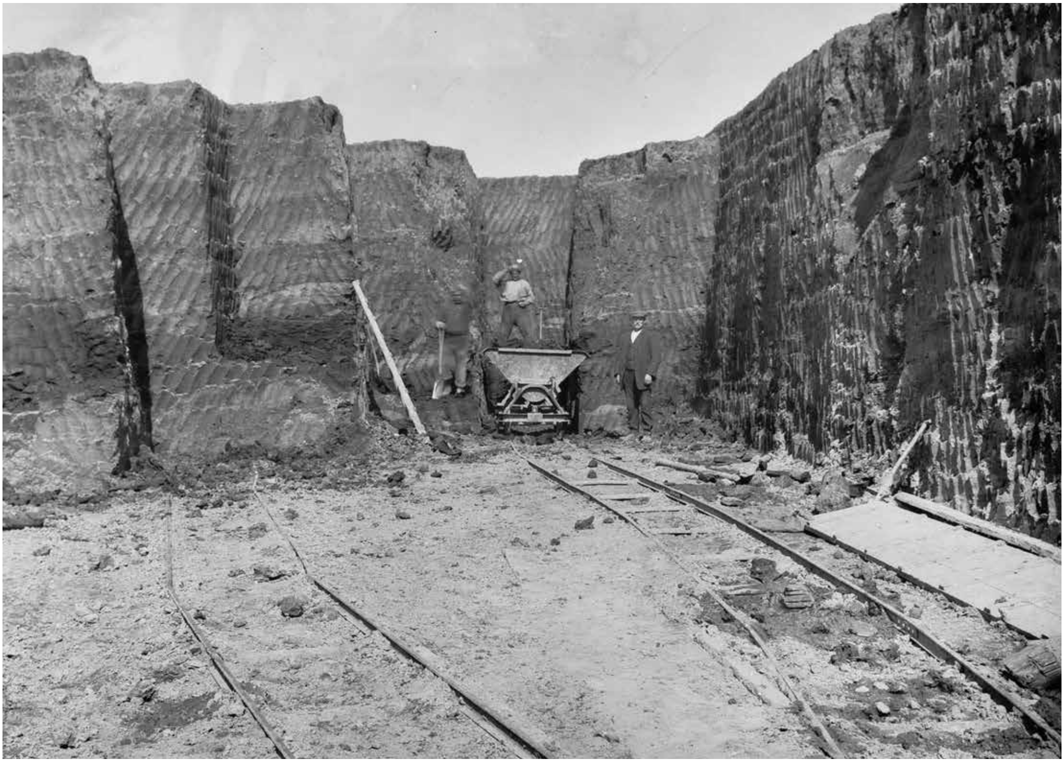
» The legendary El Dorado may have been a culture of arable farmers. «

microorganisms for which the large surface area of the charcoal provides the necessary habitat. Accordingly, efficient faecal matter management in combination with charcoal can improve the soil in such a sustainable way that high yields can be achieved in a small space, almost independent of the substrate. Unlike fertilised soils, *terra preta* does not leach out, but regenerates and its fertility is permanently maintained. The Slavs in distant Europe probably also produced such "black gold", which provided them with the basis for food in a sustainable subsistence economy (Fig. 3). This knowledge was forgotten when Christianisation and medieval Empire formations led to a fundamental transformation of the lifestyle system, which also affected agriculture. From then on, the stables and the dung heap there also became the place for the necessities.

But even in areas with fertile soils that require less fertilisation, dung had its uses. In the fertile marshes along the North Sea coast, the dikes did not protect against flooding until the High Middle Ages. From the Iron Age onwards, the marsh dwellers concentrated on keeping livestock, because without dike protection, farming was only possible on a small-scale on particularly high and protected marsh ridges. Byre-houses were built on residential mounds, the *Warften*, *Wurten* or *Terpen*, to protect them from floods. Animal and human faeces were both a curse and a blessing here. The dung flowed out of the slightly sloping house platforms and was deposited outside. In this way, the terps literally grew upwards on their own dung (Fig. 4). On the one hand, the additional flood protection was welcome, but on the other hand, the byre-houses also had to be regularly moved and rebuilt so that the sewage did not become a problem and enter the houses again. This pattern of "wandering houses" and the resulting large village terps runs through the entire first millennium. It was not until the extensive diking

↑ Figure 3. Slavic ceramic pot with charcoal stored in it in a find situation from a deep black cultural layer of the 10th century Slavic settlement at Brünkendorf on the Elbe, Lower Saxony (Photo by J. Schneeweiß; image modified).

