



Greek and Roman ideas about healthy drinking-water in theory and practice

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Abstract

Healthy drinking-water is one of the basic conditions to survive, in all times and all places. So the presence of healthy drinking-water is a must to found a city.

Ancient medical writers such as the authors of the Hippocratic Corpus, Galen and others have their ideas which qualities of drinking-water are the best. There are different types of water: warm and cold, clear and unclear, light and heavy. Also the sources of water are important. There were, roughly, five origins of drinking-water: rain water, source water, well water, surface water (river water, lake water) and marsh water. Even the orientation of the water source was, according to some authors, a factor: to the west, to the east, etc. Did their opinions correspond with the opinions of non-medical ancient authors like Aristotle, Pliny the Elder and Frontinus? And did the opinions of ancient authors correspond with the situation in practice? Which type of drinking-water did the city governments prefer to distribute to the citizens?

In my paper, I hope to show and prove that opinions concerning drinking-water in cities, stated by ancient medical authors are (amongst them) roughly the same, but they sometimes differ from non-medical authors, with different argumentations; in practice, the urban drinking-water supply was completely dependent to the local circumstances.

Keywords

Ancient medicine, drinking water, ancient literature, ancient archaeology.

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Des idées grecques et romaines sur l'eau potable saine, dans la théorie et la pratique

Resumé

L'eau potable saine, c'est une condition primordiale pour l'existence, toujours et partout. Pour cette raison, un approvisionnement d'eau potable saine est une *conditio sine qua non* pour fonder une ville.

Auteurs anciens comme les auteurs du Corps hippocratique, Galien et quelques-uns autres ont examinés quelles qualités d'eau potable sont les meilleures. On distingue plusieurs types d'eau: chaude et froide, limpide et trouble, légère et lourde, dur et douce (les conceptions anciennes et modernes de «dur» et «douce» diffèrent fondamentalement!). Les origines d'eau sont importantes aussi. En gros, on distingue cinq origines d'eau potable: l'eau de pluie, l'eau des sources, des puits, des rivières et des marais. Même la position d'une source était, selon certains auteurs, un facteur important: vers l'est, vers l'ouest, etc. On peut se demander si leurs idées correspondaient à la réalité. Quel type d'eau potable était choisi par les administrations municipales pour la distribution aux citoyens?

Dans cet article, je souhaite de montrer et de prouver que les appréciations à propos de l'eau potable dans les villes qui sont mentionnés par les anciens auteurs médicaux, ce sont (parmi eux) à peu près le même, mais ils sont parfois différentes que des auteurs non-médicales. Dans ce cas, des argumentations ne sont pas égales, donc, dans la pratique, l'approvisionnement en eau potable en milieu urbain était complètement dépendante des circonstances locales.

Mots clés

Médecine ancienne, eau potable, littérature ancienne, archéologie ancienne.

Introduction

The Roman architect Vitruvius acknowledges the crucial importance of water for mankind. In his work *De architectura* [*On Architecture* (Vitr.)] 8.3.28 he states: *Nulla enim ex omnibus rebus tantas habere videtur ad usum necessitates, quantas aqua*, 'For of all things, not one seems to be as necessary for use as water'.¹ Just as today, in the Greco-Roman world drinking-water was considered as a crucial factor for human survival. Where drinking-water is absent, human life is impossible.

But which type of drinking-water was the best one for consumption? In Greco-Roman literature, several qualitative distinctions were made: warm and cold water, soft and hard water, light and heavy water, and different types like rain water, spring water and well water. All these types of water were discussed in detail, within the context of ancient medicine and elsewhere.²

Some waters were judged healthy, others not (Rufus, *Quaestiones medicinales* [*Medical Questions* (Ruf.)] 63-72; Haak, 2013, p.56-58 and p.74-78). Is, for example, rain water considered as healthier than spring water, and why?

This article is divided into three parts. In the first (theoretical) part, I will discuss the different qualities (heavy, light, hot, cold etcetera) and types (rain water, spring water etcetera); in the second part, the situation in practice and, finally, the relation between theory and practice. This article will be concerned with drinking-water only; the use of water for other purposes like bathing or irrigation is not at issue here. To stress the continuity in these theories during twelve centuries I have chosen for a thematic approach. I will draw attention to variants and historical developments whenever necessary.

¹ Cf. Vitr. 8.1.1 [sc. *aqua*] *Est enim maxime necessaria et ad vitam*.

² The cited authors are, chronologically, the following: the authors of the Hippocratic Corpus (5th -1st century BC), Aristotle (384-322 BC), Theophrastus (371-287 BC), Erasistratus (3rd century BC), Varro (116-27 BC), Vitruvius (85-20 BC), Celsus (± 25 BC-50 AD), Columella (4-±70 AD), Pliny the Elder (23-79 AD), Frontinus (30-104 AD), Galen (131-± 210 AD), Plutarch (1st-2nd century AD), Antyllus (2nd century AD), Rufus (2nd century AD), Athenaeus (2nd-3rd century AD), Oribasius (4th century AD), Aëtius (6th century AD) and Paul of Aegina (7th century AD). Although these authors span a period of twelve centuries, in ancient medicine there is so much continuity on the subject of drinking water that, in spite of occasional differences, they can be considered as part of one and the same living tradition. Wherever necessary I will highlight differences.

1. Theory

1.1. QUALITIES OF WATER

1.1.1. Light and heavy water

In Antiquity, 'heavy water'³ is supposed to contain more weight, more elements, than 'light' water. Light water is considered as healthy water: it warms up and cools off quickly, it is cold in summer and warmer in winter; since it contains only a few elements, it has no smell or taste and passes through the intestines quickly. Light water is also good for the balance of the four humours inside the human body.⁴ According to ancient medical authors, a healthy man can drink every type of water, but is heavy water as fit for consumption as light water? According to Paul of Aegina, a Byzantine follower of the Hippocratics, all authors consider heavy water as more noxious than light water, because heavy water would have more weight, containing more material or elements and warms up and cools off less quickly than light water (Paul. Aeg. 1.50.1). The Hippocratic treatise *De victu* mentions that water must contain as few elements as possible. People having light waters in their bodies react more quickly to season changes; the quantity of particles of water (the element) in their bodies have not yet reached the maximal capacity (πλησμονή); they are more flexible and for this reason, people can reach the age of 40, or more (Hippocratic Corpus, *De victu* [*Regimen* (Hipp. *Vict.*)] 32). So, light water is better for human consumption than heavy water, but what is exactly the definition of light and heavy water? There appears to be no agreement on this topic.

³ Nowadays, 'heavy water' refers to the chemical property dideuteriumoxide (D₂O).

