Wastewater management techniques from ancient civilizations to modern ages: examples from South Asia

H. F. Fardin, A. Hollé, E. Gautier and J. Haury

ABSTRACT

Wastewater management appeared about 3000 BC in South Asia, and spread on the whole subcontinent with the development of urbanization during its early history. Domestic grey water and black water were canalized through street-side drains, and cesspits was implemented at house outlet level, or at drain crossing, in order to avoid the clogging of the system. Nothing seems to be known about the ultimate place where the drains canalized wastewater. In South India, wastewater was managed previously to the 1st century AD, at the very same period as the presence of Mediterranean population on the subcontinent. But, we cannot confirm a Mediterranean influence on wastewater management, because of the previous development of several techniques in the region. In today rural Puducherry area, traditional techniques are used to manage wastewater, quite similar to the method used to treat wastewater of Puducherry urban zone.

Key words | ancient history, Arikamedu, ecotechnology, harappa, Puducherry, South Asia, wastewater

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INTRODUCTION

Wastewater management in ancient civilization is a key-theme for the development of technologies adapted to a specific area, especially where patrimonial landscape is considered as determining for todays cultural and socio-economic life. Several authors have described the historical development of wastewater management (Cooper 2001; Lofrano & Brown 2010), especially about the Antiquity. Whereas several researches have been undertaken on the Mediterranean zone (Angelakis *et al*. 2005; Chatzakis *et al*. 2006; Hopkins 2007) and on Central America (Becerril & Jimenez 2007), few studies have focused on the wastewater management in ancient South Asia, the single exception being about the Early and Mature Harappan period of the Indus civilization. (In the present study, I will use 'Indus civilization' and 'Harappan civilization' interchangeably.) (Jansen 1989), around 3000 BC. Despite the decline of the Indus civilization (Lahiri 2000; Kenoyer 2006), urbanization development has continued during early South Asian history (500 BC to 300 AD). Because contacts occurred between South Asia and the Achaemenid, the Greek, and even the Roman empires, we will wonder if these cultural meetings could have generated transformations in the management of wastewater. Moreover, we will study present time wastewater management in South India, in order to determine the heritages between ancient and contemporaneous wastewater management, especially in rural Pondicherry (all the South Asian places cited in the text are represented on the map of the Figure 1) area.

Thus, we will first briefly review the development of wastewater management, in particular in South Asia. Then we will describe the specificities of wastewater

doi: 10.2166/ws.2013.066

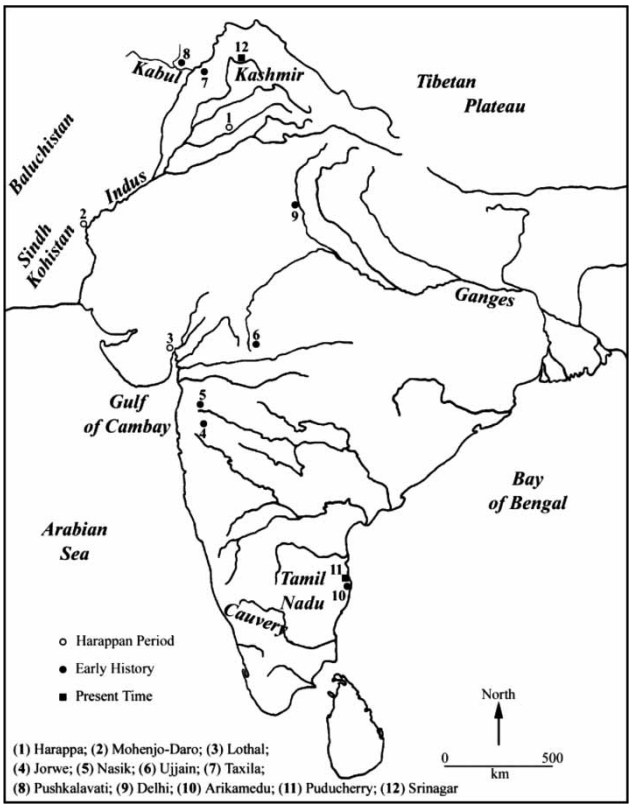

Figure 1 | South Asian sites cited in the text.

management in todays Puducherry area, for which data have been collected in the scope of a doctoral research. Thereafter, the role of technological/cultural diffusion in the development of wastewater management in south-east India will be analysed.

