

## Appraisal of Ancient Sewage Systems with Special Focus on Developmental Stages and Application of Geographical Knowledge

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### Abstract:

*We have strong ancient historical base about the innovations. Many ancient civilizations, sites and monuments have the examples that have providing such evidences. For the evaluation of the same, many scholars from different disciplines have worked a lot. The present paper is mainly devoting to assess such innovations in the context of sewage system. By selecting five ancient civilizations i.e. Mesopotamia (4000-2500 BCE), Indus Valley (3000-2000 BCE), Minoan (3000-100 BCE), Egypt (2000-500 BCE) and Roman (800 BCE- 300 CE), the present paper deals with in-depth and spatio-temporal analyses of sewage system with special focuses on applied skills and techniques for wastewater management. The present appraisal mainly depends upon the previous published works, regarding with research problem. The research papers and articles from reputed journals, reports of recognized international institute, reference and edited book, authentic websites etc have been analyzed for present investigation. It is concluded that in that ancient era, they had quit familiar with scientific streams like geometry, gravity,*

*measurements, scales, geological and geographical aspects, process of decomposition, infiltration and evaporation, etc. In short, even now a day we have number of sewage related issues. That means we have not been understood, well from our ancient historical innovations.*

**Key words:** Sewage system, Sewer, Pit Toilet, Flushed Toilet, Cesspit Toilet, Geographical Knowledge

## 1 INTRODUCTION

Development is the process of discovery and application of knowledge. Availability, necessities and curiosity of understanding are the basic elements which promote the innovations towards progress. On the basis of this principle, human life changed from nomadic to modern urbanized style (Kadam et al, 2002). It reveals the history of life transformation from individual to community (Shingote and Kadam, 2006). This journey has the creations and modifications of residential style, food type and socio-cultural aspects etc (Wilkinson, 2000). Many ancient civilizations discovered such things, mainly on the basis of knowledge regarding geography (Raikes and Dyson, 1961; Possehl, 1967; Allchin, 1976), in addition of engineering (Eddy, 1932; Oates, 1990), architecture (DeLaine, 1990; Roaf, 1995; Manzoor and Seung, 2013; Khan and Lemmen, 2014), urban planning (Hoyt, 1962; Jansen, 1985; Kenoyer, 2003) etc at individual to whole civilization. The ruins of ancient civilization have been displaying the picture of historical human life style and their knowledge behind such innovations (Corrigan, 1932). On the basis of these evidences and pervious literature, the present investigation aims to discuss and draw a developmental route map of ancient sewage system. Many archeological excavations discovered the organized water supply and wastewater management systems (Angelakis and Koutsoyiannis, 2003; Koutsoyiannis and Angelakis, 2003;

Dooge, 2004; Kaphale et al, 2005; Agelakis et al, 2006; Mays et al, 2007; Mays, 2008; Koutsoyiannis et al, 2008; Zarkadoulas et al, 2008; Feo et al, 2013; Voudouris et al, 2013; Juuti et al, 2015). As stated by Kadam and Saptarshi (1999) that even in the recent past, local geographical aspects have been affecting overall development of the human life style. By selecting five ancient civilizations i.e. Mesopotamia (4000-2500 BCE), Indus Valley (3000-2000 BCE), Minoan (3000-100 BCE), Egypt (2000-500 BCE) and Roman (800 BCE- 300 CE), the present paper deals with in-depth and spatio-temporal analyses of sewage system with special focuses on applied skills and techniques for wastewater management.

## **2 OBJECTIVES**

Followings basic objective have been selected for the present study.

- To review concern previous literature for the basic study of the selected five ancient civilizations.
- To understand the geographical characteristics of the civilizations.
- To enlist ancient innovations related to sewage system of each selected civilization.
- To assess the geographical knowledge, skills and scientific techniques behind the construction of sewage system.

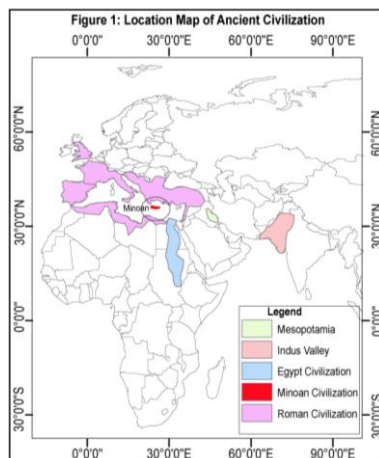
## **3 RESEARCH METHODOLOGY**

The present appraisal mainly depends upon the previous published works, regarding with research problem. The research papers and articles from reputed journals, reports of recognized international institute, reference and edited book, authentic websites etc have been analyzed for present investigation. This study tries to find out the developmental

route map of the complete sewage system and geographical knowledge behind the innovations.

