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'Akko III

The 1991–1998 Excavations

The Late Periods

Part 2: The Knights' Hotel Site, The Messika Plot and Miscellaneous Studies

Danny Syon and Ayelet Tatcher

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Back Cover: The sea at 'Akko (photographer, Daphna Stern); inset: ampulla and molds from the Crusader-period pilgrim-souvenir workshop (photographer, Danny Syon)

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DANNY SYON AND AYELET TATCHER

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THE MESSIKA PLOT

‘AKKO: MISCELLANEOUS STUDIES

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Abbreviations

AASOR	Annual of the American Schools of Oriental Research
ABSA	*The Annual of the British School at Athens*
ADAJ	*Annual of the Department of Antiquities of Jordan*
AIHV	Association internationale pour l'histoire du verre
AJPA	*American Journal of Physical Anthropology*
'Akko I	E.J. Stern. *'Akko* I: *The 1991–1998 Excavations; The Crusader-Period Pottery* (IAA Reports 51). Jerusalem.
'Akko II	M. Hartal, D. Syon, E. Stern and A. Tatcher. *'Akko* II: *The 1991–1998 Excavations: The Early Periods* (IAA Reports 60). Jerusalem.
ANSMN	*American Numismatic Society Museum Notes*
ARCE	American Research Center in Egypt
BAIAS	*Bulletin of the Anglo-Israel Archaeological Society*
BAMA	British Academy Monographs in Archaeology
BAR Int. S.	British Archaeological Reports (International Series)
BASOR	*Bulletin of the American Schools of Oriental Research*
BMMA	*Bulletin of the Metropolitan Museum of Art*
BSAE	British School of Archaeology in Egypt
BSAJ	*British School of Archaeology in Jerusalem*
CIEPO	Comité International des Études Pré-Ottomanes et Ottomanes
DAFI	*Cahiers de la délégation archéologique française en Iran*
DOC 3	P. Grierson. *Catalogue of the Byzantine Coins in the Dumbarton Oaks Collection and in the Whittemore Collection* 3: *Leo III to Nicephorus III. 717–1081*. Washington, D.C. 1973
DOP	*Dumbarton Oaks Papers*
ESI	*Excavations and Surveys in Israel*
HA	*Ḥadashot Arkheologiyot*
HA–ESI	*Ḥadashot Arkheologiyot–Excavations and Surveys in Israel* (from 1999)
IEJ	*Israel Exploration Journal*
IGLSyr	*Inscriptions Grecs et Latines de la Syrie*
IJNA	*International Journal of Nautical Archaeology*
INJ	*Israel Numismatic Journal*

INR	*Israel Numismatic Research*
JAC	*Jahrbuch für Antike und Christentum*
JARCE	*Journal of the American Research Center in Egypt*
JAS	*Journal of Archaeological Science*
JEA	Journal of Egyptian Archaeology
JEMAHS	*Journal of Eastern Mediterranean Archaeology and Heritage Studies*
JERI	*Journal of Excavation Reports in Israel*
JESHO	*Journal of the Economic and Social History of the Orient*
JGS	*Journal of Glass Studies*
JNES	*Journal of Near Eastern Studies*
JRA	*Journal of Roman Archaeology*
JSOT	*Journal for the Study of the Old Testament*
LA	*Liber Annuus*
MA	*Mediterranean Archaeology*
MDAIA	*Mitteilungen des deutschen archäologischen Instituts, Athenische Abteilung*
MDAIK	*Mitteilungen des deutschen archäologischen Instituts, Abteilung Kairo*
NC	*The Numismatic Chronicle*
NEAEHL	E. Stern and A. Lewinson-Gilboa eds. *The New Encyclopedia of Archaeological Excavations in the Holy Land* 1–4. Jerusalem 1993.
NNM	Numismatic Notes and Monographs
OIP	Oriental Institute Publications
PAS	*The Portable Antiquities Scheme*
PEQ	*Palestine Exploration Quarterly*
QDAP	*Quarterly of the Department of Antiquities of Palestine*
RDAC	*Report of the Department of Antiquities, Cyprus*
SAOC	Studies in Ancient Oriental Civilization
SBF	Studium Biblicum Franciscanum
SCI	*Scripta Classica Israelica*
SEG	*Supplementum epigraphicum graecum*. Leiden 1923–
ZDPV	*Zeitschrift des deutschen Palästina-Vereins*

Chapter 27

Water and Sanitary Installations in Crusader 'Akko: Construction Techniques and Parasitological Analyses

Danny Syon, Eliezer Stern and Piers D. Mitchell

This chapter analyzes the wealth of information on installations of water supply, drainage and waste removal that were uncovered in the three excavations presented in this volume (*'Akko* III): the Hospitaller Compound, the Knights' Hotel Site and the Messika Plot (see Chapters 3, 7, 16, 26, and excavation plans therein), as well as related finds from other excavations in the old city of 'Akko and its vicinity. The important features of these installations are summarized in Tables 27.1–27.4 and some noteworthy examples are discussed in more detail. The elaborate and unparalleled sewage system of the Latrine Complex in the Hospitaller Compound is described in depth. Also included in this chapter are bioarchaeological/parasitological analyses of sediments from two of the sewage installations for the purpose of identifying human parasites and examining the diet and the state of health of the city's population in the Crusader period.[1]

Water-Supply Installations

While 'Akko of the Hellenistic and Ottoman periods was supplied with water through an impressive aqueduct (Frankel, Getzov and Syon 2002), as far we know this was not the case in the Crusader period, even though the city housed quite a large population at that time; it appears that the city of that period relied on cisterns and wells located within its walled expanse and the nearby spring of 'Ein el-Baqar, east of the city (Kedar 1997:173–174).[2]

Most of the wells and cisterns of Crusader 'Akko were partly hewn in bedrock and partly constructed of stone, with the proportion of stone construction in each case probably related to the depth from the surface at which bedrock was encountered, which varies greatly across the city. It is likely that rainwater collected in cisterns was the preferred source of drinking water in Crusader 'Akko, as the groundwater in wells in the medieval Levant was notoriously prone to contamination by effluents and wastes (for a discussion of historical evidence of such pollution in Islamic-period Caesarea, see Raban and Arnon 2006).[3]

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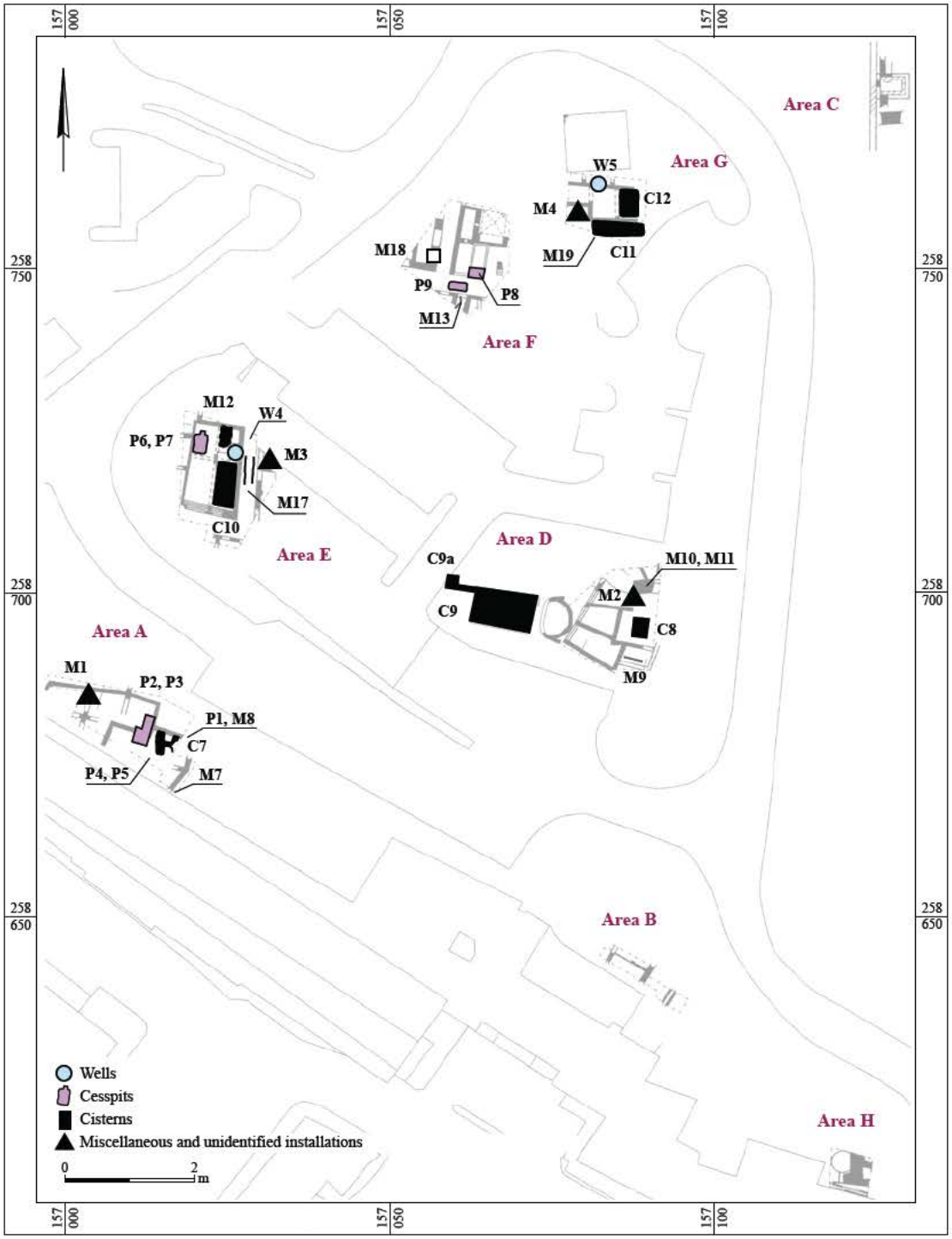
[1] The bioarchaeological/parasitological analyses of the waste from the Latrine Complex in the Hospitaller Compound and the cesspit in Ha-'Amal Street were conducted by Piers Mitchell.