» Animal and human faeces were both a curse and a blessing here. «



↑ Figure 4. Around 1910, the terp of Eenum (province of Groningen, The Netherlands) was quarried commercially. Dung, bones and house remains from the terp's thick stratigraphy were rediscovered as a valuable fertiliser and sold to agriculture, leading both to the destruction of the terps as well as to archaeological discoveries; image modified (Supplied photo: @ University of Groningen, Groningen Institute of Archaeology. For commercial use contact documentatieGIA@rug.nl. CC BY-NC 4.0. https://creativecommons.org/licenses/by-nc/4.0/deed.de).

and marshland colonisation of the Middle Ages that he dung was also increasingly driven to the fields or dried here and used as valuable fuel.

This basic, appreciative way of dealing with faeces had changed little in rural society over thousands of years. In the agricultural areas of Germany, where the soil was often poor in nutrients and had to be improved by fertilisation, the excreta of humans and animals were mixed with straw in the stables until the early 20th century, which turned into dung and was used as fertiliser on the fields. The dung heap was valuable and represented the centre of the farm.

» The dung heap was valuable and represented the centre of the farm. «

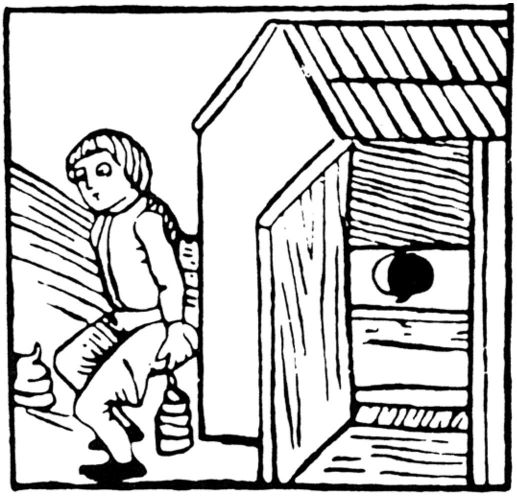
Faeces were always present in rural settlements and remained part of the rural "smellscape". We all know the smell of "fresh country air" to this day, but how bad was it really back then? To counteract the stench, it is above all necessary to dehydrate the dung or separate urine and faeces. Already after the

↑ Figure 5. A man defecates in the town below a privy. Detail from an illustrated manuscript of Boccacio's *Decamerone*; image modified (Source: Bibliothèque nationale de France, MS 5070 réserve fol. 54v; gallica.bnf.fr / BnF. https://gallica.bnf.fr/ark:/12148/btv1b7100018t/f122).

removal of 50% moisture, dung appears as a slightly odorous solid.

It becomes problematic in urban contexts when larger groups of people live together permanently. Then the disposal of what they leave behind quickly becomes a problem, regardless of whether it is food waste, commercial waste and dirty water or faeces. The relationship to this has always been ambivalent in cities (Fig. 5).

Urban organic waste was also a valuable raw material. At the same time, the fear of diseases was great, because foul odours and "miasmas" were considered to be their carriers. Disposal issues were virulent in the cities of the Middle Ages and were reflected in a variety of written sources. Even in the Middle Ages, the chamber pot was generally not simply poured out on the street. Urine, for example, was an important resource, among other things for dyeing. And human excrement was also disposed of in designated facilities, latrines or outhouses. In most towns in the Middle Ages, there were public privies, the designs of which are particularly well documented in Nuremberg and Erfurt. Private properties had their very own "secret chamber", usually in the form of a privy at the far end of the yard towards the border with the neighbour (Fig. 6).



↑ Figure 6. The air in the cloacal houses was not always the best, so that they were sometimes avoided, as this woodcut from around 1470 illustrates (Source: Rötting 1997, 54 fig. 26; image modified).