#### 4 STUDY AREAS

The selected five ancient civilizations had been emerged around the world with spatio-temporal variations. Figure 1 has devoting to show the geographical locations of these selected civilizations with present context. The Mesopotamia, Indus and Egypt have been recognized as river valley civilizations. Geographically, they have fertile agricultural lands enclosed with mountains, deserts and oceans. The land between the rivers of Euphrates and Tigris was the birth place of Mesopotamian civilization. Today, this ancient land acquired by Iraq, Iran and Syrian countries. The most sites of Indus Valley civilization discovered in the Pakistan and some of in western India and Afghanistan. This civilization developed along the Indus River and its tributaries. The third ancient civilization had also grown alongside of river Nile, at present situated in Egypt.



The ancient Greek civilizations come to exist on mountain island of Crete i.e. Minoan and slowly ruled over the entire basin of Mediterranean sea at the time of Roman emperor. The Roman region observed from northern England to southern Egypt and from Atlantic coast to Peninsular Gulf.

## **5 RESULT AND DISCUSSIONS**

According to many scholars like Tzanakakis et al (2006), Tseropoulos et al (2013), Angelakis et al (2013), Angelakis and Zheng (2015) and others, such ancient civilizations and their present ruins have been providing the evidences, showing the proofs about the stages, structures and planning of such residential construction mainly related to the sewage system. It also gives basic idea about their knowledge, skills, techniques and scientific base behind these activities (Angelakis, 2005).

In the present paper, step by step development of sewage system i.e. from individual to public toilet and sewer system from small scale to whole civilization, have discussed with the examples and mainly on the basis of authentic secondary literature. The whole system has been divided into basic four stages with their sub points for the present discussions. The main emphasis of the present study has consecrated on the knowledge, skills, techniques, scientific base, geographical approach etc behind these creations, which is discussed in the end.

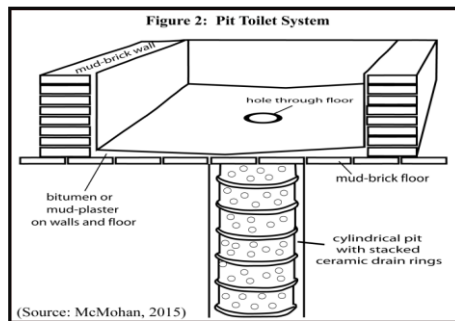
### **5.1 The system of toilet and bathroom**

The system of closed toilet is an important alternative for open defecation, which supports to environment and health protection (Lovell, 1997). The approach towards closed toilet system emerged with first settlement of the world i.e. Mesopotamian (Lafrona and Brown, 2010). Afterwards, it spread to other such ancient civilizations of the world and

applied with different kinds of techniques, methods, utensils, equipments, tools etc as discussed below.

### 5.1.1 Toilet Pot

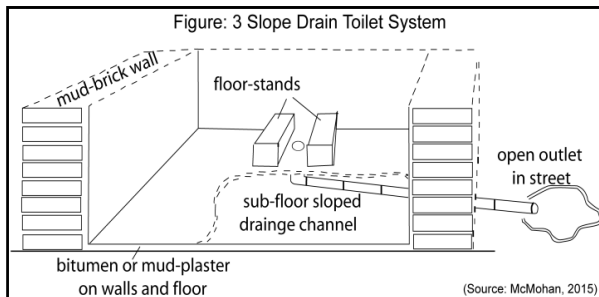
At the initial stage of civilization, they have been applied manual cleanup system for disposal of the human wastes. In this method, human waste collects into the pot (Figure 2) and carried outside the houses for disposal (Aytac, 2004). Such kinds of method found in Mesopotamia at the early stage of civilization. This system had also observed in Egypt civilization (Genc, 2009). They had been used stool shaped toilet seat of limestone or wood, which had hole on top of the surface (Urruty, 1997). The clay pot filled with sand, placed under the stool for collection the waste and manually it dumped outside the house (Bond et al, 2013; EI-Gohary, 2014).



In case of Roman civilization, because of the tenement housing system, they used common tub for collection the waste. In addition to this, for collection of the waste from individual houses by common tub, they used trolley system for carrying material from all the houses. The common tub or trolley had emptied manually at the open area or mound of other wastes (Taylor, 2005; Brown and Lofarna, 2005).