⁴ Hippocratic Corpus, *Aphorismi* [*Aphorisms* (Hipp. *Aph.*)] 5.26; *Epidemiae* [*Epidemics* (Hipp. *Epid.*)] 2.2.11; Jouanna 1994, p.30; Aristotle, *Problemata* [*Problems* (Arist. *Pr.*)] 873b27; Theophrastus, *Fragmenta* [*Fragments* (Thphr. *Fr.*)] 214A; Vitruvius, *De Architectura* 8.4.2; Celsus, *De medicina* [*On Medicine* (Cels.)] 2.18.12; Pliny the Elder, *Naturalis Historia* [*Natural History* (Plin. *Nat.*)] 31.37; Bollen 1943, p.85-91; Galen, *De ptisana* (*On the Ptisan, or Barley-Water* (Galen, *De ptis.*)), ed. Kühn (hereafter K.) 6.818-819; *In Hippocratis epidemiarum VI commentarii* [*On the Epidemics of Hippocrates VI* (Galen, *In Hipp. Epid. VI comment.*)] 4.10 (17b.156 K.); *In Hippocratis Aphorismos commentarii* [*On the Aphorisms of Hippocrates* (Galen, *In Hipp. Aph. comment.*)] 5.26 (17b.814 K.). Cf. Galen apud Oribasium, *Collectiones medicae* [*Medical Collections* (Galen apud Orib.)] 5.1.2; Aëtius of Amida, *Libri medicinales* [*Medical Books* (Aët.)] 11.15.23; Paul of Aegina, *Epitomae medicae* [*Sixteen Books on Medicine* (Paul. Aeg.)] 1.50; Garzya 1994, p.109; Rogers 2013, p.7. For a list of authors and their statements concerning light (healthy) water see Bollen (1943, p.140-142). She does not mention Aristotle, Vitruvius and Galen, but they have the same opinions.

According to the author of the Hippocratic treatise *De aëre aquis et locis* [*Airs, Waters, Places* (Hipp. *Aer.*)] 7,⁵ rain water is a light type, and therefore healthy (Aristotle, *Ethica Nicomachea* [*Nicomachean Ethics* (Arist. *EN*)] 1142a21). Some authors, especially Celsus (Cels. 2.18.12, *Nam levis pondere apparet*, 'For by weighing, the lightness of water becomes evident') agree.⁶ The heaviest water is sea water (Arist. *Pr.* 932b8-10). Other authors have a different opinion. The Alexandrian physician Erasistratus, well-known for his experiments, has a surprisingly rational view: he is doubtful concerning the statement that heavy water is worse than light water. There is good and bad drinking-water, but this cannot be deduced from its weight; he states that unhealthy water has the same weight as healthy water (Erasistratus apud Athenaeum, *Deipnosophistae* [*Deipnosophists* (Erasistratus apud Ath.)] 2.46c; Erasistratus, *Fragmenta* [*Fragments* (Erasistr. *Fr.*)] 159, 117; Von Staden, 1994, p.81-83). Pliny the Elder radically rejects the importance of the weight of water; it does not matter at all (Plin. *Nat.* 31.32; cf. 31.38; Von Staden, 1994, p.82-84), so his opinion is diametrically opposed to that of Celsus. This raises the question whether the 'weight' of water was a purely theoretical qualification or was really put to test.

A fragment of Erasistratus' work sheds some light on this problem. After a discussion concerning potable water, Erasistratus states: δοκιμάζουσι τινες τὰ ὕδατα σταθμῶ ἀνεξετάσως. There are, in my opinion, three possible interpretations of this sentence.

- Firstly, σταθμῶ ἀνεξετάσως may be interpreted as a word group, independent of δοκιμάζουσι: 'some people evaluate water, without inspection of its weight'. In this context, τινες are right: they consider weight of such little importance that they do not examine it (ἀνεξετάσως), confirmed by γάρ in the following sentence (ἰδοὺ γὰρ τοῦ ἐξ Ἀμφιάρου ὕδατος καὶ <τοῦ> ἐξ Ἐρετρίας συμβαλλομένων, τοῦ μὲν φαύλου τοῦ δὲ χρηστοῦ ὄντος, οὐ δὴ τίς ἐστὶ διαφορὰ κατὰ τὸν σταθμὸν ('Witness that, when water from the Amphiarus spring and from Eretria is compared, although one of them is bad and the other good; there is no difference in weight whatsoever').⁷

⁵ In Greek: Περὶ ἀέρων καὶ ὑδάτων καὶ τόπων (ὑδάτων is plural).

⁶ According to Aristotle, light water has a better taste, passes the stomach quickly and does not cause intestinal diseases. He uses the word λεπτός, not only meaning 'light-weighted' but also 'with a fine structure': Arist. *Pr.* 873b27. Cf. Thphr. *Fr.* 214A vol. 1, 384-385; vol. 3.1, 204-205; Von Staden, 1994, p.80-81; Vitruv. 8.4.2; Bollen, 1943, p.47; Seneca, *Quaestiones naturales* [*Natural Questions* (Sen. *Nat.*)] 3.2.2.

⁷ In Garofalo's edition, οὐ δὴ τίς is mentioned; this gives the statement a more stressed signification than the one of Erasistratus apud Ath. 2.46c οὐδ' ἦτις, 'although one of them is bad and the other good, there is no difference in weight.' There are two springs called Amphiaros: one in the Amphiareion in Oropos, a good one;

- Secondly, the word σταθμός can mean 'weight' (τό), but also 'balance' (ὄ). So another translation of these words would be: 'some people evaluate water without inspection, by means of a balance'. This interpretation does not make much sense; moreover, in this interpretation, there is no coherence between the two sentences connected by γάρ. Furthermore, it seems illogic to measure a weight without the use of a balance. Pliny translates Erasistratus' quotation roughly: *quidam statera iudicant de salubritate frustrante diligentia*, 'some people evaluate (sc. waters) by means of a balance; but their efforts are senseless' (Plin. *Nat.* 31.38). He continues stating that weight is not important.
- Thirdly, σταθμῶ specifies δοκιμάζουσι ('some people evaluate water by its weight, without [critical] inspection'). In this case, τινες are researchers who are wrong; according to the next sentence, weight is not of any importance at all. I prefer this last possibility: this is the clearest explanation (more stressed if οὐ δὴ τίς is used), there is coherence between the two sentences doing justice to γάρ and the use of τινες suggests that some people evaluate water by its weight.

In the second option, balances were mentioned. There are three authors who discuss the use of balances explicitly: Plutarch (who describes people using and even constructing balances for measuring the weight of water, *Fragmenta [Fragments (Plu. Fr.)]* 81); Pliny the Elder (see above, Plin. *Nat.* 31.38), and even Galen (mentioning that who wants to know the weight of water has to use a balance, *In Hipp. Aph. comment.* 5.26 (17b.815 K.).⁸ Moreover, Theophrastus claims that he has weighed water at Mount Panggaion; in winter, the water weight is 96 units, in summer 46; water clocks would be inaccurate due to the changing density of water. This story seems to be doubtful. There is no evidence for a change of weight of water in summer and winter (in winter more than twice as much!). Theophrastus' use of the word *gnomon* (ἐν τοῖς γνώμοισι) (Theophrastus apud Athenaeum, *Deipnosophistae [Deipnosophists]* (Theophrastus apud Ath.)] 2.42a-b) provides another puzzle since a *gnomon* is a sundial which does not contain water. The exact numbers suggest that he has weighed water by means of a

the other in Lerna, a bad one. See for this discussion concerning the Amphiaraios springs compared with the spring of Eretria Bollen (1943, p.108-111). According to Nutton (1996, p.226), Evenor refers to the Amphareion water in Oropos.