[2] The precise location of this spring is unknown.

[3] Similar problems are known, for example, in medieval London (Sabine 1934:318).



Plan 27.1. Water installations at the Knights' Hotel Site.

Cisterns (Table 27.1)

Features common to most of the cisterns are barrel-vaulted construction and the use of heavy-duty, fine-quality plaster that is often found in a good state of preservation. The cisterns were constructed below buildings and courtyards, with shafts for drawing water that reached up to

Table 27.1. Cisterns in Crusader-Period ‘Akko

No.	*Site**	*Locus*	*Dimensions: W × L × H** (m)*	*Bottom Elevation (m asl)*	*Approx. Volume*** (cu. m)*	*Water-Drawing Mechanism*	*Water-Filling Mechanism*	*Construction Technique*	*Remarks*
C1	HC: under the Sugar Vessels Halls		Two cisterns: 5.00 × 13.00 × 7.35; 13.00 × 4.00 × 6.45	1	650	One shaft in southeastern corner	Opening in north and shafts in walls	Partly hewn; the two cisterns connected by a passage (4 m wide, 3 m high)	Coated with several layers of brown-orange plaster. Plan 27.2; see Chapter 7: Figs. 7.29, 7.30
C2	HC: under the Hall of Columns		Two identical cisterns: 5 × 14 × 4	0.4	Each 280	A plastered shaft in hall’s northern wall; shaft reached upper story	Channel across courtyard and down through vertical chutes in hall’s eastern wall that pass through a settling tank functioning as a filter	Partly hewn; the two cisterns connected by an arched passage	Coated with several layers of gray plaster, middle layer containing large fragments of ‘Acre bowls’. See Chapter 3: Fig. 3.27)
C3	HC: under Eastern Street		3 × 5 × 4	Not reached	50	Not identified because vault partly missing	Shaft in western wall	Stone built, vaulted and plastered	Coated with gray plaster. See Chapter 3: Plan 3.1:16)
C4	HC: under Southern Street		1.5 × 2.5 × 2.5	?	7.5	Square shaft	Chute in eastern wall	Stone built, vaulted ceiling	Coated with gray plaster. See Chapter 3: Plan 3.1:19
C5	HC: northern side of courtyard	16024	1.5 × 2.0; H c. 2	Approx. 3	5	One shaft	Channel entering from side	Construction uncertain, vaulted ceiling	Plan 27.2
C6	CSJ		?	?	Not measured	Square shaft	?	Stone built, vaulted ceiling	Water-filled to this day. See Chapter 3: Plan 3.1:21)
C7	KH Area A	137, 173	L137: 2.4 × 1.8 × 2.6	1	L137:10	Two shafts	?	Stone built	Twin cisterns, irregular shape; L173 partly excavated. See Chapter 16: Figs. 16.13, 16.14
C8	KH Area D	631	2.8 × 3.4; H c. 2.2	c. 1.8	13	One shaft	?	Stone built	Rectangular; dark red plaster; signs of burning
C9	KH Area D		3.9 × 7.5; H c. 8	Below sea level	120(?) (measured to top of plaster)	Three narrow and one wide shaft; stairs	Upwelling groundwater	Hewn and stone-built, groin vault	Built in two stages; did not fill to top in late stage; connected by narrow tunnel to C9a
C9a	KH Area D		2.8 × 3.4; H c. 6	Below sea level	50	Two shafts	Possibly one shaft	Hewn and stone-built, completely plastered	Connected by tunnel to C9
C10	KH Area E	705	2.5 × 7.5 × 3.5	1	50	One shaft	One ceramic pipe	Lower part probably hewn	Almost rectangular with rounded corners; shaft topped by column base; paved area around the shaft. See Chapter 16: Figs. 16.31, 16.37

Table 27.1. Cisterns (cont.)

No.	*Site**	*Locus*	*Dimensions: W × L × H*** (m)*	*Bottom Elevation (m asl)*	*Approx. Volume**** (cu. m)*	*Water-Drawing Mechanism*	*Water-Filling Mechanism*	*Construction Technique*	*Remarks*
C11	KH Area G	916	2.20 × 9.55 × 2.70	2.7	45	Two shafts	One or two ceramic pipes	Hewn	Slightly irregular rectangular shape with rounded corners. See Chapter 16: Fig. 16.59
C12	KH Area G	923	3.10 × 4.95 × 2.50	2.45	33	One shaft	One or more ceramic pipes	Hewn	Rectangular with rounded corners; paved area around a semicircular shaft. See Chapter 16: Fig. 16.57
C13	MP	23	4.10 × 5.05 × 4.10	-0.59	70	Two shafts	One ceramic pipe	Possibly partly hewn	Reused in Ottoman period. See Chapter 26: Fig. 26.8

* CSJ = Church of St. John; HC = Hospitaller Compound; KH = Knights' Hotel Site; MP = Messika Plot.
** The height (H) is measured from the highest point of the vault.
*** The volume of the cisterns was approximated with the intent to determine their capacity when full, including the space taken up by the vault; watermarks on the walls show that most of the cisterns filled to their capacity.

street level and even the upper stories of buildings. Rainwater from the roofs of buildings was directed into the cisterns for use as drinking water, while additional water drained from the roofs was channeled through elaborate piping systems under houses and streets for flushing sewage drains. In the domestic quarter exposed in the Knights' Hotel Site, water was collected into cisterns with ceramic pipes, while in the Hospitaller Compound, stone chutes were installed within the walls for this purpose. Under the Compound's Hall of Columns (C2), which presumably served as a dining hall, a settling tank for water filtration was employed to reduce the sediment load in the water flowing into a cistern.

A rather unusual cistern found in Area D of the Knights' Hotel Site comprises two underground chambers of different sizes (C9, C9a), with the large chamber (C9) revealing no clear openings for inflowing water. Water could be drawn from the cistern through four shaft openings in the ceiling of its large chamber, as well as by descending stairs into the chamber through a 54 cm wide opening (Fig. 27.1). The cistern was plastered to only about half its height and only on some of its walls. The upper edge of the plaster on the chamber's eastern wall preserves the outline of an arch, suggesting that this installation replaced a much smaller cistern that originally existed at the site (Fig. 27.2). Also unusual is the cistern's groin vault, as other cisterns uncovered in 'Akko were barrel vaulted.