### 5.1.2 Pit Toilet system

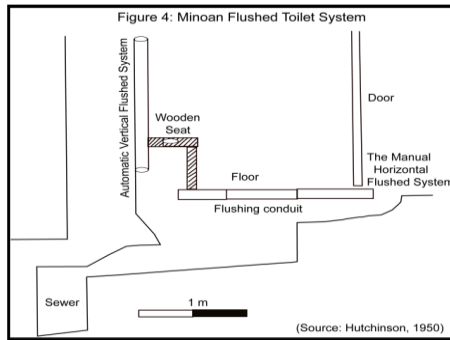
The dry or less water used system of pit toilet observed in ancient Mesopotamian civilization (Figure 3). In this method, the big sized porous clay pipe had been constructed in the underground dug pit (McMahon, 2015).



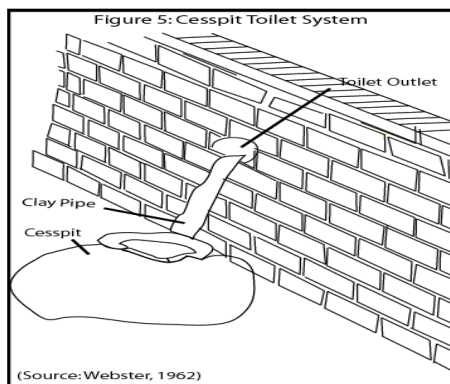
The porous nature used for the purpose of infiltration of the liquid and part of solid material into the earth. The size of pit depends upon the number of inhabitation in house (Feo et al, 2014). After such pit toilet system, the manual head loading and carrying system had been minimized in the civilization. Because of other innovations in these eras, the pit toilet system has not been observed in other civilizations.

### 5.1.3 Flushed Toilet System

The system of sloped drain toilet, cesspit toilet and flushed toilet have the creations of Mesopotamia, Indus and Minoan civilization (Gray, 1940). This was the idea or technique applied for flushing out the human waste by water. In flushed toilet system, indoor lavatories constructed between the outer wall of the houses and street drain line, which had the prime innovation of Mesopotamia (McMahon, 2015). The solid and liquid material directly dumped into the main sewer line by the tilted clay pipe (Figure 4). For flushing the roof rain water and courtyard wastewater have also been attached with clay pipe to the toilet sewer line (Molloer and Molloer, 2009).



In case of Minoan water flushed toilet system, they had used rectangular sized stone toilet seat. It had hole on the top of the surface. The horizontal pipe for Manual and vertical pipe for automatic flushing had been attached in the system. They had also used steps for increasing pressure by slope with minimum length, which was helpful for speedily flush (Figure 5). It also used for imitation of unwanted gasses developed in the wastes (Hutchinson, 1950).

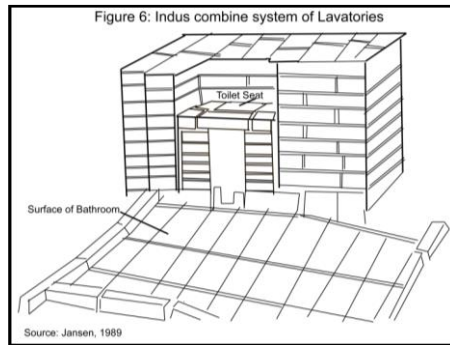


### 5.1.4 Cesspit Toilet System

The cesspit toilet system and modern typed Septic Tank Toilet system has very much similarities. It means modern septic tank system have great ancient history from Indus valley civilization. The indoor lavatories constructed next to the outer wall of house and near to the street drain line. The toilet seat



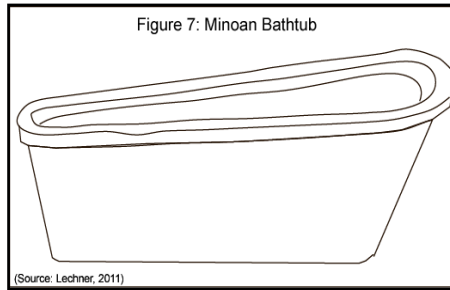
constructed with fired or sundried brick (Khan, 2014). The waste material collected through vertical hole and drain into the pit or cesspit (Figure 6).