⁸ Cf. Rufus apud Oribasium, *Collectiones medicae [Medical Collections]* (Rufus apud Orib.)] 5.3.26.

balance, but the incredible elements of this story make it hard to believe.⁹ The notion of practical experiments by Erasistratus and, moreover, by Galen is striking.

Some authors mention the possibility that the weight of heavy water might be reduced by boiling. Galen states that water has to be boiled and later cooled off: at first, it must be put down in an open jar or barrel and the next day one has to sprinkle the barrel (Galen, *In Hipp. Epid. VI comment.* 4.10 (17b.153-166 K.); Bollen, 1943, 86). During the boiling process, the water elements are divided and when the water is cooling, heavier elements like salt or bitumen sink down to the bottom and the lighter elements remain in the upper part of the barrel.¹⁰ This process testifies to the view that added elements deteriorate the quality of water.

The Hippocratic treatise *De aëre aquis et locis* speaks of 'hard' (σκληρός), roughly comparable with 'heavy' water. 'Hard' water is not water containing lime or calcium, like nowadays, but water containing particles of rock, sometimes with added metals or bitumen. People with a 'hard digestion' are advised to drink 'soft' water and people with a soft digestion to drink 'hard' water, *contraria contrariis* (Hipp. *Aer.* 7; Bollen, 1943, p.29; Crouch, 1993, p.50; López Férez, 1992, p.538; Jouanna, 1996, p.37).¹¹

In short, waters containing a lot of elements were supposed to be heavy, so unhealthy. Some authors were convinced by the fact that waters have different weights from place to place, so the salubriousness of waters differs too. Other authors, however, were doubtful concerning this topic; salubriousness of water was, in their opinion, independent from its weight.

1.1.2. Hot and cold water

Ancient authors distinguish hot (heated) and cold water. There are two types of hot water: water, hot by nature, from hot springs; and water, artificially heated by fire. Lukewarm water is heated artificially. All other water is cold: rain water, cold spring water, well water and cistern water. 'Hot', 'lukewarm' and 'cold' are, of course, relative notions, also in Greco-Roman times; cold for the one, fresh for the other. So, 'cold' can mean 'fresh', 'cool', and even 'icy cold'.

⁹ The translator of the Loeb text (ed. 1927) justly adds in a footnote: 'This is the only passage in which γνώμων = κλεψύδρα, "water-clock." What follows is uncertain in text and meaning'. In ed. 2006: 'gnōmōn has this sentence nowhere else, but it is difficult to see what else the text could be referring to'.

¹⁰ Boiling, cooling and reheating of water: Rufus apud Orib. 5.3.36; Haak, 2013, p.75; apud Aët. 3.165; cf. Paul. Aeg. 1.50; Winkelman, 1994², p.167.

¹¹ Cf. Athenaeus, *Deipnosophistae* [*Deipnosophists* (Ath.)] 2.42c; Wellmann 1900, p.357.

In *De aëre aquis et locis*, hot water contains elements (a.o. sulphur, alum and bitumen), making it heavy and therefore unhealthy. Here, Vitruvius is an adherent of *De aëre aquis et locis*: he states that water, by its nature, is cold; if hot, there are elements like sulphur, alum or bitumen (Vitr. 8.2.8.0¹²). In some cases, however, hot springs produce healthy water and cold springs unhealthy water (Hipp. *Aer.* 7; Thphr. *Fr.* 214A vol. 1, 384-385; vol. 3.1, 205-206; Campbell, 2012, p.343; Vitr. 8.2.8-9). Nevertheless, in view of his use of words like *autem* in 8.3.1, *sunt autem etiam nonnulli fontes calidi, ex quibus profluit aqua sapore optimo*, 'there are, however, also some hot springs from which water flows of excellent flavour' and *etiam* in 8.3.2, *sunt etiam odore et sapore non bono frigidi fontes*, 'on the other hand, there are cold springs not of pleasant smell or taste', it may be inferred that, according to Vitruvius, hot springs produce mainly more noxious waters than cold springs (Vitr. 8.3; Winkelmann, 1994, p.167; Campbell, 2012, p.339).

Galen permits sick people to drink cold water if they used to do so while they were healthy; this suggests that Galen does not advise drinking water to be cold (Galen, *In Hipp. Epid. VI comment*, 8 ed. Pfaff, CMG V 10.2.2, 489-490; Horstmanshoff 1999, p.138). He gives a list of cases concerning the use of cold water. Cold water (as medicament) is wholesome against fever (*contraria contrariis*), to restore the temperature of the body, but sometimes, it is better not to use cold water (Galen apud Orib. 5.2.1-9). Hot water – I suppose heated water – was also used as medicament, especially as emetic.¹³

In general, cold water was supposed to be healthier for consumption, because this is a natural phenomenon; hot water should contain more (noxious) elements – but there are some exceptions. Hot water, however, is recommended as emetic.

¹² Sulphur, alum and bitumen: see note 18.

¹³ Recommending cold water: Hippocratic Corpus, *De morbis* [*On Diseases* (Hipp. *Morb.*)] 2.40 (against fever, *contraria contrariis*); Cels. 1.3.23; Galen, *De methodo medendi* [*On the therapeutic method* (Galen, *De meth. med.*)] (10.757 K.) and (10.759 K.); Galen, *De compositione medicamentorum secundum locos* [*On the composition of local remedies* (Galen, *De comp. med. sec. loc.*)] (13.170 K.); Paul. Aeg. 1.40.1. Cold water as emetic: Cels. 3.9.3; Rejection of cold water: Diocles, *Fragmenta* [*Fragments* (Diocl. *Fr.*)] 182 line 207; Galen, *De sanitate tuenda* [*On the preservation of health* (Galen, *De san. tuenda*)] (6.56 K.); Orib. (*libri incerti*) 40.52. Recommending hot water: Hippocratic Corpus, *De locis in homine* [*Places in Man* (Hipp. *Loc. Hom.*)] 27; López Férez 1992, p.536. Warm water as emetic: Hipp. *Epid.* 2.5.19; Rufus apud Orib. 7.26.167; Antyllus apud Oribasium, *Collectiones medicae* [*Medical Collections* (Antyllus apud Orib.)] 5.29.1-4; Galen, *De antidotis* [*On antidotes* (*Antid.*)] (14.144 K.); Aët. 5.108.

1.2. TYPES OF WATER

Now I will discuss the several types of water (precipitation water and water on earth). There are, roughly, four types of water: rain water, spring water, well water and surface water. The last type can be subdivided into marsh water, river water and lake water. Which type of water was recommended by ancient authors for consumption and which was not?