GEOHISTORY OF WASTEWATER MANAGEMENT IN ANCIENT SOUTH ASIA

Harappan period

The development of sewage is basically linked to urban development, since one can consider that 'guaranteeing pure water for people became a prerequisite for successful urbanization' (Vuorinen *et al.* 2007: 50). Drainage systems are considered as a cornerstone of urbanism development in the history of India (Smith 2006: 130). Indeed, it has been demonstrated that drainage and sanitation are some of the major characteristics of the settlements of the Indus civilization (Kenoyer 1991: 354). Jansen (1989) has given a good review of the wastewater management in Mohenjo-Daro. According to Wright (2010: 122) only a few houses had toilet facilities. These toilets were of two types: made of earthenware bricks with a seat; or a simple hole in the floor. The domestic outlet, from toilets and bath platforms, was connected to street drains through a pipe network, or to soak-pits (Jansen 1989; Wright 2010), probably which were thereafter dumped in a specific place, as it has been hypothesized for solid waste (Jansen 1989). In order to avoid the clogging of the drainage system, cesspits were implemented at the junction of several drains or where a drain was extended for a long distance. Then, a larger drain was built at the outlet in order to receive the 'filtered water' from the cesspit of connection (Wright 2010). The implementation of the drain network was facilitated by the geometrical urban morphology. And thus, almost all the settlements of Mohenjo-Daro were connected to the drain network.

Nothing is said in the literature about a possible link between wastewater drainage and agricultural irrigation. Yet, since at least 3200 BC, it seems that most of the Harappan settlements in riverine plain used river flood canalized into ditches to irrigate dry season crops (crops of the dry season are called *kharif* crops in present day South Asia) (Wright 2010: 71). Rarely, water-retaining devices have been discovered. The only exceptions are the *gabarbands*, situated in the actual Baluchistan and Sindh Kohistan, and dating from the Early Harappan/Kot Diji phase (2800–2600 BC). Gabarbands are 'stone built dams construction designed to control and store water' (Wright 2010: 31) probably used for irrigation purposes. It has been pointed out that possibly in Lothal, some kind of rainwater reservoirs had been implemented in order to irrigate agricultural land during dry season (Wright 2010: 167). Lothal, in the Gulf of Cambay was a 'town-drainage and sanitation as characterizes the Indus cities' (Kirk 1975: 21).

Early history

Northern and Central South Asia

In Jorwe, in present day Maharashtra, it has been demonstrated that the drainage system was implemented from

1375–1050 BC (Kirk 1975: 23). Later (around 500 BC), Ujjain's 'drainage system included soak-pits built of pottery-ring or pierced pots' (Kirk 1975: 32), and it has been supposed that ring-wells were used for the disposal of wastewater (Mate 1969: 244). This supposition can help us to understand why S. H. Dhirajlal and D. S. Bhalchandra wondered about some constructions dated at 150 BC in Nasik, if they were 'ring-wells or soak-pits' (Narr 1961: 311).

In the 3rd century BC at Taxila, domestic wastewater was canalized out from the houses through earthenware drain-pipes into soak-pits (Singh 2008: 335). Pushkalavati, the ancient capital of Gandhara (Stein 1927: 437), is situated near the actual Charsadda, at the confluence of the Swat and the Kabul rivers, two of the 'main roads' linking South and Central Asia. The road through Charsadda, named Peukelaotis by the ancient Greeks, has been the one taken by Alexander to penetrate into the Indus valley (Codrington 1944). He implemented a garrison in this settlement (Stein 1927: 437). The same wastewater management was used at that time in this very settlement: drain, soak-pit and/or cesspool were commonly used (Singh 2008: 389). In the antique Delhi, during the 3rd century BC, the same kind of system was used: drains, which are still visible in todays Purana Qila, canalized wastewater into 'wells, which may have functioned as soak-pits' (Singh 2006: 119).