» This task was carried out by a specialised professional group, which had regionally different names such as *Kärrner*, *Goldgräber* or *Pappenheimer*. «

As a rule, the walls of the pit were made of stone or wood and the floor was paved or strengthened by wattle. A latrine pit could reach enormous dimensions and hold several dozen cubic metres, because emptying was to be necessary as rarely as possible due to the high costs involved. This was also the case so that the liquid components of the excrement could seep into the ground. Evidence of this can be found in the soils under excavated latrines, the smell of which leaves no room for doubt. The more solid components of the faeces remained in the shaft and compacted there. Since the latrines were not airtight, some decomposition processes could further reduce the contents. Above the shaft was the actual privy, probably mostly in the form of a small hut with a seat, a wooden lid to close the hole and the utensils needed for cleaning, from textile pumps to moss braids. In excavations, however, not only cleaning utensils but also toys, crockery and craft waste or purses and exercise books are found in the latrines, provided they were abandoned and filled in. If not, they were usually emptied only once a decade or even less frequently. This task was carried out by a specialised professional group, which had regionally different names such as *Kärrner*, *Goldgräber* or *Pappenheimer*. Specialised workers were also urgently needed, because medieval town chronicles and legal sources repeatedly report fatal accidents during pit emptying by outsiders. This is quite understandable, because after all, with pits up to 12 m deep, knowledge of underground construction was necessary and the gases produced in the latrines had to be correctly assessed. A certain insensitivity to odours was probably also part of the job description. For the disposal of the commonly called “unwanted” salvage, there were regulations by the council, which could vary. In one and the same town, dumping in the town stream, dumping in the town ditch or dumping at a certain place at a certain distance from the town could be prescribed. In any case, the faeces had to be transported at night and during the cold season in order to minimise the nuisance to the inhabitants. Nuremberg records that the specially constructed wagons did not have iron fittings on the wheels and that they had to be particularly tightly built. In addition, they were only allowed to travel very slowly in order to keep noise emissions as low as possible during these nocturnal activities.

But what happened to the excrement brought from the city? They were in great demand as fertiliser, even if three-field agriculture introduced in the

High Middle Ages helped to reduce the rapid depletion of the soil. Within the walls of every medieval and pre-modern city, there was always agriculture, from gardens and vineyards to fields with special crops. However, these cultivated areas were too small to absorb the large quantities of refuse produced there. Thus, they also found their way into the immediate surroundings of the city, which were almost always characterised by gardens and fields. These served the urban supply and were grateful potential destinations for the urban "unwanted". The great importance of fertilising is also shown by many leases of urban agricultural land, in which fertilising was an explicit part of the formulations for maintaining the value of the land. The value of the resource was also the concern of the Nuremberg council, which in the 18th century even tried to demand money from the gardeners and farmers of the surrounding countryside for the urban faeces. Incidentally, it was precisely these two professional groups that collected the so-called "gold buckets" from the inhabitants of Lübeck's *Gänge* (alleys) until the 1960s.

The medieval further use of urban faeces as fertiliser cannot always be directly proven, but there are numerous indications that speak in favour of it. Parasite cycles between latrines, fields, food and latrines can be proven. Special places for depositing and collecting the contents of the pits inside and outside the city also point to this, because these were not only buried in old sand pits or dumped into the rivers – the preferred disposal systems of the time. In Nuremberg, for example, faeces were temporarily stored at a tower of the old first wall ring. When this waste is dumped in cramped conditions and cannot be quickly recycled, it loses its value as a raw material and poses a danger. This ambivalence was very present in the Middle Ages and this is also the most important difference between town and countryside. While in rural areas the benefit as a raw material always predominated, faeces in urban contexts increasingly developed into a problem for which solutions had to be created. Since the Middle Ages, there has been an increasing urbanisation of our life, which was once again accelerated by industrialisation. Solutions to the problems of providing water, food and the disposal of waste and sewage grew along with it. Sewers were created and water closets became common, even on the countryside. The invention of artificial fertilisers and chemicals made it possible to disrupt the circular economy: By flushing away faeces and urine with drinking water, we throw away three resources every day. Our current standards of cleanliness and hygiene, including disgust of our own excreta, declare everything that is dirty to be worthless waste, causing the amount of our waste to reach unprecedented dimensions.

» By flushing away faeces and urine with drinking water, we throw away three resources every day. «

But in the meantime, a slow rethinking has begun. Interest in the circular economy is growing, whereby sustainable approaches and alternative forms of economy are being sought on a small-scale. The old knowledge, which targeted faecal management and can lead to a considerable increase in soil fertility, had been lost to us and is currently slowly being rediscovered. Archaeological-historical research has played a part in the development of an awareness of the problem and in the search for possible solutions. The clear reference to sustainability and environmental awareness has even generated a *terra preta* enthusiasm in Germany, which is gaining importance, for example, in the context of urban gardening. But no one has yet taken up arms against the water closets. ◆

Chapter 4:

Learning from the Past? Today's Challenges for the Future

↑ Plastic bottles and car tires "bloom" in a front garden on a thoroughfare – just decoration or also a warning? (Bryansk, Russia) (Photo by J. Schneeweiß; image modified).


