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Interactive comment on "Hydrology and Water Resources Management in Ancient India" *by* Pushpendra Kumar Singh et al.

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We thank the reviewer, Prof. Stefano Barontini, for offering valuable suggestions and comments to improve the manuscript. We have greatly benefited by by the comments. We provide here our responses to the comments and mention the actions taken where relevant.

Response to the Reviewer's Comments

General Comment : I read with interest the contribution Hydrology and water resources management in ancient India by Singh et al., in which, on the basis of an accurate bibliographical review, the Authors present many aspects of the multifaceted hydrological and hydraulic knowledge in ancient India. The themes addressed are the comprehen-

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sion of the hydrological cycle, the precipitation measurements, the water management (with more evidence to the hydraulic structures than to the management practices) and the wastewater management.

The paper is well written and thoroughly argumented, and it makes a state of the art of the matter, provided that the topic stands between many disciplines (history, archaeology, hydraulic engineering, history of technology and history of culture). Therefore, the paper might be eventually recommended for publication, but I encourage the Authors to strengthen its unitary perspective, in order to depict a wide portrayal, thus avoiding the risk of giving the idea of a collection of cases.

Response: We thank the reviewer for the positive feedback and for offering several comments to improve the manuscript. We have greatly benefited by the comments of the reviewer. We provide here our responses and mention how we would modify the manuscript.

Comment 1: As a first point, for example, it might be useful to explicitly state both in the Abstract and in the Introduction which are the geographical and historical boundaries of the matters, and possibly why these boundaries were chosen, and the aims and the methods of the research.

Response 1: The geographical region covers the entire Indian sub-continent to the east of the Indus river. It includes the parts of the Harappan civilization (in the present-day Pakistan) and entire India. These boundaries encompass the major centers/regions of the development in the ancient India. It would be appropriate to quote Olson (2009) here: 'India was not re-united for nearly 500 years after the collapse of the Mauryan Empire, so its end forms a logical place to end the discussion of the ancient India'. Our discussion in the manuscript is mainly concerned with this period.

This discussion will be incorporated in the revised version of the manuscript, and the geographic region will be mentioned in the Abstract, as suggested by the reviewer.

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Comment 2: Much information presented in the Introduction might be effectively contextualized in the following sections, whereas in the Introduction it is recommended to declare which is the order along which the matter is presented in each section (e.g. historical order, or process– or technology–based order, etc.).

Response 2: The manuscript has been prepared in view of the process-or technology-based order. While doing so, the historical order of those processes or technologies has also been maintained in the manuscript. The text of the manuscript in each section (including the Introduction) will be re-structured accordingly.

Comment 3: Also the concept of "hydraulic civilization", which is sometimes used in the paper, might be better defined in the Introduction. In fact in all the ancient and modern societies the water management plays a crucial role, but the attribute of "hydraulic civilization" is nowadays preferably used to identify those civilizations which survival was deeply linked with the capability of managing the water–related issues (as e.g. the water scarcity, the soil salinization, or the floods) and, in most of the cases, the management was centralized via well-structured groups of technicians and skilled workers (as it was e.g. the case of the great Central Asia oases).

Response 3: Thank you for this insightful comment. In this manuscript, the concept of hydraulic civilization was referred to in respect of the Harrapa civilization and the Mauryan Empire (321-297 BC) in India. Following discussion will be added in the revision, with appropriate editing.

"According to McClellan III and Dorn (2006), the Mauryan Empire was 'first and foremost a great hydraulic civilization.' Megasthenes (A Greek traveller in Chandragupta's Court, around 300 BC), mentions that 'more than half of the arable land was irrigated and in agriculture and produced two harvests in a year'. Further, there was a special department for supervision, construction and maintenance of a well-developed irrigation system with extensive canals and sluices, wells, lakes and tanks. The same bureau was responsible for planning and settlement of the uncultivated land. A similar description of the different institutional arrangements during Mauryan period can be had from Arthasastra. The importance of the hydraulic structures in the Mauryan period can be adjudged on the basis of the punishments/fines to the offenders. As mentioned in the Arthasastra, 'When a person breaks the dam of a tank full of water, he shall be drowned in the very tank; of a tank without water, he shall be punished with the highest amercement; and of a tank which is in ruins owing to neglect, he shall be punished with the middle-most amercement'.