Although the original floor of the large chamber was not exposed during excavation, it seems that the floor was below the water table and the water source was groundwater rather than rainwater. A plastered, rock-cut tunnel (c. 15 m long, c. 1.7 m high; Fig. 27.3) leads from the northern corner of the unplastered western wall (see Fig. 27.1) to a small rock-cut chamber that is filled with water at all times of the year to this day. This chamber is entirely plastered, its hewn lower part at least 1.2 m deep and its masonry-built superstructure roofed with a vault (Fig. 27.4). Two square shafts in the ceiling of this chamber served

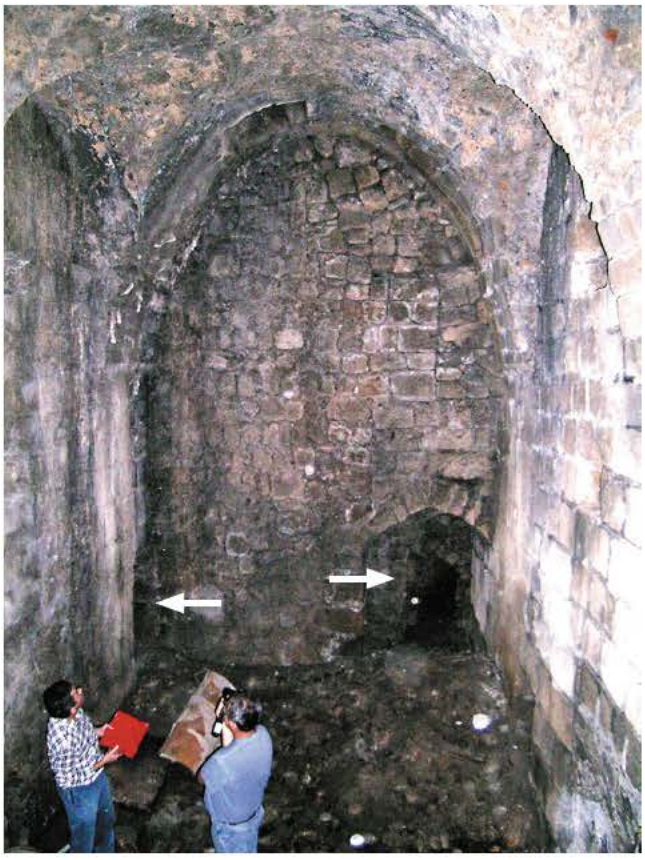


Fig. 27.1. Cistern 9, looking west; note the stairs on left and the tunnel to Cistern 9a on right (arrows).

Fig. 27.2. Cistern 9, looking east; arrow marks the line of plaster of the early stage of cistern construction.

Fig. 27.3. Tunnel from Cistern 9 to Cistern 9a.

Fig. 27.4. Wall and ceiling of Cistern 9a, looking east; water-drawing shaft in center, filling(?) shaft to left (arrow).

for drawing water, while a third shaft, in one corner, may have served as a filling shaft for rainwater. The depth of the water within the chamber today is approximately 1 m down to the mud that has accumulated above its rock floor, which could not be exposed.

The tunnel connecting the two chambers appears to be a later addition to the original construction when viewed from the small chamber’s interior, as the plaster had been cut through and the edges of the opening are ragged. In contrast, the tunnel’s opening into the main chamber is well finished. It is evident that the two chambers were originally two separate cisterns and at some point the main chamber was enlarged and connected to the smaller one by a tunnel. After the modifications, the larger structure could no longer hold large quantities of water, as it was no longer plastered on all its walls, and probably served as a public ‘fountain’ where large numbers of people could descend the stairs to access the water that welled up in the small chamber and partly filled the larger one.

The two cisterns were originally built and subsequently joined during the Crusader period. The reason for increasing the height of the main chamber is unclear; possibly it had an upper story that did not survive. As the upper part of the chamber was now above ground, this may explain the atypical use of a groin vault in its roofing. The ceiling openings may have been added in the Ottoman period, when the main chamber was reused as a cistern and a large structure with a waterwheel was built over it (see Chapter 16: Fig. 16.25). It is presumed that the small chamber was also reused in the Ottoman period for drawing water.

It is noteworthy that in Area E of the Knights’ Hotel Site, a cistern was found next to a well (Plan 27.1: C10, W4); the significance of this association is unclear.

Wells (Table 27.2)

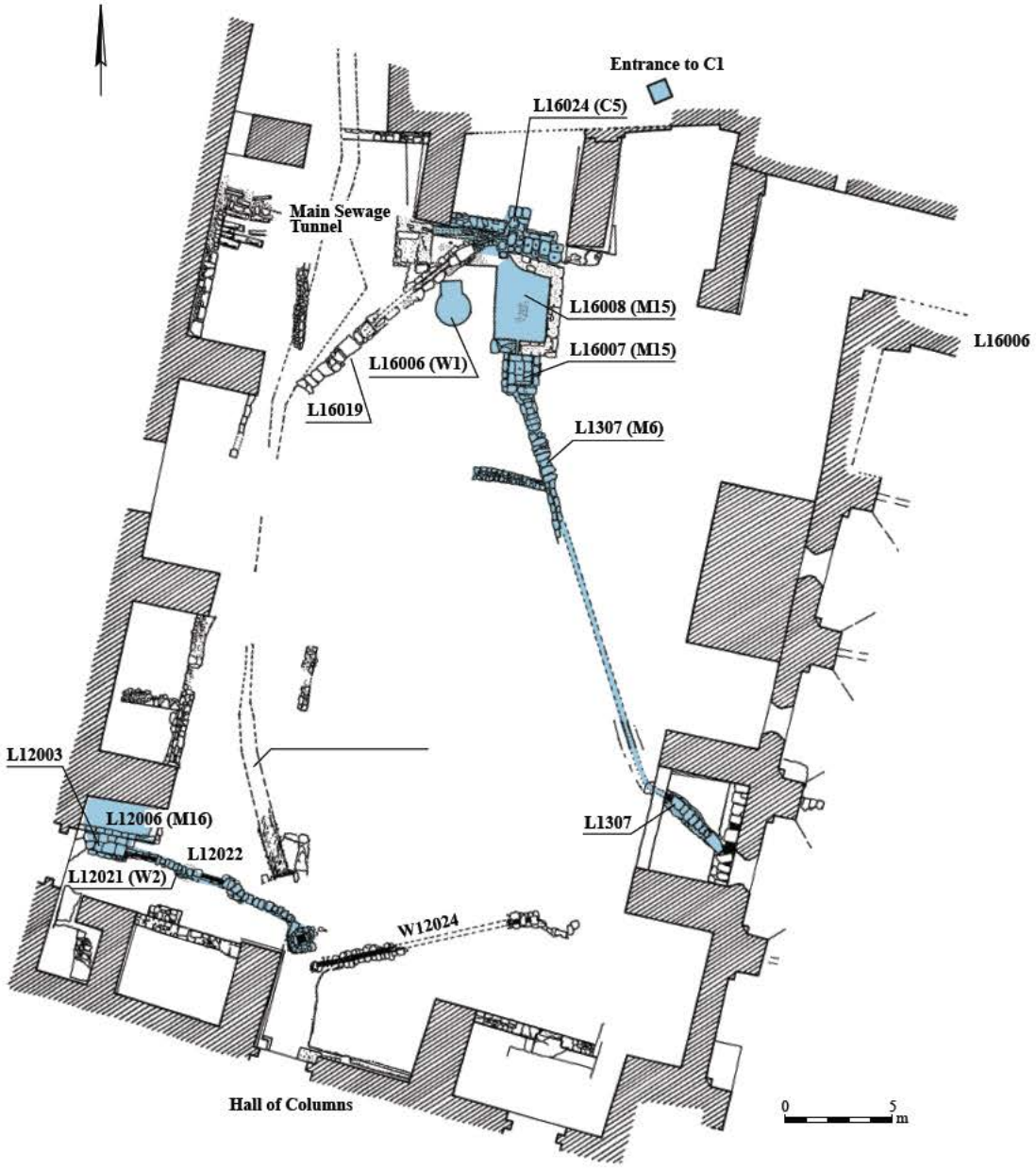
During the Crusader period, wells were probably of secondary importance as a source of drinking water, due to the likely groundwater contamination caused by seepage of effluents