WELLA

Elena Diehl and Sonja Windmüller

Is this trash yet? On rejecting and depositing

Trash can tell us a lot about culture. Looking into cast away things as well as the habits of "throwing away" provides glimpses into the values of a society and their (not always straightforward) way to deal with these things. The trash of our modern times, the build-up of mass-produced, single-use items and the sheer speed with which we go through things to throw them out of our lives is dense to a point of being a deposition and a depot at the same time.

Following this trail of depositions through the views of the disciplines of European Ethnology/ Cultural Analysis and Prehistoric and Historic Archaeology with two very different examples will bring some better understanding of this integral part of daily life. Firstly, an anthropologist will observe a phenomenon which lets museums emerge from trash. Subsequently, the archaeological focus then turns towards the urban phenomena of boxes stuffed with still-usable things, which are to be given away for free, yet only barely escaped being tossed in the bin.

From landfill to eyecatcher

Everything started off with a teddy bear on a landfill, which an employee, the bulldozer driver Erich Thomann, discovered between plenty of discarded things. According to legend, the plushie was "saved" and became the first object in the man's "Trash Museum" in Southern German Bad Säckingen which opened in 1991 and has since turned into a regional tourist attraction (Fig. 1).

However, this first, initiating exhibit – still on display these days – was not the first plush animal which ended in a landfill that gained media attention. Half a century earlier, some newspapers reported on a teddy in poor shape as part of a "colourful society of various origins which comes together in the landfill" ("bunte[n] Gesellschaft verschiedensten Herkommens, die sich auf dem Müllplatz zusammenfindet"; *Düsseldorfer Nachrichten*, 8 August, 1931) or even on a "complete department store" ("vollständiges Kaufhaus"; *Berliner Lokal-Anzeiger*, 19 August, 1925) that was on the landfill. Moreover, the phenomenon of the "trash museum" also has a long history. Since the beginnings of modern trash management in the late 19th and early 20th centuries, the then newly built trash incinerators and sorting facilities contained collections of things which had been pulled out of the rubbish, neatly stacked and displayed in representative form in small rooms or corners. The collections included metal items, especially of military origin like helmets and various weapons, as well as household objects, gauges, coins, books or plain

← Figure 1. View of a room in the Trash Museum Wallbach, founded in 1991 by Erich Thomann (Photo by S. Windmüller, 2018; image modified).

↑ Figure 2. "Trash Museum" at the Cologne waste recycling plant, 1929 (Source: Sammlung Erhard, Umweltbundesamt [Federal Environment Agency]; image modified).

oddities like spears, drums, and taxidermy animals (Fig. 2). While these ensembles tended to take up little space, one trash museum on the grounds of the City Sanitary Department in Wuppertal, which was in operation from 1962 till 1973, was comprised of about 4000 objects (Fig. 3).

Trash museums assign objects taken out of the waste stream with new value by extracting them out of the mass, cleaning them and displaying them. Presented like this, they cause a stunning reaction on what even can become waste. Exemplarily, they showcase how the status as *waste* is not a value inherent to the things themselves, but a status attributed to them – and, that this is not absolute but dynamic: one human's trash does not need to be trash for someone else. What once was considered devoid of value can gain value again (and lose it yet again as well). This value is not merely economic, but it is also an ideal – just as the fascination for the rescued teddy bear illustrates.

Things from the trash pile stimulate imaginativeness and deeper thought: where did the trashed objects come from and what were they like before they were binned? Who owned them and why were they discarded? Trash objects (and trash in general) confront us with our own finiteness – and they remind us that not just things but also humans may be considered devoid of value. At this point, trash as an assignment category takes on ethic and political dimensions as well. Trash sticks to those who handle it – this is what the objects in the trash museums also show. Although these facilities directly refer to the cultural institution of the museum, the displayed things still do not end up there and instead remain in a liminal space near the disposal facility and hence close to their own uneasy status of demise.

» Exemplarily, they showcase how the status as waste is not a value inherent to the things themselves, but a status attributed to them – and, that this is not absolute but dynamic: one human's trash does not need to be trash for someone else. What once was considered devoid of value can gain value again (and lose it yet again as well). «

↑ **Figure 3. The Wuppertal Trash Museum around 1970 (Photo by W. Jakob. Source: Nachlass Jakob, Sammlung des Bergischen Geschichtsvereins; image modified).**

Off into the box with it!