1.2.1. Rain water

According to the majority of all ancient authors, rain water is considered as the best type of water. *De aëre aquis et locis* states that rain water from the highest parts of the sky, close to the sun, is the best, because the sun makes it sweet; rain water from the lowest parts of the sky is less healthy, because rain water deteriorates quickly and close to earth, it is a dense fog. For the best result, it must be boiled before consumption preventing afflictions of the throat (Hipp. *Aer.* 8; Crouch, 1993, p.50; Bollen, 1943, p.40; Winkelmann, 1994, p.163-164; Von Brunn, 1946, p.166; Von Brunn, 1947, p.12; López Férez, 1992, p.538). The Hippocratic author makes not clear whether rain water is better than spring water (discussed below).¹⁴ Nearly all other authors prefer rain water (Theophrastus, *Historia plantarum* [*Enquiry into Plants* (Thphr. *HP*)] 7.5.2. Vitruvius, *Vitr.* 8.2.1; Gros 1997, p.1157; Winkelmann, 1994, p.167. Celsus, *Cels.* 2.18.12; Columella, *Res rustica* [*On agriculture* (Col.)] 1.5.2; cf. Palladius, *Opus agricultura* [*Work on agriculture*] 1.17.4. Plutarch, *Aetia physica* [(Plu. *Aetia physica*)] 912b-d. Galen, *In Hipp. Epid. VI comment.* 4.19 (17b.184 K.); cf. Galen apud Orib. 5.1.5; Galen apud Orib. 5.1.9-10; Rufus apud Aëtium of Amida, *Libri medicinales* [*Medical Books* (Rufus apud Aët.)] 3.165; Haak 2013, p.74-75; Paul. Aeg. 1.50).¹⁵ In addition, the physician Rufus divides rain water into rain water falling with a north wind – this type is softer and colder – and falling with a south wind – this type is harder and warmer (Rufus apud Orib. 5.3.7-11; Bollen, 1943, p.131-133; Haak, 2013, p.75). Rainfall in winter and spring is better than in summer and autumn, because in these seasons there are noxious vapours emitting from the earth (Plin. *Nat.* 31.32). Pliny the Elder is an adherent of the same opinion concerning rain water pollution. He mentions that some physicians prefer rain

¹⁴ Bollen (1943, p.42), 'rain water is the best of all'; *contra* Bollen (1943, p.112), 'Hippocrates prefers spring water to rain water'. In *De aëre aquis et locis*, there are two main groups of water: precipitation water (rain water, falling down with force or not, ice and snow water) and water on earth (spring water from rocks, earthen hills, and surface water).

¹⁵ An enumeration of all rain water adherents and Pliny as opponent is given by Bollen, 1943, p.46-47.

water (*hi (sc. medici) rationem adferunt, quoniam levissima sit imbrium, ut quae subire potuerit ac pendere in aere*, 'the lightest water, the physicians say, is rain water, seeing that it has been able to rise and to be suspended in the air'), but, according to him, rain water deteriorates quickly, due to noxious vapours from the earth. Rain water warms up quickly, because it is polluted; so he is in disagreement with nearly all medical authors who state that light water with only a few or no elements is warming up quickly. The same opinion concerning pollution of rain water caused by other elements in the atmosphere is found, however, in *De aëre aquis et locis* 8; maybe, Pliny derived his view from this treatise (Plin. *Nat.* 31.31-34; Galen apud Orib. 5.1.8). Nowadays, we know that 'acid rain' is caused by pollution.

In *De aëre aquis et locis* other types of rainfall are distinguished: rain water falling in a calm shower is preferred to rain water falling during a storm. However, if rain falls accompanied by lightning, it is even better; lightning is associated with ether, the furthest remoted from earth with its noxious vapours, and thus as pure as possible (Hipp. *Epid.* 6.4.17; Galen, *In Hipp. Epid. VI comment.* 4.19 (17b.187.7-188.11 K.); Paul. Aeg. 1.50).

Concerning the question as to whether snow, hail and ice water are better than rain water, there is discussion amongst the different authors. Some medical authors answer this question in the negative; the light and sweet particles of these waters (λαμπρὸν καὶ κοῦφον καὶ γλυκὺ) would have been diminished and the heavier ones (θολωδέστατον καὶ σταθμωδέστατον, added elements) are left behind (Hipp. *Aer.* 8; Jouanna 1996, p.31; Crouch, 1993, p.50; Bollen, 1943, p.18 and 26; López Férez, 1992, p.535; Galen, *In Hipp. Aph. comment.* 5.24 (17b.813 K.); Galen apud Orib. 5.1.10; Bollen, 1943, p.91-92; Paul. Aeg. 1.50). Pliny, on the other hand, states that according to some authors, snow- and ice water is better than rain water, because it is lighter, but hail water, only mentioned by him, is the worst of all, due to the absence of fine particles (*exactum sit inde quod tenuissimum fuerit*, Plin. *Nat.* 31.33).¹⁶

1.2.2. Spring water

The Hippocratic ideas concerning rain water survived throughout the Classical period, until the Byzantine era; according to Paul of Aegina, spring water is good, but rain water is better; the author cites *De aëre aquis et locis*: rain water contains the finest elements (Paul. Aeg. 1.50; Hipp. *Aer.* 8; Jouanna, 1996, p.39). *De aëre aquis et locis* mentions two types of spring water. Firstly water from springs rising out of rocks; they deliver hard water, containing small pieces of

¹⁶ See for the discussion concerning the quality of snow and ice water Bollen, 1943, p.74-76. Cf. Ath. 2.42c; Thphr. *Fr.* 214A vol. 1, 384-385; vol. 3.1, 206; Wellmann 1900, p.354-355.

rock. Secondly, spring water from soil producing better water (Hipp. *Aer.* 7). According to Aristotle, some salty (and, inevitably, according to ancient theory 'heavy') springs can produce drinking-water. According to him, all hot water springs produce salt water. But is this really salt water? Probably, this is mineral water containing elements causing a certain taste; in hot (mineral) water, elements can dissolve easier than in cold water. On the other hand, Diodorus Siculus mentions some hot springs producing sweet and healthy water (Arist. *Pr.* 937b and 937b18; cf. Sen. *Nat.* 3.2.1; Rogers, 2013, p.7; Diodorus of Sicily, *Bibliotheca historica* [*Historical Library* (D.S.)] 2.59.9).¹⁷

A positive aspect of spring water is the property that it flows. Varro agrees, stating that an estate must enclose it, or nearby (Theophrastus apud Ath. 2.42c.; Hellmann, 1994, p.274. Varro, *De re rustica* [*On Agriculture* (Var. *R.*)] 1.11.2). Vitruvius' opinion concerning spring water is less strict: Springs at the foot of mountains (including siliceous earth) produce more and better water than springs in a flat area, because flat areas receive more sunlight and heat; the sun pulls up the finest elements of the water, leaving behind the less tasteful part of the water. Here he disagrees with the author of *De aëre aquis et locis*, who has a negative opinion to springs rising out of rocks (Vitr. 8.1.2 and 8.1.7. Cf. Thphr. *Fr.* 214A vol. 1, 384-385; vol. 3.1, 206; Col. 1.5.2; Palladius 9.8; Callebat 1973, p.55). When spring water is passing an earth layer containing sulphur, alum or bitumen, this water will produce stench and a bad taste; it does not matter if it is hot or cold (Vitr. 8.2.8). Later, however, Vitruvius discusses the (wholesome) curative aspects of water containing sulphur, alum or bitumen; suitable for bathing, but not for consumption (Vitr. 8.3.4; Callebat, 1973, p.91; Gros, 1997, p.1166; Yegül, 1992, p.92-93). He prefers, on behalf of cities and settlements, spring waters to well waters (Vitr. 8.6.12).