Table 27.2. Wells in Crusader-Period ‘Akko

No.	*Site**	*Locus*	*Dimensions (m)*	*Depth (m)*	*Construction Technique*	*Remarks*
W1	HC: northern side of courtyard	16006	Keyhole shape; diam. c. 1.6	5.6; bottom at 0.3 m bsl	Partly stone built, partly hewn	Plan 27.2; see Chapter 3: Figs. 3.21, 3.33, 3.34
W2	HC: southwestern side of courtyard	12021	Round; diam. 0.75	Bottom at 0.3 m asl	Partly built of fieldstones, partly hewn	Probably Early Islamic. Plan 27.2; see Chapter 7: Fig. 7.42
W3	HC: under northern wall of the Hall of Columns		Round; diam. 1		Hewn, unplastered	Opens into Hall of Columns. See Chapter 3: Plan 3.8, Section 3–3
W4	KH Area E	725	Square: 0.65 × 0.65	6	Partly stone built, partly hewn	Niches for climbing; paved area around shaft. See Chapter 16: Figs. 16.37, 16.38
W5	KH Area G	925	Square: 1.2 × 1.2	5.7	Hewn	Niches for climbing; column base used as well-head. See Chapter 16: Fig. 16.55

* HC = Hospitaller Compound; KH = Knights’ Hotel Site.

and wastes (see above), although we do not know to what extent the population was aware of this. These rock-cut or built shafts reach down to the water table, although their full depth could not always be determined as excavation ceased when water was reached. An exceptional example of a well in Crusader ʻAkko is a shaft installed within the masonry core of one of the towers of the city wall of that time (Nir 1997). Another well, found in the courtyard of the Hospitaller Compound (L16006; Plan 27.2: W1), is noteworthy for its two shallow, well-plastered basins (L16007, L16008; Plan 27.2: M15) exposed adjacent to it. The basins were filled with water drawn from the well by a manual lifting wheel, and drained through a covered channel (L1307; M6) into a large cistern under the Hall of



Plan 27.2. Water installations in the courtyard of the Hospitaller Compound.

Columns (C2). The entire elaborate arrangement of a well, a lifting wheel, basins and a channel, as well as the high-quality construction of these elements, suggests the importance of the large cistern as a major water source for the compound.

Drainage and Waste-Removal Installations

Sewage Systems

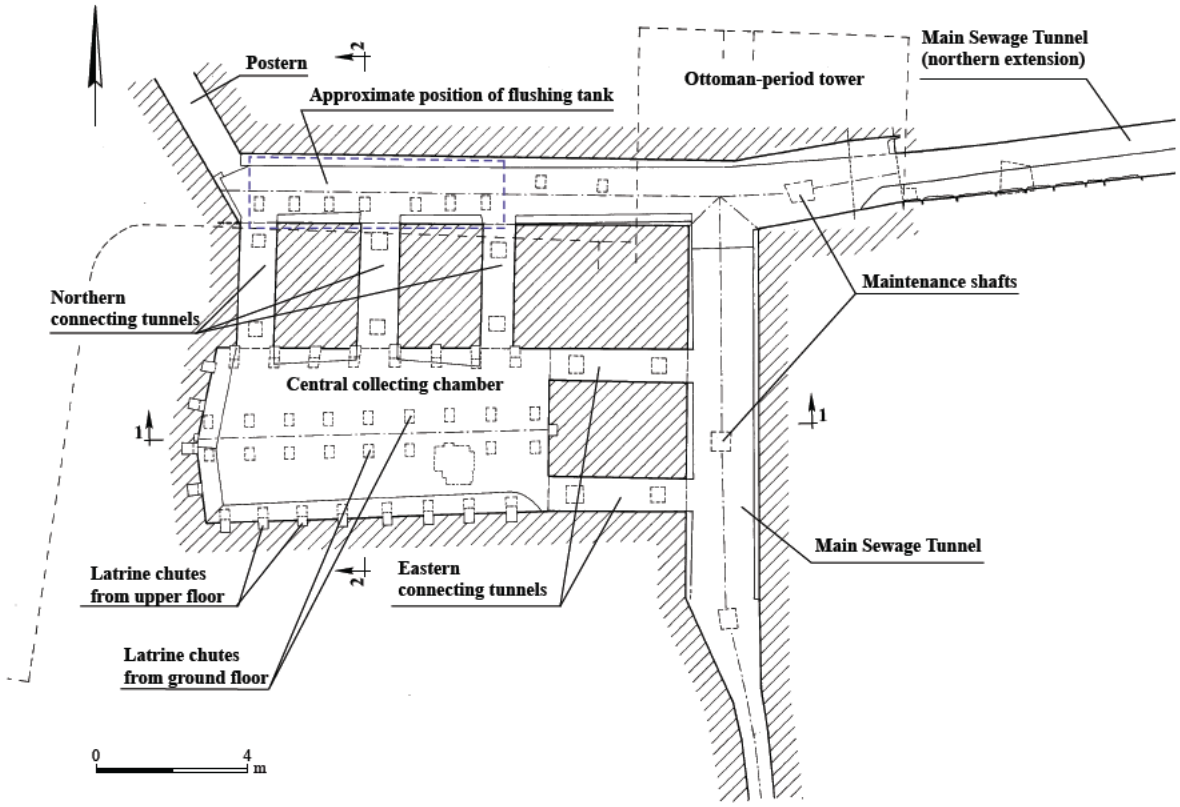
The Hospitaller Compound

The most elaborate installation for waste removal uncovered in Crusader-period ‘Akko is the three-story Latrine Complex in the northwestern tower of the Hospitaller Compound (see Chapter 3: Plan 3.1:2a; Chapter 7: Plan 7.6), which has no known parallel. The complex included two stories of latrine seats that emptied into an underground sewage-collecting chamber through stone chutes in the walls,[4] and a flushing system comprising stone chutes for draining rainwater from the roof and a water tank that flushed into a tunnel opening into the underground sewage chamber. A sewage tunnel system (Plan 27.2: Main Sewage Tunnel) passed along the Latrine Complex on the north and drained waste from both the west and the east. It then turned in a southerly direction, passing the Latrine Complex on the east, and continued under the courtyard of the Hospitaller Compound, removing effluents from the Compound. The Latrine Complex is briefly discussed in the stratigraphic chapter (see Chapter 7), while this chapter presents a detailed description of the underground sewage chamber.

The Central Collecting Chamber (Plans 27.3, 27.4). This underground chamber (4.7 × 9.0 m, 4 m high) has a pointed barrel-vault ceiling (Figs. 27.5–27.7) with two parallel rows of nine chutes each in the center of the ceiling, which connected to corresponding rows of latrine seats on the ground floor of the complex. Chutes within its walls correspond with two stories of latrine seats along the walls above this chamber, four in the western wall and eight each in the northern and southern walls. This intricate system of chutes (Plan 27.3: Section 2–2) drained the latrine seats of the ground and uppermost floors and collected rainwater from the roof for flushing the system.

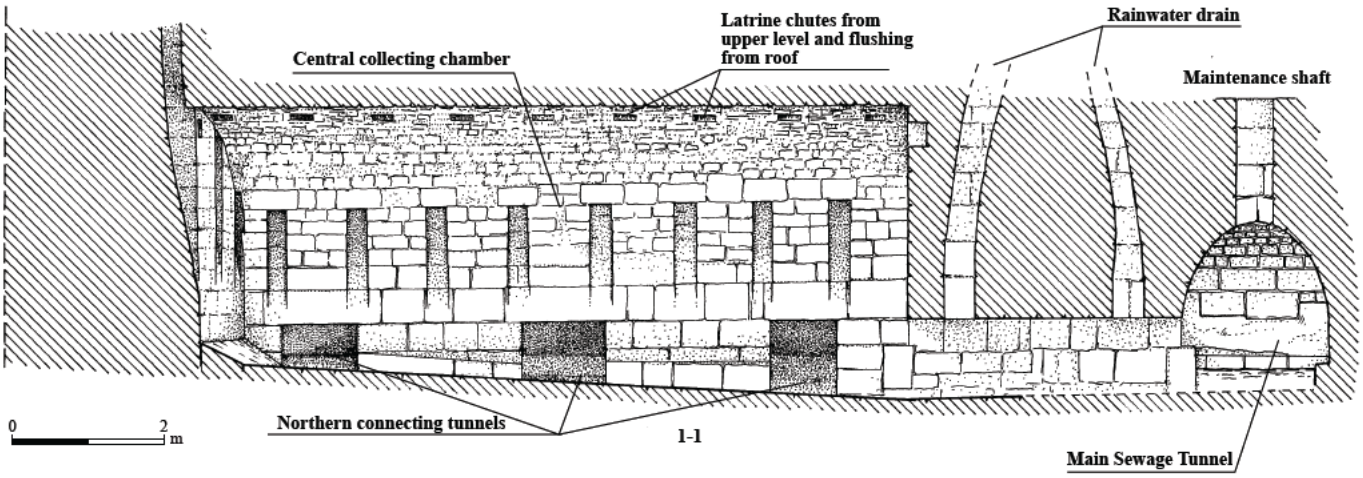
The floor of the chamber was paved with smooth, close-fitting stone slabs; it slopes gently to the south and more markedly to the east (Plan 27.3: Section 1–1; Fig. 27.5), effectively draining the chamber to its southeastern corner and into the southern of two short connecting tunnels exiting at the bottom of the chamber’s eastern wall. The waste was directed to the east, into the Main Sewage Tunnel of the Hospitaller Compound. The joint between the walls and the floor was paved with sloping stone slabs, which facilitated flushing and prevented the lodging of solid waste in the corners. The chamber is also connected to the northern extension of the Main Sewage Tunnel passing along the northern wall of the Hospitaller Compound, through three short tunnels entering the chamber along