Remarkably, the Mauryan Empire did not lack the other hallmarks associated with the hydraulic civilizations (McClellan III and Dorn, 2006). It had the departments concerned with the rivers, excavating and irrigation along with a number of regional and other superintendents such as the superintendent of rivers, agriculture, weights and measures, store-house, space and time, ferries, boats, and ships, towns, pasture grounds, road-cess, and many others along with many strata of the associated officers such as head of the departments (adhyakshah), collector-general (samahartri), and chamberlain (sannidhatri), etc. Olson (2009) also mentions that there was an extensive irrigation network organised by a state bureaucracy. According to Wittfogel (1955), the Mauryan Empire had virtually all of those characteristics that a hydraulic civilization must possess (though it was late and short lived).

Water pricing was very well defined in the Mauryan Empire. According to Arthasastra, those who cultivate irrigating by manual labour (hastaprávartimam) shall pay 1/5th of the produce as water-rate (udakabhágam); by carrying water on shoulders (skandhaprávartimam) 1/4th of the produce; by water-lifts (srotoyantraprávartimam), 1/3rd of the produce; and by raising water from rivers, lakes, tanks, and wells (nadisarastatákakúpodghátam),1/3rd or 1/4th of the produce.The Superintendent of the Agriculture was responsible for compiling the meteorological statistics by using a rain gauge and for observing the sowing of the wet crops, winter crops or summer crops depending on the availability of the water."

Comment 4: Finally, I encourage the Authors to enlighten, on the basis of the investigated literature, the links between the Indian hydraulic culture and that of the surrounding cultures, particularly regarding the water technologies (see below for details).

Response 4: A separate section, with appropriate editing, will be added in the revised manuscript.

Hydraulic Inter-linkages between the Ancient Indian and Nearby Cultures

All the ancient civilizations, i.e., Harappan, Egyptian, Mesopotamian, Chinese, and including the Minoan civilization that flourished and attained their pinnacle were largely dependent on degree/extent of their advancements in the field of water technologies. With the efficient management of water resources, they were able to produce more food grains and mitigate the damages due to natural hazards such as droughts and floods. At the same time, the advanced wastewater management techniques helped in healthy lifestyles, hygiene, and clean environments.

The ancient Indian literature, starting from the Harappan civilization to the Vedic Period followed by the Mauryan Empire, the Vedic Samhitas and Puranas, contains detailed discourses on the various processes of hydrological cycle, including groundwater exploration, water quality, well construction, irrigation by channels (kulya). Water technological advancements coupled with the architectural sophistication during the Harappan civilization were at their zenith. Nowhere in the world we had such sophisticated and impressive planning relating to the water supply and effluent disposal system (Jansen, 1989). Almost all houses were having their private wells with bath and toilet area lined with the standard size burnt bricks and draining into the soak pit or into the street drains.

Multiple flushing lavatories attached to a sophisticated sewage system were located in the ancient cities of Harappa and Mohenjo-Daro civilization (Pruthi, 2004). The Great Bath at Mohenjo-Daro and 16 reservoir system of the Dholavira and the Dock yard are the perfect examples of the excellent hydraulic engineering in the Harappan civilization. The Mauryan Empire was named as the ‘hydraulic civilization’ due to developments of the advanced means of irrigation, construction of wells, dams and reservoirs, rainfall measurements, protection of hydraulic structures, and water pricing systems in place and a stratified establishment of the bureaucratic and engineering establishment.

The effluent disposal drainage systems were well-known to almost all the civilizations at that time with varying level of technological advancements. The Egyptian civilization (∼2000-500 BC), lacked the flushing lavatories and sophisticated sewer and wastewater disposal systems at that time as was prevalent in Harappan. The copper pipes were in use in some Pyramids for building bathrooms and sewerage system (De Feo et al., 2014). The Mesopotamian civilization (ca. 4000–2500 BC) also had well-constructed storm drainage and sanitary sewer systems. However, there seems no system of vertical water supply by means of wells and it was even practically unknown in the early urban cultures (Jansen, 1989; De Feo, 2014). According to Jansen (1989) and De Feo et al., (2014), the very efficient drainage and sewerage systems, flushing toilets, which can be compared to the modern ones, re-established in Europe and North America in a century and half ago.