Another phenomenon, where things are assigned value beyond that of trash – even though they could just as well be thrown into the trash – can be observed for years now in many cities. People abandon and maroon boxes that are stuffed with things, household and daily-use objects, which they all no longer need, but still remain functional – the miscellaneous stuff that's too good to throw away yet too useless to keep (Fig. 4). From an archaeological point of view, this is ideal to poke around in – one may possibly dig up something of value!

Unlike museums, which try to keep and (re) present objects as such, these boxes almost ask one to keep using the things: *"zu verschenken"* ("give-away") is written on memos to any possible new owner who may pass along. This is not quite the same thing as trying to hand down some old pots with no handle to a friend. Usually these boxes contain a very random assortment of objects and have some sort of memo attached that everything's for free. However, sometimes the exact opposite can be observed as well – *e.g.* some over specific technical books on a low garden wall, including an empty pen holder. They are always some strange irregular occurrence, not legitimate bulky waste, and sometimes you may feel like you are being watched while looking at the stuff.

Neat stuff, everywhere, free to take – sounds great so far? But what happens when in some empty

↑ **Figure 4. A box full of things to give away, as it had been placed in front of the door (Photo by E. Diehl; image modified).**

container there's nothing left but crumpled up paper? And after a while even more… trash? Dirt and empty wrappings? Similar to the phenomena, where with registered bulky waste that has been placed outside in the evening there is mysteriously some more stuff in the morning. Then again, chairs do have legs, whether one is broken or not… In short, a deposition of stuff on the curb is not necessarily not-trash, yet not always just trash either. It is a matter that is in the eye, or mind, of the beholder, whether, where and how one can take something from a pile. Neither the storage place nor the placement turns "trash" into something useless, trashy, and unusable. Yet a visible mark or specific storage can make someone assume that something may actually be trash. It is a personal assignment of value – the end user must really want to accept something marked as trash as well. That seems to be a bit different with the before mentioned boxes. They contain stuff that just spilled over, out of a household, stuff that the one who sorted it out still values and the person who takes it also values. Something that can still be used, a mindset that turns something into not-trash (Fig. 5). Maybe the value of something therefore lies in the intention of use? The intentionality of usability?

When archaeologists try to learn about the past through artefacts they often do look at trash, discarded stuff and left-overs. It is not about the material as much as it is about the amount of information something can hold in its context. Waste pits hereby are more like *information sites*. And for modern times, in case of doubt, there is the literal science of *Garbology*. Times and values change, information on people's lives always keeps its value.

All these uncertainties can make it rather tricky to actually recognise trash as such – in the present time, in a social context that should have social norms and values – yet also in archaeological find contexts with many unclear connections of a social kind. In a classic archaeological understanding, *depositions* are groups of objects, which have consciously been taken out of their usual usage context and – also consciously – deposited. Usually at least. Exceptions apply as always. Some old gold treasure is a deposit, just like a bowl containing nothing but bowls is a deposit, no matter the material. In our modern times, a deposit can be literally anything: a store chain for decorations (literally named DEPOT), a collection and storage room for museum objects, a stack of stock food or a bank deposit of money –

↑ **Figure 5. The contents of the to-give-away-box (Fig. 4), laid out and sorted so that it can be catalogued by the archaeologist (Photo by E. Diehl; image modified).**

↑ Figure 6. Sorted out but still too nice: accumulation of "not-yet-trash" objects at a recycling station in Leipzig (Photo by K. Opitz, Leipzig; image modified).

all assortments of stuff assigned a certain value – values which await usage at a later point or are visibly displayed to represent something arbitrary or are just hidden out of sight. Not only in terms of language is the step to the landfill not far. Everything of value to be kept for later to never be deposited – just like everything else of no assigned value can be piled and eternally deposited in a landfill out of sight and mind. At their very end, it is the values we assign to them, the usability that remains, which decides if and what stuff is trash and can be binned and what stays a little longer. The archaeological value meanwhile is about all information that an object may contain, since that does not necessarily get lost once something is forever shifted from being a depot to waste in the trash.

All over? Between attributed value and loss of value

From two differing perspectives, the (re)negotiations of what is perceived and marked as valuable or worthless were examined. The associated practices of deposition are dynamic and versatile (Fig. 6). On the one hand, it was shown how a pile of things can be entirely devoid of value and not considered to be ever used again (landfill), yet on the other hand, the values of individual objects (*e.g.* museum exhibits) are placed above all others, even though they might come from the same source. Something different and yet the same is captured at the overlap between usability and recyclables and presented in such a way that shows how things can find new uses when they are picked up by people passing by.