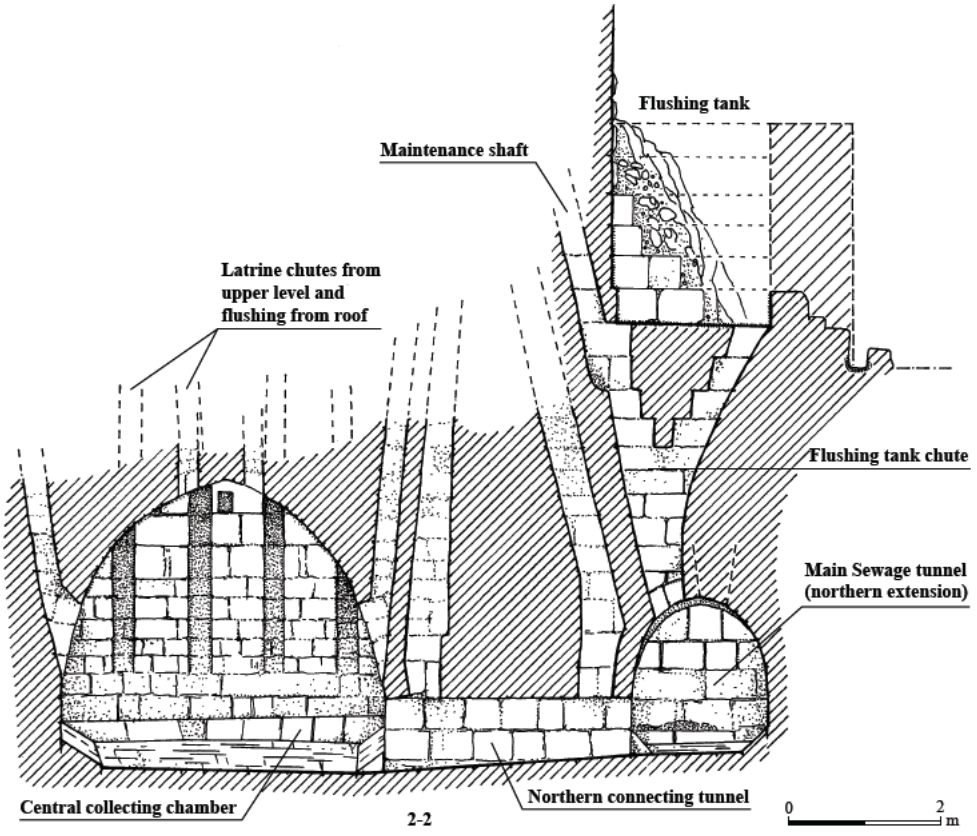
[4] An intermediate gallery above the ground floor of latrine seats, probably of wood, was not preserved; it likely did not have latrine seats.



Plan 27.3. The Latrine Complex in the Hospitaller Compound: the collection chamber.

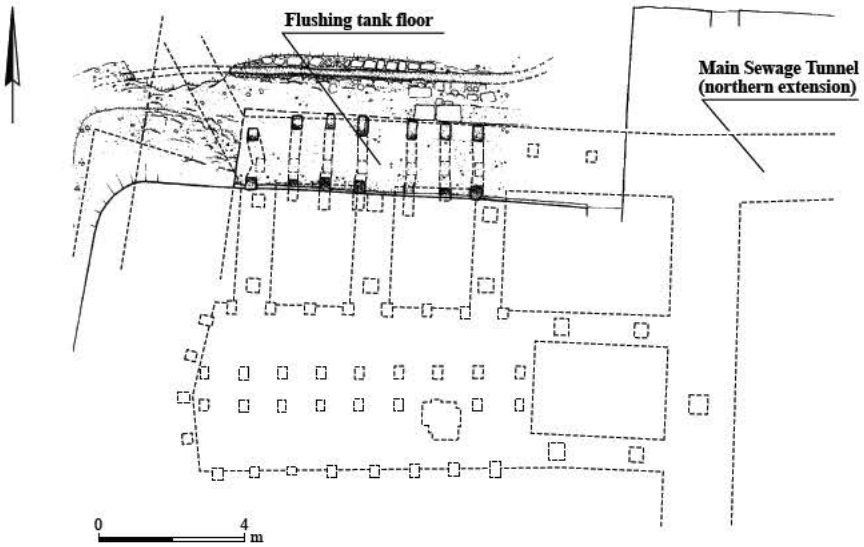
its northern wall. Each of the three short tunnels has a flat ceiling with two chutes for supplying rainwater from the roof of the complex for flushing. Additional rainwater entered the northern extension of the Main Sewage Tunnel through chutes in its ceiling (Plan 27.3). The floors of the Main Sewage Tunnel were paved with stone slabs along the part abutting the walls of the chamber, while the remainder of the floors was made of hard compacted earth.





Plan 27.3 (cont.). The Latrine Complex in the Hospitaller Compound: sections.

As flushing with rainwater was practical only in winter, a large tank (2.5 × c. 8.0 m), constructed against the exterior wall of the northwestern tower (Plans 27.3: Section 2–2; 27.4), was used for flushing in summer; only the floor of this tank has survived and its precise original capacity remains unknown. While the tank was most likely filled with water from the sea, located only about 150 m west of the Compound, the manner in which it was filled—manually or mechanically—remains unknown. The outlet from the tank was through two rows of chutes, seven in each row, that emptied into the northern extension of the Main Sewage Tunnel. From the Main Sewage Tunnel, three short connecting tunnels flowed into the central collecting chamber through its wall for the purpose of flushing the waste down the sloping floor.



Plan 27.4. The Latrine Complex in the Hospitaller Compound: the flushing tank.

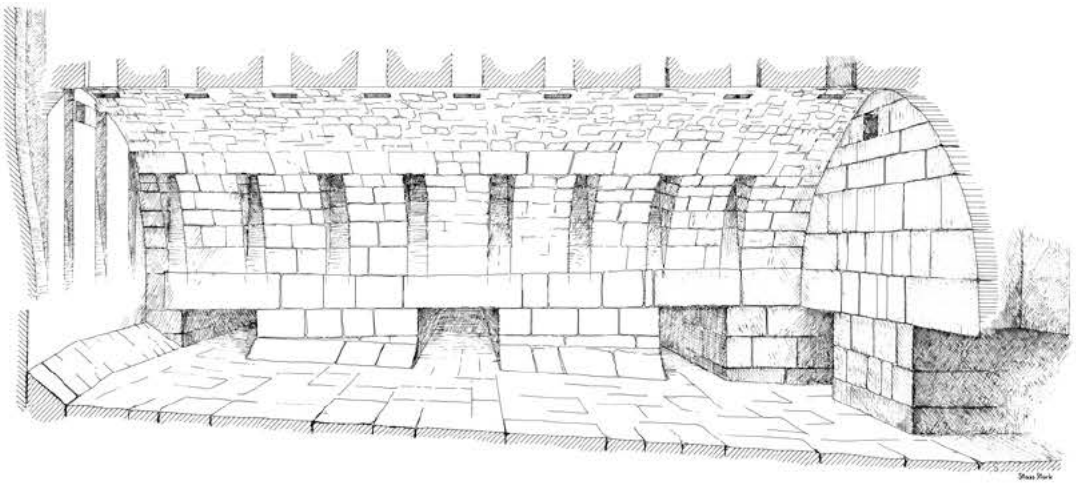


Fig. 27.5. The Latrine Complex: isometric view of the central collecting chamber, looking north. .