The Mohenjo-Daro city was serviced by at least 700 wells, whereas, the contemporary Egyptian and Mesopotamians had to fetch water bucket-by-bucket from the river and then store in the tanks at homes (Jansen, 1989). The bathing platforms in the Harappan civilizations were also unique as compared to the Mesopotamian and other civilizations. The ancient cities of the Mesopotamian civilization, i.e., UR and Babylone had effective drainage system for storm water control, sewers and drains for household waste and drains specifically for surface runoff (Jones, 1967; Maner, 1966). The ancient Mesopotamians had also developed canal irrigated agriculture and constructed dams across the Tigris river for diverting water to meet the irrigation and domestic supplies. The 'qanat' were widely used in Mesopotamian civilization for transferring the water from one place to another using the gravity. The urban centers of the Sumer (Sumerian) and Akkud (Akkadian) (third millennium BC) had water supplies by canal(s) connected to the Euphrates River. However, this lacks the advancements as compared to the Harappan civilization. The water lifting device were also used in Mesopotamian Civilization and the Saaqia (or water wheel) was widely used for lift irrigation using oxen for irrigating the summer crops (Mays, 2008).The 'asmacakra' and 'Ghatayantra' were widely in use during the Vedic and Mauryan Period. The 'Varshaman' was widely used in Mauryan Empire for rainfall measurements. It may be noted that we do not have any reference of 'rainfall measurement' in other contemporary civilizations in the old world. The Pynes-Ahar system of participatory irrigation and rainwater harvesting is a unique system developed in Ancient India.

In Chinese (Hwang-Ho) civilization, the Shang dynasty (1520-1030 BC) developed extensive irrigation works for rice cultivation. Various water works such as dikes, dams, canals and artificial lakes proliferated across the Chinese civilization. Yu the Great, is acclaimed in China as the 'controller of the waters'. During the period 1100-221 BC, the Lingzi city (covering an area of 15 km2) also had a complex water supply and drainage system, combined with the river, drainage raceway, pipeline and moat (De Feo, et al., 2014). The moat surrounding the town halls had supplies from the river works as daily water uses. The water-fortification (audaka) around the forts was also a prime requirement in the Mauryan Empire. Notably, the drainage system of the Lingzi town is supposed to be the oldest and biggest in the ancient China (Fan, 1987). The drainage systems to collect rainwater and wastewater into pools and finally discharge into river were made of the earthenware pipes. The underground urban drainage systems were also in existence in Chine during the Shan Dynasty (∼10-15 BC).

The Minoan civilization (∼3200-1100 BC) is considered to be the first and the most important European culture (Khan et al., 2020). The Crete island was the center of the Minoan civilization and was known for architectural and hydraulic operation of its water supply, sewerage, and drainage systems (Khan et al., 2020). Aqueducts made of terracotta were in use for transporting water from the mountain springs. Water cistern were used for storing rainwater and spring water for further transporting it by using aqueduct. Lavatories with the flushing system were also in use in this civilization. In words

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of Jansen (1989), ‘for the first time in the history of mankind, the waterworks developed in Harappan civilization were to such a perfection which was to remain unsurpassed until the coming of the Romans and the flowering of civil engineering and architecture in classical antiquity, more than 2,000 years later’.

Overall, if we closely look at the scale of the hydro-technologies in all the civilizations, the Harappan civilization is not only credited with the more advanced and larger scale application of hydro-technologies (hydrologic, hydraulic and hydro-mechanical) but also worked as a ‘landmark’ for the contemporary civilizations to achieve the great heights in human civilizations, on the whole.

Comment 5: As a general typographical aspect, I recommend to check and uniform all the emphases and the citations, and to add a complete English translation to all the book titles (the first time they are introduced) and to all the ancient citations.

Response 5: Yes, the suggestions will be taken care of in the revised version of the manuscript.

Comment 6: line 49 add a reference for the citation;

Response 6: The reference, Mujumdar and Jain (2018) will be added.

Comment 7: l.53 emphasize variyantra and better detail its functioning;

Response 7: A revised sentence is given here, which will be added in the manuscript: The variyantra (water machine) was similar to the water cooler. According to Megasthenes (an ancient Greek historian in the court of King Chandragupta Maurya), the variyanytra was used by the wealthier sections of the society for cooling the air.