Both observed instances exist in a tucked away liminal space, they blur the borders between deposited in a valuable way and a de-valued way, between value and total loss of value. Through this, they refer to aspects of our sovereignty of interpretation and our power to assign values. The practice of the (attempted) valorisation leads not least to questions on perception and awareness of our way of dealing with the trash in front of us, which, considering the dimension of the trash-problem of modern consumer societies, seems to be an even more pressing matter than ever before. ◆

» Times and values change, information on people's lives always keeps its value. «


Global production:
359 million tonnes of plastic in 2018
Global discharge:
4.8–12.7 million
tonnes of plastic a year
Concentration of plastic in
major ocean currents
Mussels, barnacles
and copepods consume
microplastics
Plastic waste transports
non-native (invasive) species
and pathogens
Fish eat plastic
Plastic disintegrates into
microplastic and harmful
substances are deposited
Marine creatures perish
in ghost nets
Plastic sinks to the deep sea
PLASTIC WASTE IN
THE OCEAN
Plastic is deposited in sediments
The creatures are not shown in proportion.
200 m
400 m
700 m
1,000 m
1,500 m
3,000 m
11,034 m

Katrin Knickmeier, Katrin Schöps, Ilka Parchmann

Once Around the World – Plastics, the Sea as a Transport Route and the Archaeology of the Future

Thousands of years ago, people were already producing waste, dumping it or carelessly throwing it away. Even diseases are partly attributed to it (cf. Kneisel et al., this volume). This is not different today. What has changed, however, is that since the last century a large number of artificial materials have been produced and also disposed of. While the materials were previously limited to ceramics, glass or metals, from the 1930s onwards they were joined by new materials whose properties eclipsed everything that had gone before: plastics.

For the first time, these materials offered the possibility to create and change their properties to measure. Thus, the rapid growth of industrial plastics production since the 1950s is not surprising – and reached approximately 400 million tonnes annually worldwide by 2022. This also changed consumer behaviour: a throwaway society developed a different attitude towards preserving objects. Things are increasingly quickly considered obsolete and thrown away. Disposable products – such as packaging – are designed from the outset to be used only once. As a consequence, the archaeological discipline of "garbology" (waste archaeology) emerged in the USA in the 1970s. As archaeology is an object-related science, garbologists aim at finding out more about the behaviour of people and their local social and cultural characteristics on the basis of the rubbish left behind. Another important concern of the discipline is the environment and how people could be made to deal more responsibly with raw materials and waste. Because if you look at the durability of plastics, it becomes clear that it will probably take hundreds of years until a plastic product is completely degraded and returned to the ecological cycle. The (chemical) degradation or decomposition process of plastics is at least as costly as their resource-intensive manufacturing process. This is why archaeologists call them "technofossils".

The behaviour of the throwaway society has dramatic ecological consequences: a considerable amount of our waste ends up in the environment. Plastics cannot be degraded there for the most part. As a result, remnants of these products spread further and further, and what we once considered

← Figure 1. How does plastic get into the ocean? Inputs of primary and secondary microplastics (Source: Bundesministerium für Bildung und Forschung 2022, 45 fig. w/o no.; image modified).

» We find plastic from the deep sea to Mount Everest, from the Arctic to the Antarctic. For the first time in human history, rubbish is being consciously and unconsciously distributed worldwide. «

progress has now become a massive burden. We find plastic from the deep sea to Mount Everest, from the Arctic to the Antarctic. For the first time in human history, rubbish is being consciously and unconsciously distributed worldwide. Until now, the material and shape of found objects provided clues about their origin; in connection with the place and context of the find, it was possible to draw conclusions about the biography of the objects. Due to the global distribution of rubbish, this has today already become very difficult.

The two sides of the (plastic) coin

Plastics (see *e.g.* https://www.deutsches-kunststoff-museum.de/kunststoff/einfuehrung/was-sind-kunststoffe/) consist of innumerable and long molecule chains (so-called polymers), which are connected with each other in different ways and thus enable very different properties. For example, their hardness, elasticity, and breaking strength, as well as their temperature, heat and chemical resistance can be varied. Therefore, plastics are versatile (*e.g.* they can be used for food packaging, adhesives, paints, aircraft parts, insulation, cosmetics) and often extremely durable. However, plastics also pose health risks.