Fig. 27.6. The Latrine Complex: the central collecting chamber, looking west.

Fig. 27.7. The Latrine Complex: the central collecting chamber, looking east.

The Northern Extension of the Main Sewage Tunnel (Plan 27.3). The part of the tunnel that passed along the exterior of the Compound’s northern wall, below the moat, was exposed over a stretch of approximately 70 m toward the east, without reaching the tunnel’s end. Drain and maintenance shafts observed in its ceiling presumably provided additional flushing power. Excess water from the northern part of the Main Sewage Tunnel could flow southward through the Compound. A postern discovered in the tunnel’s westernmost part, along the course of the city wall (Figs. 27.8, 27.9), may have functioned as a service access to the sewer system as well as an exit-way from the city.

Fig. 27.8. The postern in the northern extension of the Main Sewage Tunnel from the outside.

Fig. 27.9. The postern in the northern extension of the Main Sewage Tunnel from the inside.

Fig. 27.10. The Latrine Complex: Main Sewage Tunnel, looking north; note the vaulted ceiling and the openings of the two eastern connecting tunnels into the Latrine Complex at left.

The Main Sewage Tunnel. This part of the tunnel begins just east of the collecting chamber of the Latrine Complex and continues in a generally southern direction (Plan 27.3; see Chapter 3: Plan 3.1:24).[5] The first ten meters (2.5 m wide, 2.5 m high) are part of the supporting structure of the northwestern tower, housing the latrines, with the walls and barrel-vault ceiling well constructed of dressed stones (Fig. 27.10). Along this segment are two maintenance shafts at the entrance area of the northwestern tower. Further south it narrows, its height is reduced (1 m wide, 1.8 m high), and the construction is simpler, mostly of small fieldstones. In some places, the lower walls are hewn in bedrock. Here, the gabled ceiling is made of flat *kurkar* slabs (Fig. 27.11). The tunnel crosses the courtyard of the Hospitaller Compound, draining it and the

Fig. 27.11. The Main Sewage Tunnel of the Hospitaller Compound; note the gabled ceiling.

[5] A network of other small channels traversing the courtyard of the Hospitaller Compound is described in Chapters 3 and 7.

roofs of the surrounding buildings through small channels that join it at various locations (Plan 27.2; see Chapter 7: Plan 7.8). It then passes under the Hall of Columns and turns east under the Southern Alley (see Chapter 3: Plan 3.1:17). Along this stretch, its ceiling is flat, with the large cover stones (0.5 × 1.2 m) laid side-by-side also serving as a pavement for the alley. After a further 20 m, the tunnel turns south and passes along the western wall of the Church of St. John (see Chapter 3: Plan 3.1:21), where a 30 m long segment was exposed. Once outside the Hospitaller Compound, the tunnel's route followed the course of the streets, draining the buildings on either side. Other isolated segments of this channel were identified in different parts of the old city (see below). A similar sewage tunnel under a street was uncovered in Area E of the Knights' Hotel Site (M17; see Chapter 16: Fig. 16.42).

Bioarchaeological Analysis. Sediment samples from various locations in the underground sewage-collection chamber of the Latrine Complex and its connecting tunnels were analyzed for their biological contents (Mitchell and Stern 2001; Mitchell, Huntley and Stern 2008) to gain insight into the diet and health of those using the latrines. The sediment samples were fine-sieved and the various organic components were separated and identified. Some of the finds were subjected to radiocarbon dating, revealing that, while the uppermost soil layer—presumably rain-washed material—dates from the Ottoman period, thirteenth-century dates were retrieved from the lowest layer above the chamber floor and the drainage tunnel. Control samples from locations outside the Latrine Complex were also subjected to analysis of the organic remains and radiocarbon dating, to exclude the possibility of contamination with extraneous material (for details of the control samples, see Mitchell and Stern 2001).

The analysis identified many pupae from flies that laid eggs and bred among the waste in the sewage-collection chamber. Small fragments of straw found in the sediment samples may have originated from material used by people to wipe themselves after using the latrines, or may represent material laid on the chamber floor. The bones of small rodents suggest that those using the facilities shared the Latrine Complex with rats and mice. Many tiny fragments of animal bone and seeds likely represent components of the diet of those using the latrines. Some items were charred, suggesting they were cooked prior to consumption. Food plants identified include wheat, barley, oats, rye, fig and cherries. Only a few of the animal bones could be identified, due to the small size of the fragments that had passed through the intestines. The identified remains belonged to large food mammals and fish, the latter represented by both bones and scales.

Microscopic human parasitic worm eggs were separated from the sediment samples by passing the disaggregated sediment through a stack of micro-sieves of 300, 160 and 20 μm in size (see Reinhard et al. 1986). This procedure was followed by a microscopic examination of the material trapped in the 20 μm sieve (see Anastasiou and Mitchell 2013). The species of parasites were identified based on egg morphology with the aid of standard identification manuals (Garcia 2009; Gunn and Pitt 2012).

Three types of parasite eggs were identified in the latrine sediment. The most common was the whipworm (*Trichuris trichuria*). The adult worms of this species are about 5 cm long and can live in large numbers in the human intestine. They are contracted when eating food contaminated with human feces. The next most common worm egg was of the roundworm (*Ascaris lumbricoides*). The adult worms are about 30 cm long and are also contracted from eating contaminated food prepared in unhygienic conditions. The third worm type identified was the fish tapeworm (*Diphyllobothrium latum*), also documented in a Crusader-period cesspit at the Knights’ Hotel Site (Mitchell, Anastasiou and Syon 2011; see Syon 2010). This parasite, contracted from eating uncooked freshwater fish, was common in northern Europe in the medieval period, but is known in the Middle East only in Frankish contexts. It is presumed that the worms were brought to ‘Akko in the intestines of Crusaders from northern Europe (Mitchell 2011; 2015). Interestingly, the disease caused by these worms—diphyllobothriasis—did not become endemic in this region, likely because some part of the worm’s life cycle could not survive in the Middle Eastern climate. The parasites could not be killed by smoking and pickling of fish, a popular preservation method in northern Europe in the medieval period (Yeh et al. 2014), therefore such preserved foods, or perhaps raw fish, were likely part of the diet of some of the Europeans using the latrines of the Hospitaller Compound.

Evidence for protozoal parasites that cause diarrhea and dysentery was found using the technique of Enzyme Linked Immunosorbent Assay (ELISA), employing antibodies that uniquely detect proteins produced by species of infective organisms. The sediment samples were found to be positive for two types of single-celled protozoal parasites, *Entamoeba histolytica* and *Giardia duodenalis* (Mitchell, Stern and Tepper 2008). These organisms are spread by the contamination of drinking water or food with the feces of infected people.

The detrimental health consequences of infection with the various species of parasitic worms would have included malnutrition and anemia in children, as the worms remove important nutrients while consuming ingested food in the host (Mitchell 2016). Another implication is that the Crusader population may have been predisposed to starvation in times of famine and sieges (Mitchell and Stern 2001). Dysentery, with symptoms of abdominal pain, diarrhea and fever, could lead to death from dehydration. Among the various parasite species identified, the dysentery-causing protozoa are likely to have had the most significant health impact on the Frankish population of ‘Akko.

Other Parts of the Old City

Three segments of underground tunnels that were probably part of the large sewer system beginning in the Latrine Complex of the Hospitaller Compound were investigated in the old city. Below Zeituni Square, an 8 m long segment of a vaulted tunnel (1.2 m wide, 1.5 m high) was constructed of rough *kurkar* blocks (see Chapter 1: Fig. 1.1:7; Tatcher 1998). Some 40 m south of Zeituni Square, under an alley leading to the Ramḥal Synagogue, another segment of the same channel (2.5 m long) was uncovered (see Chapter 1: Fig. 1.1:8).

Yet another segment was discovered near the harbor during repair works to a modern sewer; the roof had caved in and only the walls survived (see Chapter 1: Fig. 1.1:9).

In the Genoese Quarter, a segment of a north–south sewage tunnel (5 m long, 2 m wide, 1.8 m high), constructed of well-dressed stones with a vaulted roof, was found below a section of a vaulted street approximately 70 m west of the course of the Main Sewage Tunnel of the Hospitaller Compound (see Chapter 1: Fig. 1.1:6; Kedar and Stern 1995:106).