The only non-medical author who divides water into different types is Columella. His sequence is as follows: the best water is flowing water (spring water), next well water and, third, cistern water (subdivided into, the best, rain water, second water from rocks and third water from hills) and, finally, marsh water. Flowing spring water is better than well water and stagnant water (Col. 1.5.1). But is spring water better than rain water? Columella calls rain water *salubritati corporis accommodatissima*, 'most suitable to the body's health' (1.5.2), but it is a type of cistern water, so it can be stated that, for consumption, rain water is as good as spring water. A remarkable point is that Columella prefers spring water rising out of rocks to spring water rising out of hills and valleys, in contrast to *De aëre aquis et locis*. Here we see, maybe, the practical man Columella, in opposition to the more speculative opinions of the

¹⁷ Hipp. *Aer.* 3 mentions brackish water in cities exposed to the south winds, but it is unclear if this is also drinking-water.

Hippocratics. Perhaps, in Columella's opinion, water from hills is less clear, due to layers of clay and sand.

Concerning springs, Pliny the Elder pays attention mainly to curative springs for bathing, mainly hot ones, containing sulphur, alum and bitumen – the similarity of Vitruvius' opinion on this topic (discussed above) is striking. Pliny (a critic of Greek medicine – according to Hahn 2005, p.715) gives the place and situation of water a central role (Plin. *Nat.* 31.35; Campbell, 2012, p.340): rain water is not good (due to its pollution), and water is neither considered as good by particles of sand or rock nor by the question if it is flowing or not; therefore only the place is important (Plin. *Nat.* 31.4-5).¹⁸

From where the different opinions concerning the quality of waters from rocks, sandy hills or valleys? As said, the author of *De aëre aquis et locis*, water from rocks is 'heavy', probably because rocks are heavy; sand is lighter of weight, so healthier. But particles of rock makes water less turbid than particles of finer material like sand, so Vitruvius and Columella prefer water from rocks.

The majority of the authors state that, discussing spring waters, neither their temperature, nor their origin, nor their contents do matter actually. Some of these authors, mentioning that it depends on the places, whether a source is good or bad, are Plutarch (water from Arethusa, although light, is bad); Rufus (agreeing with Plutarch on the case of Arethusa: this water causes, according to him, gout) and Athenaeus. The latter sometimes follows the Hippocratic tradition (heavy and hard water is worse than light water warming up quickly; flowing water is better than stagnant water, and water from mountains is better than water from plains). He goes on, however, to enumerate a list of healthy and unhealthy springs, e.g. in the environment of Baiae, producing unhealthy waters (Ath. 2.42e-2.43e; Thphr. *Fr.* 214A vol. 1, 386-387; vol. 3.1, 208); Strabo, however, states that these are very wholesome (Strabo, *Geographica* [*Geography* (Str.)] 5.4.5). Maybe, Strabo refers to a different spring, or water from these springs is unfit for consumption, although maybe suitable for bathing purposes.¹⁹ Authors discussing individual springs have, in contrast to authors following Hippocrates, a less speculative and less generalizing approach. The importance of cardinal directions with spring water is also mentioned by *De aëre aquis et locis*: a spring situated to the east is the best, next

¹⁸ In the next paragraphs, he discusses a lot of springs and their properties. According to Pliny the Elder (*Nat.* 31.59), sulphur is good for the sinews, alum against paralysis and collapse and asphalt and bitumen are good for drinking and as a purge, following Vitruvius 8.3.4; Bonnin 1984, p.90.

¹⁹ According to Campbell, also Galen judges each spring separately: Galen, *De simplicium medicamentorum temperamentis ac facultatibus* [*On the powers and mixtures on simple drugs* (Galen, *De simpl. med. temp. ac fac.*)] 1.6 (11.392 K.); Campbell, 2012, p.343.

a spring to the north, next a spring to the west and, finally, a spring to the south. In case of southern springs, it does matter whether there is north wind or south wind; south wind is worse than north wind (Hipp. *Aer.* 7; Jouanna, 1996, p.33-34).²⁰ Cities exposed to the south have plentiful and brackish waters; cities to the north have cold and hard waters, and cities to the west unclear ones. Cities to the east have the best waters; sweet-smelling, soft and delightful (south: Hipp. *Aer.* 3; north: *Aer.* 4; east: *Aer.* 5; west: *Aer.* 6; Bollen, 1943, p. 32-33; Lo Presti, 2012, p.178-179).

Other authors also prefer springs in the north and the east. Vitruvius is an adherent of *De aëre aquis et locis* concerning situations to cardinal directions and states that the best springs are situated in the north. It is uncertain whether Galen prefers spring water to rain water, but an important factor is the direction of the stream from the spring. Rufus prefers both north and east.²¹ But what is meant by, for example, 'to the south'? Does the author mean that the water flows to the south, so the spring is, inevitably, situated in the north? Or is the spring in the south and does the water flow to the north? According to Paul of Aegina, spring water flowing to the north is bad (Paul. Aeg. 1.50); inevitably, this spring is situated in the south, where, according to *De aëre aquis et locis* and other authors, the water is bad. Maybe, it is meant that 'a spring to the south' is a spring in the south, from where the stream flows to the north. For an explanation for preferring the east and the north, see my forthcoming article (Van Tilburg, 2014).

1.2.3. Well water

In respect to well water, the Hippocratic Corpus is less clear. According to *De aëre aquis et locis*, good water must be cold in summer and warm in winter (*contraria contrariis*); well water coming from a great depth is such water. A disadvantage is that a well contains stagnant water in the upper part, warm in summer and cold in winter (Hipp. *Aer.* 7; *Morb.* 4.25; López Férez, 1992, 535). Vitruvius prefers spring water to well water; he recommends digging wells if there

²⁰ Cf. the colder and softer north wind during rainfall mentioned by Rufus above.