The biggest problem, however, is waste: because plastics are often not disposed of or recycled correctly, they accumulate in the air, in the soil, in groundwater, in the sea and ultimately in our bodies. This affects not only ecosystems in general, but also many animals. 136 marine species are known to regularly become entangled and strangled in rubbish. Many seabirds and other animals mistake inedible pieces of rubbish for food and die as a result.

In Germany, almost 40 kg of plastic waste is produced per person every year. Be it disposable food packaging, discarded household items or garments made from modern textiles. Unlike during Neolithic times, for example, most of our waste is no longer thrown directly out the door or disposed of in waste pits close to our settlements, but is instead sent to landfills or processed further. So far, so good, but we export a large part of our plastic waste (including the associated negative environmental and health impacts) halfway around the world to Southeast Asia, for example. Many of the countries there have no or only inadequate waste disposal systems. The plastic waste ends up in the environment, especially in the oceans. This endangers entire ecosystems and thus also us humans. Even when waste is separated, by no means all of it is recycled; for the German “yellow bag”, in which plastic household waste is collected, it is assumed that only 40-60% (depending on the source) of the waste is currently recycled. Some plastics can be melted down and reused, others are fragmented and used for the production of new polymers, and still others are used, for example, in steel production or in incineration plants for heat generation. One problem with such plastics is that different materials are often combined to create a product with the most suitable properties possible, for example, for packaging. In such cases, subsequent recycling is rarely possible. Today, research projects are working on plastics that are as naturally degradable as possible (see *e.g.* https://www.umweltbundesamt.de/biobasierte-biologisch-abbaubare-kunststoffe) and still enable “customised properties”. The general avoidance of packaging is of course the most effective way to counteract environmental pollution.

In the following, we present an educational programme that makes schoolchildren aware of the consequences of global littering with plastics. It aims at promoting a more conscious and sustainable use of resources, products and waste and to show that the boundaries between these concepts are fluid.

Plastic in the ocean – A topic for research and citizen science

Recent estimates indicate that between 19 and 23 million tonnes of plastic waste enter the world’s waters every year (Fig. 1). Via atmospheric and aquatic current systems, the introduced quantities spread around the globe. Because plastic is particularly stable (this is a desired property for many uses), it accumulates in the oceans and breaks down into smaller and smaller particles, from macro to micro and to nanoplastic. Even in the deepest part of the ocean, plastic bags, such as those that you get in supermarkets for packing, have been found: at a depth of over 11,000 metres in the Mariana Trench of the Pacific Ocean. The researchers discovered it while combing through the Deep-Sea Debris Database, a database of marine debris that has been collecting photos and videos from 5,010 dives for 30 years. This database has recently been published (Link: http://www.godac.jamstec.go.jp/catalog/dsdebris/e/index.html).

An international survey by the Alfred Wegener Institute for Polar Research shows that the plastic “flood” has long since reached remote habitats in the Arctic. Large quantities of plastic are transported to the Arctic via rivers and ocean currents as well as atmospheric circulation systems, which promotes their accumulation in certain areas. Various concentrations of meso- and microplastics can be found in water columns, on the seabed and on beaches, even in ice and snow. We seem to find plastic waste almost everywhere we look.

But how can the further rapid growth of this flood of plastic in the ocean be prevented in the future? In the meantime, there are political guidelines in the EU, such as the so-called Single-Use Plastic Directive (Directive 2019/904/EU on reducing the impact of certain plastic products on the environment) and a global plastic agreement, in which 193 countries, including China and the USA, agreed on a joint strategy to curb global plastic pollution at the United Nations Environment Conference in Kenya in March 2022. The United Nations Environment Programme (UNEP) is to work with an intergovernmental working group to draw up a legally binding agreement on plastic waste by 2024. However, questioning one’s own actions, changing consumer behaviour and production processes from a throwaway society to a sustainable circular economy (*e.g.* cradle to cradle = approach to a continuous and consistent circular economy) and changes in awareness in society are also necessary to stop this environmentally harmful influence.

An example of an educational project involving scientists, teachers and pupils is the Europe-wide Citizen Science project “Plastic Pirates – go Europe!” (https://www.plastic-pirates.eu/de). Here, research aspects, awareness raising and citizen science work are combined. Since 2016, this Citizen Science project has offered participating schoolchildren the opportunity to take part in real scientific data collection by collecting waste data from schools on

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It is likely that in future archaeological investigations countless unrecognisable plastic remains will be found that belonged to things we have thrown away today. «

specific rivers, which is then analysed and published by scientists. The participation of many schools enables citizen science research with a large number of data sets, while at the same time achieving a broad awareness of environmental issues. Another goal of the Citizen Science project is to show students and teachers their own options for action in the face of societal challenges and thus to strengthen their self-efficacy (the belief that they can cope well with difficult or challenging situations).