South India

In south-east India, during the Sangam Period (300 BC to 300 AD), the development of water management began to spread: rainwater was stored in tanks (*ery* in Tamil) in order to irrigate paddy fields (Sita 2000: 35), and fishing was practiced in lotus ponds (*tamaraikulam* in Tamil) (Sita 2000: 36). During the 1st century AD, the Grand Anicut was implemented on the river Cauvery. This dam had been realized to protect the downstream populations from floods, and to provide water for these very same populations. At the same time, the stored water could be used for irrigation purposes (Bijker 2007: 111).

Arikamedu is considered to have been occupied since the Northern Black Polished Ware (NBPW, or NBP), and most probably between the end of the 1st century BC and the middle of the 1st century AD (Begley 2004). This settlement is an ancient port-town situated in South India, a few kilometres south of Puducherry. Several ceramics have been dated to an age of 300 BC through archaeomagnetic methods (Ramaswamy & Duraiswamy 1990). But we have to keep in mind that 'it is frequently not possible to postulate when an object arrived at a site, when it was discarded and when and how a fragment from it was deposited in a given location' (Begley 2004). Some authors considered this settlement as a Roman colony (Kirk 1975), since Roman elements have been found in Arikamedu, such as coins or ceramics, and since the presence of Greeks and Romans in the area in the very same period has been demonstrated (Ray 1988). The presence of these Mediterranean populations gave the opportunity to local blacksmiths to improve and diversify their techniques (Sita 2000: 32). What is interesting for us is the presence of drains certainly used as sewage disposal, since the beginning of the urban phase of Arikamedu, thus since the 1st century BC (Casal 1949). The wastewater management has been improved around 150 AD with corbelled drains, which seems quite unique for the area (Begley 1983). This system drained water from basins (Bharadwaj 1997), supposed to be a part of a textile and dye industry (Begley 1983). So, whereas in the rest of Ancient India, drains and other wastewater disposal were implemented for domestic effluents, in Arikamedu the wastewater management concerned the industry. Once again, a conceivable link between wastewater treatment and irrigation is not mentioned by any authors. Even so, irrigation through water channel and ditches was commonly used to water the paddy fields of the area (Bijker 2007).

Cultural and technological diffusion in South Asia

Technical diffusion and heritage

The development of drainage technology in Tamil Nadu coincides with the very period when Mediterranean populations settled in this part of South Asia. And, since there has been diffusion of pottery and blacksmith techniques, why might not these be the same type of technological transfer about runoff drainage and wastewater management? Moreover, is the corbelled drain of Arikamedu a 'Roman loan' corbelled drain? Indeed, in the same period, Roman implemented the largest sewage disposal of the Antiquity: the *Cloaca Maxima*. This work had been implemented at

the end of the 7th century BC (Hopkins 2007). It is considered that the *Cloaca Maxima* was almost completed at the end of the 1st century AD (Cooper 2001), when it became necessary to develop sanitation because of the population growth. This is in this very century that vaulted drains were most probably built (Adam 1999: 319 & 321). But it has been pointed out that the corbelled vault was also used in Mohejo-Daro for the drainage of the Great Bath (Jansen 1989: 185), so we cannot confirm that corbelled drains of Arikamedu have a Roman origin.