²¹ For his education in architecture, knowledge of medicine was needed: Vitr. 1.1.10; 1.1.13; Mazzini 2014, p.89. It is remarkable that he uses the words *aeris et locorum* [...] *aquarumque*, possibly a reference to *De aëre aquis et locis*. Best springs in the north: Vitr. 8.1.6 (cf. Callebat, 1973, p.60-61); 8.2.6 and 8.2.8. Galen, *De san. tuenda* 6.57 K.; Bollen, 1943, p.90-91; Galen apud Orib. 5.1.4; Rufus apud Orib. 5.3.12-16; Bollen 1943, p.133-134 (directions of streams); cf. Rufus apud Aët. 3.165 and Rufus apud Oribasium, *Synopsis* [*Synopsis* (Rufus apud Orib. *Syn*)]. 4.41.1-12; Wellmann, 1900, p.352.

are no springs (Vitr. 8.6.12. Guillaume 1877-1919, p.1209). Varro and Columella recommend respectively a reservoir and a well if a spring is not present (Var. *R.* 1.11.2; Col. 11.3.8).²²

Some authors state that the quality of well water is worse than spring water. In the water order of Celsus, well water comes after rain water, spring water and river water (Cels. 2.18.12; Jouanna, 1996, p.39; Hellmann, 1994, p.275; Bollen, 1943, p. 46; cf. Wellmann, 1900, p.352). The fact that well water is placed after river water is astonishing, because surface water is usually estimated as an unhealthy type of water. Probably, Celsus prefers river water because it is flowing, like rain and spring water.²³

Only Pliny is an adherent of well water, on condition that it is continuously flowing, and that the location provides fresh air and shadow (Plin. *Nat.* 31.38-39; Bollen, 1943, p. 71). Another advantage is the fact that it has been filtered through earth layers (Plin. *Nat.* 31.38). But well water does usually not flow, except after tapping; why, nevertheless, his preference for well water? Maybe, his disdain for theoretical Greek doctors (who prefer rain water and spring water) and his preference for simple medicine. Well water was used on a large scale in the Vesuvius area where he lived (Hahn, 1991, *passim*). So we can conclude that well water is usually less favourite than rain water and spring water. Apart from the fact that it contains more elements, it does not clearly flow.

1.2.4. Cistern water

Cistern water is rain water, stored in cisterns. On the one hand, it is rain water, according to the majority of the authors the best type of water. On the other hand, it is stagnant water, the worst type.

The only author who mentions cistern water is Evenor, a 4th century BC physician. He recommends cistern water and, in the same discussion in Athenaeus' book, Praxagoras recommends rain water (Ath. 2.46d; Hellmann, 1994, p.274; Bollen, 1943, p. 73; Wellmann, 1900, p.356; Nutton, 1996-, p.226).²⁴ Aristotle states that cistern water must only be drunk in

²² Varro writes *sub tectis* if he discusses drinking-water. This expression can refer to a roofed well or underground storage. I suppose that the latter is meant, because Columella writes *cisternae hominibus, piscinaeque pecoribus* (1.5.1-4) describing the polarisation between men and animals; Morley, 2005, p.197.

²³ There are slowly flowing rivers with turbid waters and rapidly flowing brooks; probably, Celsus refers to the last ones. Rufus is negative about well water, but it can be improved by moving it: Rufus apud Orib. 5.3.1.

²⁴ It is remarkable that cistern water is considered as different to rain water. Probably, the taste has changed during the storage, or cisterns were filled with other types of water.

case of emergency, if no other water is available (Aristotle, *Politica* [*Politics* (Arist. *Pol.*)]1330b; Hellmann, 1994, p.274).²⁵ For water supply at an estate, Varro recommends a cistern if there is no flowing water and Columella recommends it if there is no spring or well. This cistern must be filled with rain water; if this is lacking, with water from rocks; if this is lacking too, with water from hills. Pliny's opinion concerning cistern water is very negative. He states that some physicians recommend cistern water (maybe Evenor is one of them), but it is unhealthy: it contains slime (*limus*, maybe a reference to algae, covering the masonry of a half-filled cistern) and other noxious creatures (Var. *R.* 1.11.2. Col. 1.5.2. Plin. *Nat.* 31.34; Oleson, 2008, p.290; Rogers, 2013, p.7). Due to the fact that cistern water is stagnant water, containing a lot of elements (added during the storage), it must have been usually considered as a relatively unhealthy type of water.

1.2.5. Surface water

Surface water is water from slow-flowing rivers, lakes and marshes. Particularly marsh water is discussed and condemned by nearly all authors as the worst type (Hipp. *Aer.* 7; Bollen, 1943, p. 18-25; Jouanna, 1996, p.33-36; López Férez, 1992, p.537. Arist. *Pr.* 884a32-34; Argoud, 1987, p.209. Cels. 2.18.12; Jouanna, 1996, p.39; Bollen, 1943, p. 46.; Col. 1.5.3; Rufus apud Aët. 3.165; Garzya, 1994, p.109; Bollen, 1943, p.149; cf. Paul. *Aeg.* 1.50).²⁶ Galen dissuades the consumption of water from pools or puddles, stench-producing, muddy and salt water, so also marsh water (Galen, *De san. tuenda* 6.56-58 K.).²⁷ Rufus states that beside marsh water also lake water is unhealthy; in summer and wintertime, it causes diseases like dysentery and dropsy. Only a marsh in Egypt is not unhealthy, because there are less season influences and Nile water is refreshing the marsh from time to time (Rufus apud Orib. 5.3.3-6; Haak, 2013, p.75; apud Aët. 3.165; Garzya, 1994, p.110; Bollen, 1943, p. 128-130).²⁸ Other authors are,

²⁵ Actually, the situation in practice (see below).

²⁶ Varro does not discuss explicitly stinking marsh water, but the infamous reputations of marshes in general: Var. *R.* 1.12.2.

²⁷ According to Galen, the quality of fish depends on the corresponding water quality: fish living in muddy water is unhealthier for consumption than fish living in clear water. The most unpleasant fish is fish, living in water polluted by city sewers: Galen, *De alimentorum facultatibus* [*On the powers of foods* (Galen, *De alim. facult.*)] 3.24-31 (6.708-730 K.); Grant 2000, p.174-183.

²⁸ Rufus mentions a disease called 'ophis' in Egypt, caused by worms after the consumption of water (Ruf. 65-69); Haak, 2013, p.57 and 76-77. If Nile water is drunk, this water is not healthy, contradicting his statement concerning Nile water.

however, sometimes less negative (Xenophon, *Historia Graeca* [*Greek History* (X. HG)] 3.2.19 (Leucophrys); Plin. *Nat.* 31.31).²⁹

It is clear that standing water, containing all elements like smell, taste, colour and even mud is, actually, the worst type and unfit for consumption. The poor quality of surface water is also understood by Frontinus, the author of *De aquis urbis Romae*. Water has to be clear and turbid water is unhealthy. The best aqueducts of Rome are the Aqua Marcia and Aqua Claudia, containing spring water, better than rain water (Frontinus, *De aquis urbis Romae* [*On Aqueducts* (Fron. *Aq.*)] 2.91, 1.12-13 and 2.89); but the worst water for consumption comes from the river Anio aqueducts. Galen praises the excellent quality of the water of Rome (better than Pergamum: Galen, *In Hipp. Epid. VI comment.* 4.10 (17b.159 K.)), but unfortunately he does not mention the name of the aqueduct. As has been said, there were good and bad aqueducts.