A wide, very well-constructed tunnel, found in a well-preserved state, led from the headquarters of the Templar Order in the southwestern part of the city, east toward the harbor (see Chapter 1: Fig. 1.1:13; Avissar and Stern 1998); its eastern end seems to have been destroyed and its precise route remains unknown.

Areas Outside the Old City

A 13 m long segment of a north–south tunnel (c. 1 m wide, 1.5 m high) was discovered in the course of construction of the Nautical School (see Chapter 1: Fig. 1.1:36; Kedar 1997:171, Fig. 16). It had a vaulted ceiling and was constructed of well-dressed stones. According to Kedar, the exposed part of the tunnel made a slight turn to the east and then a full turn to the west at its northern end.

A segment of a Crusader-period sewage tunnel (1 m wide, 1.8 m high) was discovered along a 30 m stretch below Ha-Arba‘a Road (see Chapter 1: Fig. 1.1:37; Stern 1997). It was constructed of roughly dressed stone blocks and had a gabled ceiling made of flat slabs (Fig. 27.12). A tunnel with identical dimensions, although rock-hewn rather than built, was exposed below the Hospitaller fort (Belmont Castle) at Ẓuba near Jerusalem (Fig. 27.13; Benjamin Z. Kedar, pers. comm.).

Fig. 27.12. Crusader-period tunnel below Ha-Arba‘a Road.

Fig. 27.13. Tunnel at the Hospitaller fort at Ẓuba (Belmont Castle) near Jerusalem.

Cesspits (Table 27.3)

These are underground, mostly vaulted, dry-built structures of fieldstones, without a floor and with unplastered walls. The openings are rectangular chutes and/or shafts installed in walls, some of them plastered. Cesspits for the collection of solid and liquid wastes were found in almost every building at the Knights' Hotel Site, apart from Area G.[6] Evidence that these features contained organic wastes was attested to by the strong yellowish-green tinge of the soil and an encrustation of the same color adhering to pottery found inside the pits. The liquids from these wastes inevitably seeped down into the groundwater and probably caused its pollution, as attested at Caesarea (Raban and Arnon 2006). The large quantities of discarded kitchen and tableware found in the cesspits suggest that they were used for both wastewater and garbage. It is noteworthy in this respect that no installations that could have been used as either cesspits or garbage pits were found in the Hospitaller Compound, and it remains unclear how garbage removal was managed within the compound.

Parasitological Analysis of the Cesspit on Ha-ʻAmal Street

Mitchell and Tepper (2007) analyzed sediment samples for parasites from a Crusader-period cesspit excavated at the corner of Ha-ʻAmal and Gedud 22 Streets in ʻAkko (Table 27.3: P11; see Chapter 1: Fig. 1.1:47). Eggs were found of parasitic worms that lived in the intestines of the thirteenth-century inhabitants of the houses served by the cesspit. Control samples from above the cesspit did not yield any parasite ova. The most common eggs within the cesspit were those of the whipworm (*Trichuris trichuria*; Fig. 27.14). Also present were the eggs of tapeworms (*Taenia* sp.), belonging to one or more of three different varieties,

[6] Locus 648 in Area D (see Chapter 16) was not included in Table 27.3 as its function is unclear.

Table 27.3. Cesspits in Crusader-Period ‘Akko

No.	*Site**	*Locus*	*Dimensions W × L × H (m)*	*Bottom Elevation (m asl)*	*Openings*	*Remarks*
P1	KH Area A	162, 170	c. 1 × 3	2.2	?	Roof missing
P2	KH Area A	147	1.3 × 1.8 × 2.7	Below water table	One	
P3	KH Area A	152, 159	2.8 × 3.3 × 3.1	0.75–1.00	One(?)	L159 blocked at some time. See Chapter 16: Fig. 16.11
P4	KH Area A	150	Shaft: c. 0.4 × 0.6	?	One(?)	Not excavated
P5	KH Area A	156	W 0.4–0.6	?	One(?)	Partly excavated
P6	KH Area E	721	Shaft: 0.35 × 0.35	-	One(?)	Not excavated; plastered chute. See Chapter 16: Fig. 16.40
P7	KH Area E	723	1.65 × 2.60 × 2.30	2.1	Three passages: one open, one blocked (connecting to P6?), one unexcavated	See Chapter 16: Fig. 16.36
P8	KH Area F	856	0.35 × 1.00 × 2.50	4.5	One	Channel leading out to east
P9	KH Area F	858	2.65 × 5.50 × 2.20	4.2	Two open, one blocked	Channel leading in (L845). See Chapter 16: Fig. 16.48
P10	MP	22	1.5 × 2.8 × 2.2	1.3	Plastered chute from M20 and pipes; blocked opening	
P11	HAS		c. 1.5 × 3.0 × 6.8	5.61	Built against wall of building	Top part did not survive. See Chapter 1: Fig. 1.2:47

* HAS = Ha-‘Amal Street; KH = Knights’ Hotel Site; MP = Messika Plot.

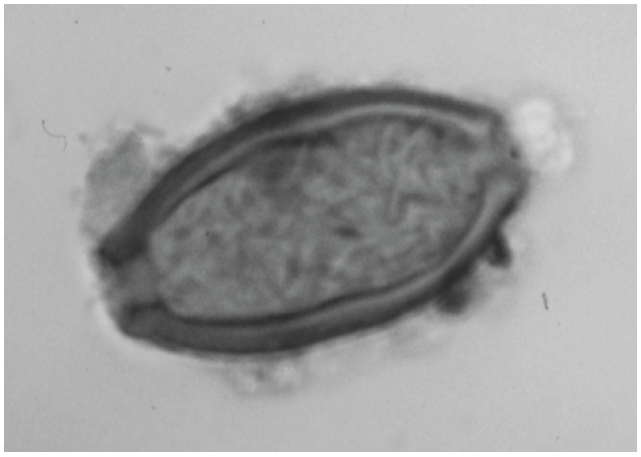


Fig. 27.14. Whipworm ovum (Trichuris trichuria) from a Crusader-period cesspit on Ha-‘Amal Street.

the beef, the pork and the Asiatic tapeworm, which are morphologically indistinguishable. While the whipworm is an indicator of poor food-handling hygiene as mentioned above, the tapeworms are spread by eating undercooked pig or cow meat, common in the local Crusader diet (Cartledge 1986; Croft 2000). Both of these parasitic worms could have contributed to malnutrition within the population of ‘Akko.

Miscellaneous Installations

A number of installations of which only the opening was exposed, and the function and manner of construction remain unknown, are listed here (Table 27.4:M1–M5). This category also includes a plastered pool (M16; 1.4 × 3.2 m, 1 m deep) with a drain that connected to the Main Sewage Tunnel in the courtyard of the Hospittaler Compound (see Plan 27.2: L12006, L12022).

Table 27.4. Miscellaneous and Unidentified Installations in Crusader-Period ‘Akko

No	*Type*	*Site**	*Locus*	*Dimensions W × L × H (m)*	*Construction Technique*	*Remarks*
M1	Well or cistern	KH Area A	165	Opening: 0.35 × 0.35		Not excavated. See Chapter 16: Fig. 16.16
M2	Well or cistern	KH Area D	639	Opening: 0.7 × 0.7		Not excavated
M3	Well or cistern	KH Area E	726	Opening diam. 0.4		Not excavated
M4	Well or cistern	KH Area G	912	0.40 × 0.45	Probably hewn	Not excavated; topped by built shaft extending to upper story. See Chapter 16: Fig. 16.61
M5	Well or cistern	ZS	122	Exterior diam. 1.35, interior diam. 0.6		See Chapter 1: Fig. 1.2:7
M6	Covered channel	HC	1307	Extending across entire courtyard	Ston built, plastered	Connecting basins M15 to Cistern C2. Plan 27.2; see Chapter 7: Fig. 7.36
M7	Covered channel	KH Area A	156	W 0.15	Unplastered	Possibly leading to a cesspit
M8	Covered channel	KH Area A	178	W 0.15	Stone built, plastered	Possibly Early Islamic. See Chapter 16: Fig. 16.15
M9	Covered channel	KH Area D	643	W 0.40	Unplastered	Unknown function
M10	Drain	KH Area D	648	1.50 × 1.25 × 2.00		Fed by channel and pipe
M11	Covered channel	KH Area D	-	W 0.3	Plastered	Leading into drain M10
M12	Pit and covered channel	KH Area E	724	Channel: W 0.15	Channel unplastered	Not excavated
M13	Covered channel	KH Area F	845	W 0.2, H 1.4	Unplastered	Leading into a cesspit (L858). See Chapter 16: Figs. 16.46, 16.48
M14	Channel or pool	MP	28, 29	W 0.55; H >1.6	Unplastered	
M15	Shallow twin basins, northern side of courtyard	HC	16007 16008	2.2 × 3.1, H 0.6, 1.2 × 1.4, H 0.45	Stone built, plastered	Pink, hydraulic plaster; iron rod installed across the narrow pipe opening connecting the two pools. Plan 27.2; see Chapter 3: Fig. 3.21; Chapter 7: Figs. 7.33–7.35

Table 27.4. Miscellaneous and Unidentified Installations in Crusader-Period ʻAkko (cont.)