Furthermore, it has been pointed out that an ancient trade route was situated between Ujjain and Taxila, at least from the emperor Asoka period, i.e. 3rd century BC (Eggermont 1966). We can consider this trade route as a possible way for the spread of wastewater management techniques. But, do they come from Indus Valley culture, or from Greek culture? Magee *et al.* (2005) pointed out that the diffusion of NBP, probably from west to east, may occur previous to the currently accepted date of 500 BC, as the example of Jorwe could confirm. This road was well known by the population of the Mediterranean zone during the 1st century AD, as mentioned by Pliny the Elder and Ptolemy (Eggermont 1966: 262) or in the *Periplus of the Erythraean Sea* (Ray 1987: 98). Thus, contacts between northern South Asian populations and Mediterranean populations occurred during Achaemenid and the Gandhara periods, and wastewater management was practiced during the Harappan and the NBP periods. Kenoyer (1997: 277) mention that 'many of the technologies first developed in the Indus cities provided the foundation for later technologies used in South Asia and other regions of the Old World'. Indeed, wastewater management diffusion in northern South Asia was prior to the first contact with Mediterranean populations. But in South India, wastewater management appeared during the NBP period, thus when the trade and cultural contacts between South Asia and the Mediterranean region were already important.

Nowadays, in some rural area of the valley of Kashmir, south-east of Srinagar, wastewater drains and rain/storm water drains are separated. As in the Indus civilization, latrine and bathroom are on the street side of the houses (Jansen 1989: 189), above a semi-open drain, in order to facilitate wastewater drainage. The public washhouses are supplied by rainwater and stormwater through open drain. The wastewaters (grey water and black water from houses and grey water from washhouses) join the village stream, which is the main source of irrigation. According to a recent personal survey, this system came from a local 'innovation'. Have they been inspired by an ancient technique? More investigations have to be undertaken in order to verify that hypothesis.

CONTEMPORANEOUS WASTEWATER MANAGEMENT IN RURAL TAMIL NADU AND PUDUCHERRY

In today Tamilian villages of Puducherry area, wastewater can be considered to be treated in a traditional way. Indeed, grey water goes through open drain on the street or lane sides (Figure 2(b)), and sloped to a pond, as in Periyamudaliarchavadi (Figure 2(c)). Basically, this type of pond, named *kulam* in Tamil, is not for irrigation purpose. These *kulam* are considered as sacred places, since they are always linked to a Hindu temple situated on the banks. In Alankuppam, for example, this pond's name is *tamarai kulam*, the pond of the lotus, according to the vegetation of this artificial water body. (We can note that here it is not a proper lotus (*Nelumbonucifera* Gaertn.), but a water lily (*Nymphaea nouchali* Burn. f.), called *karuneythal* in Tamil (Nair & Henry 1983: 9).) Aquaculture is practiced in this pond, from the end of the rainy season (December–January) to the dry season (April–May). During the rainy season, the overflow of the water of *tamarai kulam* runs to a ditch and goes to fulfill the downstream *ery*. We find the same kind of system in various villages in the Puducherry area. This drainage system canalizes only the grey wastewater. Indeed, open defecation is still a habit for most of the rural population, as in the rest of India (WHO/UNICEF 2010), and the few families equipped with latrines have their own soak-pit or septic tank.

The technology used at the wastewater treatment plant (WWTP) of Puducherry is very similar to the traditional one occuring in rural areas. The secondary treatment of a part of the inflow is realized through stabilization ponds and lagooning system with floating macrophytes,

Figure 2 | (a) Puducherry WWTP; (b) domestic outlet and street drain in a Tamilian village; (c) Periya-mudaliarchavadi *kulam*.

namely duckweed [*Spirodela polyrhiza* (L.) Schleiden]. Moreover, some of the partly-treated waters are used to irrigate agricultural land producing mainly fodder (Figure 2(a)). Furthermore, the outflow of the WWTP supplies several ponds in order to recharge underground aquifers.

The most important difference between rural and urban wastewater treatment systems is about the quantity of effluents which enters the ponds, few in rural areas, and a huge amount for the urban zone. Indeed, whereas the urban system is centralized, treating the wastewater of about 150,000 people equivalent (PE), the rural one concerns always less than 5,000 PE, and so can be considered as decentralized. Moreover, the quality of the inflow is also different, grey water for the villages, and a mixing of grey- and black water for the city, with even wastewater from hospitals and small industries. Yet, systems are similar, since wastewater is filtered through floating macrophytes lagooning, and then 'polished' via ditches and soil.