Regarding the different types of water, sometimes summed up by authors, rain water and spring water were considered as the healthiest; surface water, however, as the most unhealthy. The other types of water, well water and cistern water, were considered as moderate.

1.2.6. Conclusion

So, in short, we see in literature roughly the same preferences of water types. Light water is better than heavy water, because it does contain no or nearly no added elements; the best drinking-water is clear, without any smell or taste. Choosing cold or hot water, there is a clear preference for cold water for consumption. Discussing the types of water, we found that rain water was favourite, preferred by the majority of all authors, and especially by medical authors. Sometimes, other types of drinking water were preferred by authors, like Pliny the Elder and Columella. But what was the situation in practice? Did people really consume mainly rain water? Or another type of water, maybe considered as less suitable for consumption than rain water but available in a larger quantity and easier to supply by local or regional authorities? Was there, in practice, a preference for 'light' or cold water? In the next paragraph, I hope to answer these questions.

²⁹ Surface water can be relatively good, but it must flow; cf. Var. *R.* 1.11.2 and Col. 1.5.2.

2. Practice

2.1. WELLS, SPRINGS, CISTERNS AND AQUEDUCTS

Once more: people cannot survive without water. This statement was also recognised in the Greco-Roman world. So governments had to distribute water of high quality to the citizens.

Which type of water was, in daily life, supplied to the citizens? Did the theoretical and even speculative qualities of water play a role of any significance for water supply in practice? I have argued that, according to the literary sources, 'soft' and 'light' water, cold water, rain water and spring water were considered as the best types of water. In practice, however, all water types have advantages and disadvantages. A spring can dry up due to an earthquake or a change in climate. If there is the wish to remain in the same place, one is forced to look for another water type. Rain water is an alternative. The disadvantages of rain water, however, are the flat taste (caused by the absence of minerals) and the fact that rain does not always fall, and not everywhere. The Mediterranean area has hot, dry summers and one has to collect and save rain water in other seasons as much as possible for dry periods. This was accomplished by the construction of cisterns: bricked underground water cellars for saving water. A disadvantage of the cistern is that water is stagnant like marsh water, as we have seen in the first part of this article, considered as the worst water type. Cisterns had to be cleaned and maintained regularly, and one had to check that there were no cracks, caused by earthquakes or wearing of the building material. Mortar which covered the interior part of the cistern was especially vulnerable (Brinker, 1990, p.71-73; Reinholdt, 2009, p.204-206; Oleson, 2008, p.288-289). We know that people were severely punished if they did not maintain their cisterns meticulously (Bonnin, 1984, p.36). Finally, well water is actually always available, but sometimes one is forced to dig deep to reach it; the level can change or the well may even dry up.

When cities arose, we see a change from individual water supply to communal water supply, constructed and maintained by the city government or local authority. The construction of cisterns, wells and sometimes a spring for water supply for their own property in the countryside could be done by individuals, but water supply for a city needed more investment. One had to look for the most suitable tap points and means of transport for water supply. Water tapping from the spring was important for the whole community – which was forced to pay for it, by means of taxes – and it was crucial that water supply was not hampered. To achieve this, it was preferable to construct underground water pipes or aqueducts. According to Vitruvius, water must remain cold and, moreover, be inaccessible to unauthorised people who

could tamper with the water supply (Eck, 1987, p.60 and 88-89; Fahlbusch, 1982, p.22-23), pollute or poison the water, a suggestion mentioned for example by Frontinus (Frontinus, *Strategemata* [*Stratagems* (Fron. *Str.*)] 3.7.6. Crouch, 1993, p.22-24 and 123-126; Thucydides, *Historiae* [*Histories* (Th.) 2.48.2 (in Piraeus, 429 BC); Grmek, 1979, p.146-147) or destruct aqueducts (Th. 6.100.1; Höcker, 1996-, p.414; Procopius, *De bello Gothico* [*On the Gothic war* (Procop. *Goth.*)] 5.19.13). So it is crucial that only in the fountain house water is available to people.

Some cities had a large quantity of aqueducts at their disposal, like Pergamum, Syracuse and Rome, but if springs were lacking, cisterns remained in use (also urban cisterns), for example in Carthage. So the number of inhabitants was not a crucial factor to construct more and longer aqueducts. Also, the best type of water was not always available. In Rome, spring water supply was insufficient, so here even river water was in use. The invention of the arch construction and the unity of the Roman Empire made it possible for the Romans to construct their famous long arched aqueducts.

2.2. DRINKING-WATER IN THE GREEK WORLD

Greek settlements were usually founded, in the first instance, in the neighbourhood of springs, but later (from Mycenaean times onwards, according to Höcker, 1996, p.407) wells were dug out and underground water pipes were constructed. Spring water remained the preferred water type. Sometimes well water remained in use, e.g. at the Asklepieion of Cos. Here was a continuous flow of underground water (Reinholdt, 2009, p.192), apparently considered as better than rain and spring water – in contrast to the discussion above, where rain water is considered as the best.

Around 400 BC, we see a change from spring and well water into cistern (rain) water. The reason of this is a point of discussion. According to Camp and Crouch the climate became drier (especially in the years 335-325), so water became scarcer and rain water had to be stored in cisterns. The drought is mentioned by Aristotle in his *Meteorology* (Aristotle, *Meteorologia* [*Meteorology* (Arist. *Mete.*)] 352a; Crouch, 1993, p.66 and 109; Camp, 1982, p.9-17).³⁰ According to Thommen and Maise, however, while the climate between 850 and 600 BC was cooler and wetter and in the 6th and 5th century it was hotter and drier, the 4th century and 3rd century were cooler and wetter again. The information given by the C14 level in ice cores

³⁰ According to Camp (1977, p.22 and 145) the drier period started at the beginning of the 4th century BC; according to Argoud (1987, p.210) at the end of the 5th century.

corroborates the latter supposition. Maybe, the Greek drought was local, caused by deforestation (Thommen, 2009, p.27; Maise, 1998, p.219 and 224-233)?³¹ The quotation that, according to Brinker, cisterns were already in use in Athens in the 6th century BC (Brinker 1990, p.11), can refer to the dry period between the 6th and 5th century. But what about the use of cisterns in the cooler and wetter 4th and 3rd century? Maybe, an increase of rainfall was just a reason to build them, or a better taste than well water or a larger demand by population growth. For larger demands, aqueducts supplying spring water were built. Only at places where spring water was not available, cisterns were used, e.g. in Rhodiapolis and Sagalassos (Asia Minor).³² Sometimes, after the construction of an aqueduct, cisterns were filled up with spring water, so there is the evidence that the storage method of cisterns was considered as good (Bildirici, 2006, vol. 1, p.148-149 in Keramos). Metropolises like Alexandria and Carthage had the disposal of many and large cisterns, due to the absence of sufficient spring water in the neighbourhood. Climate change and population growth stimulated the use of cisterns in Carthage, replacing wells from the 3rd century BC onwards (Guillaume, 1877-1919, p.1209-1210; Euzennat, 1992, p.75; Oleson, 2008, p.288-289).