Comment 8: l.57 pynes and ahars are very interesting structures, also in this case I recommend to better define their functioning (e.g. whether ahars are fed by pynes or by the slopes) and, if possible, their diffusion;

Response 8: Thank you for the suggestion. The Pynes are man-made channels to utilize the river water flowing through the hilly rivers of South Bihar and Chhota Nagpur plateau, whereas the Ahars are catchments with embankments on three sides to store rainwater and the water from the Pynes (Naz and Subramanian, 2010). The Ahar-Pyne system is still widely practiced in these regions and it is a shining example of participatory irrigation management (Pant and Verma, 2010). The Pynes feed many Ahars and several distributaries are then constructed from both Pynes and Ahars for irrigating the field (Sengupta, 1985; Verma, 1993). The Ahar-Pyne system is extremely suitable for the regions having scanty rainfall, highly undulating and rocky terrain, soils with heavy clay or loose sand (lower moisture holding capacity) and steep slope thus causing extensive surface runoff.

The Pynes are of different sizes. If the Pynes are originating from the Ahars, then these are smaller in size (3 to 5 km) and used for irrigating cultivable fields, where as if these originating from the rivers, then the size may vary from 16 to 32 km in length and some of them known as dasianpynes (pynes with 10 branches) to irrigate many thousand acres of the land (O' Malley, 1919). Apart from participatory irrigation system, the Ahar-Pyne system also works as flood mitigation system (Roy Choudhry, 1957). Worth mentioning, recently the Government of Bihar has started the 'renovation' of the traditional water bodies (Ahar-Pyne system) under 'Jal Jeevan Hariyali' programme. This reflects the importance of this ancient hydraulic structure for water harvesting even in the modern times in India (as shown in Figure 1).

We will add a brief discussion on this in the manuscript.

Comment 9: l.73 it is meant the Arthashastra of l.50, isn't it?

Response 9: Thank you. Yes, it is same as in line # 50, i.e., (Arthashastra). The meaning of the Arthashastra is the 'the science of material gain'.

Comment 10: l.115 it can be inferred. . . : this is an important point for the comprehension of the hydrological cycle.

a. Since what it is reported, it seems that the correct comprehension of the hydrological cycle was already achieved in ancient India, as it was few centuries later in ancient Greece, before the Aristotelian statement according to which the water of great rivers could not be stored inside the Earth. Are there explicit references to issues related to the infiltration and to the storage in subsoil reservoirs?

b. This conjecture (the Aristotelian one) paved the way to an (uncorrect) description of the hydrological cycle based on the concurrence of two cycles: one external to the Earth, driven by the Sun, and a more important one internal to the Earth, driven by an engine placed within the Earth's depths. At Authors' knowledge, are there reflections of this conjecture in the Indian late–antiquity hydrological culture?

c. Moreover, Puranas are reported to be written between 600 B.C. and 700 A.D.: is it possible to provide a closer time range for the ones which are cited by the Authors (and particularly for the Vayu Purana)?

Response 10:

a. The infiltration process and sub-soil reservoirs is defined in the Brihat Samhita (550 AD) as given in Line # 162-163. However, the Verses 184.15-17 of Mahabharata state that the plants drink water through their roots. It is said that the water uptake process is facilitated by the conjunction of air. b. The 'Sun' is the main source of the hydrologic cycle [Lines # 107-108; Page# 3] was very well know from the days of Vedic periods. In Rigveda [Lines 100-101; Page #3 of the manuscript], it is mentioned therein that 'the God has created ''Sun' and has placed it in such a position. . .. .". c. The Puranas are a class of literary texts, all written in Sanskrit verse, whose composition dates from the 4th century BCE to about 1,000 A.D (http://southasia.ucla.edu/religions/texts/puranas/). Further it would be interesting to quote Dimmitt and van Buitenen (1978): ". . .each of the Puranas is encyclopaedic in style, and it is difficult to ascertain when, where, why and by whom these were written: "As they exist today, the Puranas are a stratified literature. Each titled work consists of material that has grown by numerous accretions in successive historical eras. Thus, no Purana has a single date of composition. It is as if they were libraries to which new volumes have been continuously added, not necessarily at the end of the shelf, but randomly."

Comment 11: l.125 Do ancient texts use the word smoke instead of vapour? It might be interesting, as in the Aristotelian tradition smoke is used for the dry air in opposition to vapour which is used for the moist one;

Response 11: In fact, it is vapour (the moist air). The 'smoke' is mainly related with the burning. However, to symbolize the burning process (here evaporation process), it was termed as smoke. It has been corrected as 'vapour' in the revision.

For enhanced understanding this sentence maybe rectified as: The Vayu Purana (Verse 51. 14-15-16) states that "the water evaporated by sun rises to atmosphere by means of the capillarity of air, and gets cooled and condensed and then it rains".

Comment 12: l.132 Add an English translation (as well for the other citations and titles, see before in the general comment);

Response 12: Thank you for the suggestion. It will be added in the revised manuscript, as suggested.