Archaeology thanks to rubbish – What would archaeologists of the future find?

A central research approach for archaeologists is the decoding of information contained in found objects. The result is a reconstruction of the "life path" of these objects, their production, use and final deposition – the so-called object biography. In the process, the paths of an object are mapped, various transport routes and recycling routes are narrated and economic transformations are explored. The focus lies on both local and global contexts. Detailed research follows the transport routes of objects and thus leads from the disposal sites to the people who used the objects and ultimately to the various source materials, the raw materials.

Taking this perspective into account in educational projects underlines the long-term effects of global littering. But already today, waste archaeologists have difficulties in reconstructing the origin of found plastic objects, and this will certainly not become easier in the future. It is likely that in future archaeological investigations countless unrecognisable plastic remains will be found that belonged to things we have thrown away today. Scientists expect to find archaeological layers containing plastic almost everywhere in the world. Plastic serves as a kind of guide fossil, a "technofossil". This is why our epoch is already called the "Plastocene", reflecting the global spread of plastic. Many items of clothing, for example, are now transported around the world from production to use to disposal. The cotton (or the modern plastic) used to make it comes from India or China, for example, the yarn is spun in Turkey, the fabric is made in Taiwan, bleached or dyed in China, the garment is sewn in Bangladesh, shipped or flown to Europe (and put into different plastic packaging several times in the process). It is then sold in Europe, worn for a while, put into the used clothing collection, sorted in Holland, sold further and finally ends up on a pile of rubbish in the Atacama Desert in Chile or in Malaysia, for example. With such a world journey, the place of manufacture and the clothing remnant found in the rubbish at the end can hardly be attributed to the user's specific way of life. In the past, coveted high-quality materials, such as flint or iron, or luxury goods, such as silk or amber, were long-distance trade goods that were transported over great distances; today, it is often cheap mass-produced goods that are flushed

↑ **Figure 2. Not only the morning after – everyday litter on the banks of the Spree in Berlin, the German capital (Photo by K. Knickmeier; image modified).**

↑ **Figure 3. Modern flotsam and jetsam in Southeast Asia, an unfortunately increasingly common picture (Photo by B. Hennigsen, Kiel; image modified).**

across the globe. To visualise the consequences, it is not even necessary to look into the future. Figures 2 to 4 show the littered banks of a river in Germany and polluted beaches from South-East Asia and Denmark. This makes it all the more important that international projects like *Plastic Pirates – go Europe!* take up the problem right on our doorstep. The school classes and their teachers collect litter data on "their" rivers and streams, exchange information with school classes from other regions and also consult data from other countries. The aim is to raise awareness of the fact that the littering of rivers and oceans is a global problem that concerns us all and that something urgently needs to be done about it. Everyone can start with themselves! ◆

↓ **Figure 4. No message in a bottle here either: beach rubbish in Denmark (Photo by S. Fromke, Kiel; image modified).**

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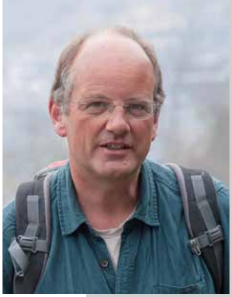

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Growing mountains of waste, decreasing resources and global environmental pollution confront us today with challenges of unprecedented dimensions. Against this background, interest in sustainable and resource-saving concepts is increasing; it is not uncommon to fall back on (supposedly) traditional approaches from times past. But what do we really know about the roots of the circular economy? What turns everyday objects into worthless rubbish, what turns others into highly sought-after objects? What actually is waste? Researchers from various disciplines in the humanities and natural sciences have joined forces to get to the bottom of these and similar questions in short stories. In them, they provide *en passant* or explicit insights into the broad spectrum of methods available to research today. The selected stories are loosely based on the authors' research projects, whereby emphasis was placed on bringing together different disciplinary perspectives. Moreover, it is noteworthy that all academic levels from Master's degree students to professors are represented. The result of these sometimes very different perspectives on seemingly everyday things leads to entertaining, sometimes surprising and often instructive insights that are quite intentionally thought-provoking about our world today.

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