This cesspit tank or pit placed next to the outer wall of toilet (Ratnagar, 2014). The rounded big clay container or brick constructed pit had been used for this system (Webster, 1962). The solid materials settle at bottom and liquid wastewater flow from the outlet of pit into the main sewage line via clay pipe or small brick sewer. They had combine lavatories system, in which the wastewater from bathroom attached with toilet. Other domestic wastewater had also been collected into the pit (Foil et al, 1993).

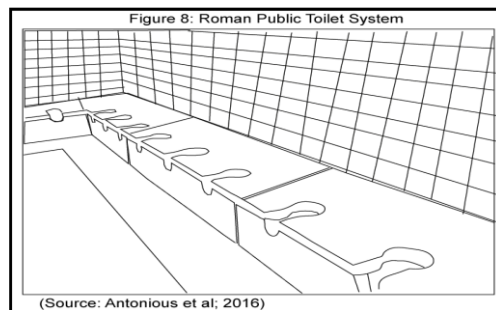
### **5.1.5 Bathroom and bathtub**

The ancient traditions had also have combine system of bathroom and toilet. It had been observed in Indus civilization particularly (Fitzsimons, 1970). The toilet place was arranged at the corner of the big sized room and the rest of the area had been utilized as a bathroom. The surface of the whole room had toward the corner, where the toilet system constructed. In short, the wastewater of bathroom has also been used for wash and flushes the toilet and human waste respectively (Figure 7). In case of the Minoan and Egypt, bathtub system had also been placed in lavatories (Lechner, 2011).

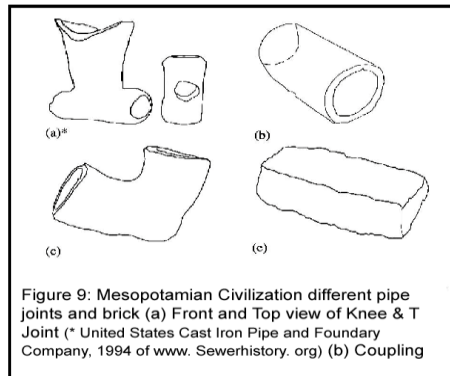


## 5.2 Public toilet and Bath system

The system of public toilet emerged under the concept of sanitation for poor people and for traveler by Indus and Roman civilization respectively (Vourinen et al, 2007). In Indus public toilet system, a line of brick toilet seats constructed upon a pit as shown in Figure 8. In Roman public latrine system, stone toilet seat had been constructed on a sewer line (Antoniou, 2010; Khan, 2014).



Such rounded cut toilet seats were arranged one after next, at a regular interval without wall or barrier (Figure 9). The waste, collected in sewer line drain out by continuous water supply and the wastewater of bathroom (Bond et al, 2013; Feo et al, 2014). The sewer had been connected with main sewer line of the city.



They had also been constructed public bath system as like a modern swimming pool i.e. Grate Bath in Mohen-Jodaro and Baths at Bath, Landon in Roman era. In Grate Bath system, the clean water filled by hand from adjacent well. The wastewater drain out through sloppy outlet channel connects with main sewer line of city civilization (Jansen, 1989).

### 5.3 Sewer line

In ancient civilizations, different kinds of sewer lines utilized for drain out the domestic wastewater. The artifact, stone cutting and shaping, construction etc techniques had been used for creation of usable sized and shaped tools, utensils, material etc for sewers as described below:

#### 5.3.1 Clay Pipe and their joints

According to archeological findings, the skeletons of clay pipes in different shapes have been excavated in ancient civilizations like 'U' shaped, closed or cylindrical, half rounded or circular, rectangular etc. Such kinds of handmade clay pipes had been used to drain out the wastewater from kitchen, washing and bathing places, rain water from roof, courtyard etc to the main sewer line (Angelakis et al, 2012; Angelakis et al, 2014; Tamburrino, 2010). In addition to this, it had also been used in construction of toilet and bathroom. These civilizations mainly

Mesopotamia, have also been creator of clay joints i.e. connected joints, Knees and T-joints as showing in figure 9 (Brown and Lofarna, 2005).

### **5.3.2 Stone sewer line**

The art of stone carving had been used for creation of stone sewer in ancient Minoan and Roman civilization. The Minoan had underground main sewer line, which was constructed by using shaped stones (Angelakis et al, 2005; Angelakis et al, 2012).