No	*Type*	*Site**	*Locus*	*Dimensions W × L × H (m)*	*Construction Technique*	*Remarks*
M16	Pool, southwestern side of courtyard	HC	12006	1.4 × 3.2	Stone built, plastered	Pink, hydraulic plaster; located next to a paved stone surface. Plan 27.2; see Chapter 3: Fig. 3.22; Chapter 7: Fig. 7.40
M17	Drainage tunnel	KH Area E	719, 729	W 0.8–1.0	Stone built, no floor	Drain pipes situated along wall. See Chapter 16: Fig. 16.42
M18	Basin	KH Area F	814	0.50 × 0.55	Installed inside wall	Original depth unknown. Plan 27.1
M19	Regulation tank	KH Area G	928	0.15 × 0.40	Stone built, plastered	Fed by vertical pipe; feeds two cisterns: L916 and another unexcavated installation. See Chapter 16: Fig. 16.60
M20	Kitchen(?)	MP	26		Stone built, plastered	Sinks, basins, pipes and chutes. See Chapter 26: Figs. 26.3–26.5

* HC = Hospitaller Compound; KH = Knights' Hotel Site; MP = Messika Plot; ZS = Zeituni Square.

Discussion

The city of ʻAkko in the Crusader period had highly developed systems of water supply and waste removal. The water-supply system consisted of wells and cisterns that were filled mostly through ceramic pipes and occasionally by stone chutes or shafts. The drainage and waste-removal systems consisted of tunnels, covered channels and cesspits. The fact that all the tunnels discovered so far in ʻAkko are high enough to allow human passage with reasonable ease is likely related to the need for regular maintenance. In addition, some of these systems were intended to serve for clandestine activity within the city and perhaps as a means of escape during a siege.[7] Bioarchaeological analysis of sediment samples from the latrines and cesspits provides information as to the diet and parasite-related human diseases among the Crusader-period inhabitants of ʻAkko.

These elaborate infrastructural systems clearly testify to a high degree of urban planning that included municipal construction and maintenance of the systems. Evidence from the compounds of two of the major military orders, the Hospitallers and the Templars, demonstrates that they played an important role in this endeavor. The sewage tunnel that originated in the Hospitaller Compound was shown to join a city-wide system upon exiting the Hospitaller Quarter, and this may have been the case as well with the tunnel found associated with the Templar Headquarters. A similar situation appears to apply to the tunnel exposed in Area E of the Knights' Hotel Site. In all probability, additional parts of these systems await discovery.

[7] The most well-known case of such an activity occuring in ʻAkko is that of Riccardo Filangieri of Tyre, who is reported to have come to the city for negotiations and entered and left it through a postern facing the Montmusard Quarter, probably the postern in the Latrine Complex (Pringle 2009:85).

The archaeological evidence from ‘Akko is in apparent contradiction with an observation made by the twelfth-century Muslim traveler Ibn Jubayr in 1184 CE:

> “…[‘Akko’s] roads and streets are choked by the press of men, so that it is hard to put foot to ground. Unbelief and impiousness there burn fiercely, and pigs [Christians?] and crosses abound. It stinks and is filthy, being full of refuse and excrement…” (Ibn Jubayr 1952)

Assuming this account faithfully represents the conditions in ‘Akko at that time, it is possible that either the main thrust in the development of the city’s urban infrastructure occurred in the thirteenth century, subsequent to Ibn Jubayr’s visit, or the efforts of the local authorities to ensure sanitary living conditions were insufficient in the face of the high population density and crowding. Unfortunately, there are no historical sources relating to the cleanliness of ‘Akko in the thirteenth century, nor any archeological finds of relevance relating exclusively to the twelfth century.

While the concept of urban planning in thirteenth-century ‘Akko may seem trivial, the preoccupation with waste removal and drainage on such a scale is a rather novel concept considering the situation in contemporaneous Europe. During the early medieval period, Europe lost much of the immense knowledge accumulated in the Classical periods relating to sanitation, both public and private. Until the late twelfth century, the drawing of water from wells and rivers and the disposal of human and domestic waste in public (including rivers) were still the norm in Europe (Fig. 27.15; Sabine 1934; Bond 1993; Magnusson 2001:99–101, 155–159, passim). Water channeling and semi-systematic waste removal, where latrines (*necessaria*) were built over cesspits or diverted springs, were mostly confined to monastic establishments; nevertheless, a considerable increase in the private and public deployment of water-conduit systems, fountains and latrines equipped with flushing systems began in Europe in the late twelfth century. Latrines were often built as outhouses for the homes of the low classes, or as cells attached to the exterior walls of castles of the aristocracy, with a chute overlying a moat or a river (e.g., Borchert 1987).

There is little doubt that upon initially arriving in the Holy Land in the twelfth century, the Crusaders encountered hydraulic installations and sanitary practices far superior to what was available in their homelands. Twelfth-century urban planning among the Fatimids was probably of the most advanced level in the Old World since Late Antiquity, and quite possibly far superior to that of Late Antiquity (Scanlon 1970:194). The installations of Fatimid Fustat (Old Cairo, Egypt) included water conduits, fountains, cisterns and latrines (Scanlon 1970). Similar systems and installations were discovered in Fatimid-period Caesarea (Raban and Arnon 2006).[8] They included a network of drains under the city’s streets, some for accommodating raw sewage that emptied into the sea; cesspits of several ‘grades’ for filtering used water to replenish groundwater; wells and cisterns. While most of

[8] Especially important in this regard are the excavations by the Combined Caesarea Expeditions (Holum et al. 1988; Vann 1992; Raban and Holum 1996; Holum, Raban and Patrich 1999).

Fig. 27.15. A woodcut from 1554 CE, depicting the manner of domestic waste disposal in Europe at that time (Damhouder 1554).

these elements at Caesarea had been in use throughout the Early Islamic period, the Fatimid period saw their renewal and expansion. The Fatimids also reintroduced the extensive use of cisterns for collecting rainwater from rooftops through ceramic pipes, for the first time since the Byzantine period.

Although much smaller than Caesarea of that time, Fatimid-period ʻAkko may have boasted similar infrastructural development. Unlike the situation at Caesarea, however, where the latest Islamic-period stratum is immediately superseded by that of the Crusader occupation and there is evidence of appreciable continuity in the urban layout, the Fatimid-period remains of ʻAkko—for example, the silos uncovered in Areas C and F of the Knights' Hotel Site (see Chapter 16)—are especially meager. It appears, therefore, that most if not all the water-related installations uncovered in ʻAkko were constructed during the Crusader period, specifically within the thirteenth century.

There is presently no indication as to how soon after their arrival in the Latin East, the Crusaders began adopting local standards and technologies of water management and

sanitation; nonetheless, it is quite clear that by the thirteenth century, they had not only adopted these local practices but also improved them. The highly sophisticated latrine system uncovered in the northwestern tower of the Hospitaller Compound, especially its elaborate flushing system, remained without parallel in Europe for at least a century to come.[9] It is likely that the Crusaders introduced the innovations encountered in the Latin East to Europe, in part leading to an increase in the number, variety and quality of water systems found across the continent toward the end of the twelfth century.

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[9] A fourteenth-century example of such a latrine system, although of a smaller scale of construction, is known at Langley Castle, Northumberland, where there are twelve latrines in three stories (Sabine 1934:303). Most latrines and associated installations known in medieval London are no earlier than the beginning of the fourteenth century (Sabine 1934).

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