2.2.1. Casus: Corinth

Pausanias mentions that in Corinth drinking-water was tapped out from some springs, and rain water was used for baths (Pausanias, *Graeciae descriptio* [*Description of Greece* (Paus.)] 7.27.4; Oleson, 2008, p.295-296). The most famous spring was the Peirene (Herodotus, *Historiae* [*Histories* (Hdt.)] 5.92b.21; Ath. 2.43b). In addition, a large number of cisterns were found at the Acrocorinth, probably constructed as military or emergency accommodation. Outside Corinth, there were other acropolises containing cisterns (Crouch, 1993, p.85-88, 126-132 and 319).³³ So spring water was preferred to rain (cistern) water; cistern water (at the acropolises) was only in use if spring water was insufficient or even lacking.

³¹ Maise's research area is Central Europe.

³² Wiplinger 2006, vol. 1 *passim*, e.g. the contributions of Murphy, p.159-164 (Rhodiapolis) and Martens, p.168-169 (Sagalassos). Cf. Spagnolo 2012, 359-370 (wells and cisterns in Gela, Sicily).

³³ 80 cisterns were found at the Lindos acropolis (Crouch, 1993, 90) and also 80 at the Pergamum acropolis (in the entire city of Pergamum 107); Garbrecht, 1987, p.13-47.

2.3. DRINKING-WATER IN THE ROMAN WORLD

When Rome was still a small town, the local water supply was not a problem. Frontinus mentions that the first Romans drank out of the Tiber, so in these times, river (surface) water was sufficient. When Rome became a metropolis, the quality of the Tiber water decreased by pollution, other water types were used and aqueducts were constructed (Fron. *Aq.* 1.4; Fahlbusch, 1987, p.145; De Kleijn-Eijkelestam, 2001). In addition, the Romans used cisterns and in cases of large demand for water (as was the case in Rome), surface water was improved by filtering. As compared to the Greeks, the Romans used more surface water (Fahlbusch, 1987, p.147-148).³⁴ Galen, knowing the situation in Rome very well, describes that the citizens drank water from wells, springs via aqueducts and lakes, rivers and rain water out of cisterns (Galen, *In Hipp. Epid. VI comment.* 4.19, 17b.183 K.). He praises the excellent quality of the water of Rome (Galen, *In Hipp. Epid. VI comment.* 4.10, 17b.159 K.). Probably, filtering was a success. Everywhere in the Empire, city governments could choose their own water supply: wells, cisterns and aqueducts.³⁵ In Constantinople, more than 70 cisterns were found (Höcker, 1996, p.413; Mays, Sklivaniotis & Angelakis, 2012, p.33-34).

2.3.1. Casus: Pompeii

There were no springs inside the boundaries of Pompeii. For a continuous water supply, wells were dug out. The wells had a depth of \pm 30 metres. Excavations and further research indicate that it was very difficult to construct these wells; one had to dig through lava layers before ground water was reached. Apparently, there was a sufficient supply of water, but on its quality opinions differ (Jansen, 2002, p.20-22, p.75 n. 67 and 68).

One of the most significant features of Pompeii houses are the ones with an atrium, compluvium and impluvium, containing cisterns. This way of water management was probably more sufficient and satisfying than digging wells. When the eastern part of Pompeii was built (second half 4th century),³⁶ the cistern system was in use on a large scale. Nevertheless, the inhabitants were, ultimately, not satisfied with rain and well water and built aqueducts; cisterns were filled with spring water from this aqueduct and street fountains replaced the wells.

³⁴ Examples are Rome, Trier and Aix-en-Provence; Labisch & Koppitz 2005, p.916.

³⁵ Nijmegen (Netherlands): Koster, Peterse & Swinkels, 2002, p.12 and 17. England: Rogers 2013, p.187.

³⁶ In a few cases, cisterns are lacking: Jansen, 2002, p.77 n. 92.

Probably, \pm 80 BC there was already a water pipe system in the city (Ohlig, 2001, p.271; Jansen, 2002, p.17-18, 26 and 56-57; Eschebach, 1979, p.3-25).³⁷ In Herculaneum, more wells and less cisterns were found (wells are less deep here) and in Ostia, mainly well water was consumed; it was easy to reach (Jansen, 2006, p.175-176; Camardo, Martelli Castaldi & Thompson, 2006, p.183).

2.4. CONCLUSION

The drinking-water supply in practice was based on the availability of drinking-water. In its most primitive way, surface water like river water (or spring water) was in use: prehistoric man was forced to drink this type of water. When cities arose, well water and spring water became the most usual types of water. Cisterns were realised in a later time, in the Mediterranean area from the 6th century onwards. It is unclear if they were used due to scarcity of water (period of drought) or due to a lot of rainfall. Both in Greek and Roman cities, we see that rain water was mainly in use in times of emergency, when another type of water was not available. The Romans consumed usually spring water, delivered by their famous aqueducts, spending a lot of energy and money to construct, maintain and protect them. Nevertheless, the use of rain water remained in use, even when other water supply was in use, like in Pompeii. Surface water was usually considered as unfit for consumption.

Final conclusion

Theories on the qualities of drinking-water were formed within the intellectual framework of the medical authors. In most cases, these theories were not based upon empirical perceptions and proofs, but on axioms. Qualifications of water as 'heavy' and processes like 'keeping humours in balance' were classified according to their contribution to human health. All such theories have a preference for rain water; sometimes, they mention spring water as a good type of water. The fact that these views on water quality remained unchanged – without evolution – up to the Byzantine era, even to the year 1000 (according to Avicenna's notation in his *Canon* 361-392) is striking. The ideas of medical authors are sometimes contested by other authors; their opinions

³⁷ Eschebach mentions (p.7) some dates of the construction of the aqueduct 201-90 BC (citing Mau) and mid 2^e century (Maiuri). Some fountains are older: Jansen, 2002, p.56 and 85-86 (n. 257).

are more diverse, using experiences and perceptions; for example, they state that spring water is sometimes good and sometimes bad. Nevertheless, all authors, both medical and non-medical, observe that flowing water is preferable to stagnant water and condemn the consumption of marsh water.

In practice, all qualities and types of water – ‘heavy’ and ‘light’ water, hot and cold water, rain water, spring water and well water, sometimes even surface water – were in use (hot water did, actually, not play a role for the regular drinking-water supply, but was only in use for curative purposes). One was aware of the crucial importance of water in general and the advantages and disadvantages of the different types. In the first settlements, river water, wells and springs were in use. After \pm 400 BC, however, a climate change took place and people began to collect rain water in cisterns, beside their wells. But the Greeks and Romans preferred spring water and constructed aqueducts, spending a lot of money and effort. Thus, rain water was consumed only at dry times when water was scarce and spring and well water were not available. So, the real situation in practice is in sharp contrast to the opinions of the medical authors, who all have a strong preference for rain water. Theory and speculation had little impact on water supply in practice.

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