Comment 13: ll.162âĂŤ163 It is a very interesting point, as the veins metaphore was common also in other contexts (see e.g. Leonard from Vinci). What feds such veins, as it is reported by Brihat Samhita? And which is the direction along which do they flow?

Response 13: In Brihat Samhita (Chapter 54, Dakargalam), the veins symbolize the 'water table' and the water that falls from the sky feed such veins. It also mentions that the techniques for finding groundwater will be different for different regions and will depend on the type of the landuse and landcover [Verse 54.86]. There are also mentions of the plant species/stone pitching in details for bank protection of water channel. Here, it would be appropriate to mention Murty (1987) that Varajmihir could be ascertained as the 'earliest hydrologist' of the contemporary world similar to the Leonardo da Vinci, 'Master of Water'.

Comment 14: ll.216âĂŤ217 probably not necessary;

Response 14: As suggested, this has been removed in the revised manuscript.

Comment 15: l.223 Kautilya. . . : add a reference;

Response 15: The reference Shamasastry, (1961) is added.

Comment 16: l.231 It seems an astronomical approach, rather than an empiristic one: were there found evidences for multiannual precipitation cycles?

Response 16: We agree with the Reviewer. Distinctively, the Arthasastra, does not mention about the multi-annual precipitation cycle; however, it mentions the precipitation cycles based on the types of the 'clouds' as "three are the clouds that continuously rain for seven days; eighty are they that pour minute drops; and sixty are they that appear with the sunshine–this is termed rainfall" (Shamasastry, 1961).

Comment 17: l.242 Please, check whether capillary is properly used;

Response 17: Here, capillary (actual word in Sanskrit is 'NAADI' means artery, column, nerve, pulse) and hence we have replaced it with 'air columns'.

Comment 18: l.257 In which sense it is used change in the direction of flow of groundwater?

Response 18: Thank you for this comment. The sentence "Well before many centuries of Christ" has been replaced with "based on the extensive reviews of the works on water sciences from Mature Harappan civilization to the Mauryan period, it can be established very well that the ancient Indians were aware of cloud formation, rainfall prediction and its measurements, underground water bearing structures, high and low water tables at different places, hot and cold springs, groundwater utilization by means of wells, well construction methods and equipment, underground water quality and even the artesian well schemes.

Comment 19: l.260 Artesian wells seems not been introduced before, a reference will be useful;

Response 19: It is already mentioned in Line 75.

Comment 20: l.267 In which sense are introduced Eastern and Western hemispheres?

Response 20: Eastern and Western hemispheres represent the 'whole ancient world' (Yannopoulos et al., 2015). Further, the Eastern Hemisphere is sometimes called the "Old World," and the Western Hemisphere is called the "New World." However, the Western Hemisphere is a purely geographic term and should not be confused with other mentions of the "western" world, which is often used to describe parts of Europe, North America and other world regions that share some economic, social, and cultural values (https://www.nationalgeographic.org/encyclopedia/hemisphere/).

Comment 21: ll.281âĂŤ282 It seems more a saqiya than a naoor / noria: could the Authors add few details?

Response 21: Agree with the views of the Reviewer. 'Asmacakra' was used for lifting water from wells for irrigation purposes. Few more details are further added in the next response.

Comment 22: l.285 and followings Probably it is not necessary to enter here the debate on the origin of the noria, or it is better to strengthen the cited references base on this topic;

Response 22: Thank you for this useful suggestion. We would support the statement with references. During the Vedic period, the water for irrigation purposes was taken from lakes (hrada), canals (kulya), and wells. The exact meaning of the 'asma-cakra' is 'stone-pully'or a 'disk of stone'. The buckets (kosa) tied with the strings made of leather (varatra) were pulled around a stone-pulley and then emptied into the channels

(Mukerji, 1960; Yadav, 2008). Arthasastra mentions irrigating the agricultural fields by raising water from rivers, lakes, tanks and wells using a mechanical device known as 'Udghatam' (Srinivasan, 1970).

Comment 23: l.336 In which sense low cost is used?