DISCUSSION AND CONCLUSIONS

Irrigation as wastewater treatment

According to the examples from the ancient civilization of South Asia cited above, nothing seems to be known about the place where the wastewater was canalized. About the Indus civilization, Kenoyer (1991: 355) argues that the presence of 'a well and associated drains […] need not be related to irrigation' since it correspond with 'a standard feature of Harappan Phase drainage systems'. But, using wastewater for irrigation was practiced in the Mediterranean zone since the Minoan period (2nd millennium BC) (Angelakis *et al.* 2005) and later in Western Europe (Leibundgut 2004). Soil has been a way to treat wastewater in various localities during the entire history (Tzanakakis *et al.* 2007). Thus, it is conceivable that this type of irrigation might have been used in the Harappan settlements. Furthermore, nothing is said about possible sedimentation ponds in

order to treat wastewater, as it was used in other parts of the world (Chatzakis *et al.* 2006). Indeed, about Ancient India, where did wastewater go? Is it conceivable that these technologically advanced cultures could have threatened the good quality of their underground water by 'filling' the wells (cesspools) with wastewater? Further researches should be done on these aspects, in order to understand the management of health risks linked to wastewater contamination.

The efficiency of soil as wastewater treatment system has been demonstrated (Gilbert *et al.* 1976; Papadopoulos *et al.* 2009; Misra *et al.* 2010). Utilization of wastewater for irrigation is advised by the World Health Organization, respecting some precautions in order to avoid contacts between pathogens and humans, so as to reduce sanitation risks (WHO 2006). Furthermore, as phytoremediation techniques demonstrate, we have to keep in mind the potentiality of some plants to accumulate pollutants (Mackova *et al.* 2006; Tiwari *et al.* 2008). Thus, the agricultural production from wastewater irrigated lands could accumulate pollutants, as it has been pointed out about rice (Rahman *et al.* 2008), and other foodstuffs (Singh *et al.* 2010). So the quality of the effluent, and above all the presence of non-biologic contaminants, has to be controlled so that the use of wastewater for irrigation could be considered as safe, as proposed by Trapp & Kulhanek (2006).

Society, wastewater and health in South Asia

Manual scavenging and the practice of dry latrine is a key factor of the failure of modern sanitation development in South Asia (WaterAid 2009; Permutt 2011). Indeed, because of the South Asian social structure, and above all the cast system, the persons who have to clean up sewerages, drains or even latrines are a specific category of the population, a cast known under various names according to the places, who inherit this duty from their ancestors (Chandra 1999). Even if manual scavenging of dry latrines is an ancient practice, it seems that it has been intensified during the colonial period (Chaplin 1999; Prashad 2001). Despite the Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993, the rehabilitation of manual scavengers is still one of the main factors of social and health problem in the South Asian subcontinent (Chandra 1999). Thus, the cultural aspect of excreta and urine has to be taken into account in order to develop techniques which could be socially accepted by the populations (Drangert & Nawab 2011). But first of all, this is the political context, with a high degree of corruption in health and sanitation sector, which should be cleaned up (Davis 2003).

Yet, South Asian populations have undertaken to manage wastewater since the beginning of their history, matching with the beginning of the development of urbanization. Even in southeast India, wastewater has been managed for at least 2,000 years. Moreover, wastewater management appeared at the same period as irrigation techniques, that's why we can conceive that irrigation might have been a system to reclaim wastewater. In the rural areas of present day southeast India, wastewater management is realized through what is similar to modern ecotechnologies, a fact noticed in contemporary southeast China (Yin & Shan 2001). But these basic techniques to treat wastewater, which are efficient for rural areas in a decentralized way, cannot be considered efficient for the contemporaneous pollution (heavy metals, acid, fluoride, radio-elements, antibiotics, etc.) if the wastewater is not previously pre-treated through a physical chemical system.

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First received 4 August 2012; accepted in revised form 21 November 2012