The Cloaca Maxima is the well-known bigger sewage system introduced by Romans around 600 BEC (Amulree, 1973). This sewer line constructed along the street and covered with cemented flat stones. It had holes on vertical wall of sewer and horizontal inlet, purpose for collection of storm water and the dumped human waste from cleaning program of roads. Sometimes, this main sewer line connected with private and public latrine, finally emptied into the river (Taylor, 2005; Bertrand-Krajewski, 2008; Taylor, 2015). Such types of underground sewer had also been constructed at Pompeii, the ancient Roman city. But it had not been fully constructed throughout the city (Delleur, 2003). They had also been used half rounded stones for sewer line along the road side

### **5.3.3 Constructed sewer**

The sewer line constructed by brick mainly observed in cities of Mesopotamia and Indus. Such types of main sewer lines had been constructed along the roads in the entire settlement (Fitzsimons, 1970). These sewer lines had covered with bricks, flat stones and clay plates (Mughal, 2011).

## **5.4 System of Maintenance**

In ancient management system, variety of skills employed for convenient flow of sewer lines i.e. removable covered system, big size sewer construction, pit system (Webster, 1962;

Ratnagar, 2014), vertical and horizontal manhole covers (Lafrona and Brown, 2010) etc. The physical effort had been mainly devoted in such kinds of applications. The works related to the maintenance like remove the solid and sludge material from the sewer, collection and dumping of solid waste, construction of new sewer line and maintain the old lines were the basic responsibilities of ancient municipal ruler. The Mesopotamia, Indus, Minoan and Roman had such type of legislative facilities.

## **6 INNOVATIONS, DISCOVERIES AND GEOGRAPHICAL KNOWLEDGE**

This is an ancient history of origin and developmental stages of urban sewage system. It is not only reveals the discoveries but also present the basic understanding and adjusting with surrounded environment. This is a narration of experimental expansion of sewage system from houses to whole settlements. It is necessary to assess the technical skills and geographical understanding behind such transformation.

### **6.1 Problem with Open Defecation and Closed Toilet System**

The main reasons behind the origin of indoor lavatories system are to protect from wild animals, natural hazards, climatic changes etc. Such facilities had been changed and modified with issues of environment and personal health. Well reorganized and modified structures from palaces had been followed for the domestic level according to their social status and professional position. The development moved toward minimization of human efforts for management of such wastes. In this attempt, they have been recognized and applied the association of the slope and water flow for successful drain out the human waste from living areas.

## **6.2 Mixing and Molding of Clay**

The various types of clay tools i.e. fired and sun-dried bricks, pots, different sized and shaped pipes, their joints, containers etc used for the successful drain out of the sewage from residential zones. It means, they had knowledge about the types of soil and their characteristics, for mixing and molding of clay as per requirements. The trial and error method have behind such kinds of innovations. This was the beginning of artifact skill.

## **6.3 Geology**

The ancient remains like stone sewer lines, art of stone cutting, shaping and carving work on stone have strong evidence that they had familiar with geological knowledge about selection of ideal rocks.

## **6.4 Geometry**

According to Kulkarni (1977), they have basic geometrical knowledge of volume and dimensional understanding of height, length and width etc, which is reflecting from their work.

## **6.5 Decomposition, Infiltration and Evaporation**

The pit and drain toilet system had been basically invented with proper understanding of biological processes of decomposition and the liquid characteristics i.e. rate of infiltration and degree of evaporation.

## **6.6 Science of Water**

They also achieved knowledge of water sciences from daily observation like chemical and physical characteristics of solid and liquid material, floating, solution, siltation and sedimentation etc.

### **6.7 Gravity and slope**

The gravity and slope have the soul of sewage system, which had applied a lot in these ancient innovations.

### **6.8 Awareness about upcoming issues**

They had also been aware about future issues regarding to convenient flow of sewage system i.e. blockage, siltation, sedimentation etc and had tried the structural solutions i.e. Manhole system, cesspit system, solid trapped vertical sieve etc.

### **6.9 Size of Sewer**

The dissimilar size of ancient sewer lines shows that they had enough understanding of variation of sewage generation rate with number of persons, usage of water and seasonal changes. On the basis of load on sewer, they had constructed small to big sewer line from source to last point.

## **CONCLUSION**

The present attempt is totally based on secondary authentic literature, collected from various sources and from different research streams. The paper has been trying to highlight the ancient innovations of the selected cases. The main focus of the same has to enlist the basic innovations of sewage and discuss about their knowledge behind such innovations. It is concluded that in that ancient era, they had quit familiar with scientific streams like geometry, gravity, measurements, scales, geological and geographical aspects, process of decomposition, infiltration and evaporation, etc. In short, even now a day we have number of sewage related issues. That means we have not been understood, well from our ancient historical innovations.

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