Response 23: There are many evidences that the Harappans constructed low cost water harvesting structures using locally available materials through public participation. The Dholavira city is located between the smaller streams Mansar in North and Manhar in South, equipped with series of small check dams, stone drains for diverting water, bunds to reduce the water velocity and thus reduce siltation in the main reservoirs (Eastern and Western Reservoirs) (Nigam et al., 2016; Agrawal et al., 2018). The Gabarbands were also in use in Harappan civilization. Similarly, the Ahar-Pyne system (an excellent example of Participatory Irrigation Management and Rainwater Harvesting in Mauryan Era) are the examples of low-cost sustainable rainwater harvesting structures.

Comment 24: l.340 and followings Rabi irrigation was a spate irrigation, a basin irrigation, or a furrows irrigation?

Response 24: It was mainly Spate irrigation throughout the Indus valley civilization (Miller, 2006; Petrie et al., 2017; Petrie, 2019) in form of Canal, Well and Lift irrigation. In the Indus context, it has been argued that perennial and ephemeral water courses were exploited for flood inundation when present, and when not, the inhabitants relied on rainfall, small-scale irrigation, well/lift irrigation and also ponds to supply water (Miller, 2006; Miller, 2015; Petrie, 2017; Weber, 1991, Petrie and Bates, 2017) and Pyne-Ahar system during the Mauryan era.

Comment 25: l.364 . . . an act of religious merit: it is very interesting to unveil the cultural link between the humans and the Nature. Could the Authors better detail in which sense building reservoirs was considered a religious merit?

Response 25: The religious merit indicates for ‘the welfare and well-being of the society’. The Arthasastra mentions that ‘He (the King) shall construct reservoirs (sétu) filled with water either perennial or drawn from some other source. Or he may provide with sites, roads, timber, and other necessary things those who construct reservoirs of their own accord. Likewise, in the construction of places of pilgrimage (punyasthána) and of groves. The State control of irrigational activities were great incentive for the agriculturists (Bhattacharya, 2012).

Comment 26: l.379 These dams seems more barrages, eventually used also for spate irrigation. Could the Authors add some more details on the discharge regime and on the use of these dams? Is it a wadi regime?

Response 26: These dams were used for spate irrigation for rice cultivation to support increasing population during the early-historic period (from the 3rd century BC), which seem to be implied by local settlement patterns and indeed the distribution of large monastic sites in Sanchi area.

These dams were specifically built for irrigation purposes, specifically for irrigation of rice (Shaw and Sutcliffe, 2001). According to Shaw and Sutcliffe (2005), it is more likely that the Sanchi reservoirs were part of the complementary irrigation system by providing extensive irrigation for rice cultivation and would have also supplemented rabi crops due to higher moisture holding capacity of the black cotton soils found in that region.

Yes, it is a wadi regime having mainly two perennial (Betwa and Bes) rivers and various nallas (streams). Rainfall is highly seasonal in this area and about 90% of the rainfall occurs in the mid of June to Sept. There is a period of water deficit from January to June (when evapotranspiration exceeds rainfall) followed by a period of July to September (rainfall exceeds evapotranspiration) (Shaw and Sutcliffe, 2001).

Comment 27: l.381 Is the return period referred to present climate or it was estimated for the ancient one?

Response 27: Yes, the return period refers to the present climate.

Comment 28: ll.434âĂŤ440 Probably not necessary here, and more useful in the Introduction;

Response 28: Agreed. This change will be incorporated in the revised manuscript.

Comment 29: l.447 tapered terra–cotta pipes: Could the Authors add some details on these pipes? They seem frustum–of–cone shaped fistulae common in the Central Asia oases and Latin world;

Response 29: Thank you. We will add details as suggested. The terracotta pipes were used for water supply and sewage, and the sewerage and drainage systems in Harappan civilization (Angelakis and Zheng, 2015). The Terracotta pipes are clay pipes with bell and spigot joints, collars and stop sealed with cement (De Feo et al., 2014). The pipes were built by well-burned bricks (Gray, 1940) having U-shape cross-section and set in clay mortar with various coverings (brick slabs, flagstones or wooden boards) could be removed easily for cleaning the pipes. These ancient terra-cotta pipes, still sound after nearly five thousand years, are the precursor of our modern vitrified clay spigot-and-socket sewer pipe (Gray, 1940).

Several types of stone and terracotta conduits and pipes were also used to transfer water, and drain storm water and wastewater in Minoan Civilization (ca. 3200–1100 BC) (De Feo et al., 2014).

Comment 30: ll.463âĂŤ465 It sounds not very clear, probably not necessary.

Response 30: This comment will be addressed in the revised version of the manuscript.

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Fig. 1. Figure 1: Renovated Ahar-Pyne system in Bihar.

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