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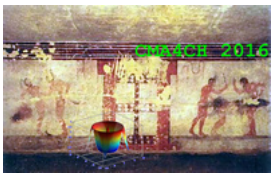

Multiparametric Comparison of Sacred Spring Waters of Roman Forum Using 4 Sample Campaigns of Chemical-Physical Data

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Abstract

The following research is part of a wider project that aims to be the first complete characterisation of spring waters in the area of Romanum Fora and surroundings, considered sacred throughout all the Roman history.

As in similar work [1] on sacred waters, the characterisation will be based on a chemical, physic-chemical and biological multiparametric analysis. Multiple samples of standpipes waters have been also collected in the area to display any possible infiltration of mains water or sewers.

Introduction

The founding of Rome is strictly bound to the nature of its territory. Rome was raised near the Tiber river in a paludal area that was reclaimed as soon as the founding. Water was a key element of the Roman growth, both for their sustenance and religion. Water springs are the most valuable richness that Rome have ever had until, the Republic era, aqueducts were built in to satisfy the growing needs of water of the expanding city.

A few springs of the Republic era have arrived to this day. In Tab.1 a list with a short description is reported.

Tab.1: List of known water sources in the Roman Forum. Green: springs reached and analysed, red: springs known from literature but not accessible anymore or lost; blue: waters from standpipes analysed for a comparison

Juturnae	Between Palatine hill, Castor and Pollux temple in a small pool dedicated to nymph Juturna.
Romulus Temple	Square well in the center of the Temple hypoteticly dedicated to Massenzio's son, Romulus.
Lapis Niger	Below the famous black marbled floor, "Lapis Niger", in an archaic complex.
Tullianum	Located in the lowest floor of the "Carcere Mamertinum", first prison of Rome, where legend says that S. Peter and S. Paul were hosted.
Basilica Ulpia	In the Fori Traiani, below the street level in a not accessible area between Vittoriano and Traiani Column.
Valentini Palace (thermal baths)	Below Palazzo Valentini, built near two imperial Roman Domus. Water still pours out of the ancient thermal baths.
Valentini Palace (well)	New excavation area of Palazzo Valentini discovering some very big columns, probably from Temple of Traiano
Meta Sudans	Ancient fount close to the Coluseum used by Gladiators to refresh themselves after the games, now unfortunately destroyed.
Lacus Curtius	Ancient well located in the Roman Fora close to the Foca Column, of legendary origins. Dried out.
Lautole	Ancient sulfuric springs located in the minor Velabro. Not anymore accessible
Acque Fontanili	Cited by Cassius Dio Cocceianus, today presumed location under Palazzo del Grillo. The exact position is under investigation, and probably not accessible
Standpipes	2 Standpipes in the area of interest, used for comparison/validation

For each source were performed "in situ" and laboratory analysis of chemical, physic-chemical parameters. The research is to be continued with other sampling campaigns for biological parameters.

Materials & Methods

All measure instruments for chemical/physical analysis were laboratory-grade and each one was checked before and after the campaign with certified reference materials (CRM). Two ion chromatographs Metrohm IC761 equipped with Metrohm and Dionex columns were used and the eluents were produced from Ultrapure reagents and CRM. For each source 3 samples were collected and measured 3 times to avoid missing-data in the matrix, the median value was used.

pH, conductivity (corrected at 25 ºC), ORP and F^-, CH_3COO^-, Cl^-, Br^-, $NO3^-$, $PO4^{-3}$, $SO4^{-2}$, Li^+, Na^+, K^+, Mg^{+2}, Ca^{+2} content in ppm was measured. A microclimate campaign is running.

Results

The 4 campaigns produced quite different values for each variable so we tried to use 2 different approaches. Two matrices were produced, the first counted 40 rows and 15 columns having in the rows the 9 sources but repeated in the 4 campaigns, plus the data by ACEA for drinking water and 2 samples from a well in a roman house of Ostia Antica. The second matrix counted 11 rows (the sources, drinking water, Ostia) and 60 columns with the measures obtained in the different campaigns (for example we have Ulpia3, Ulpia8, Ulpia9, Ulpia10 in the 1st matrix, and pHmarch, pHaugust, pHsettember, pHoctober in 2nd matrix).

As usual the Exploratory Data Analysis started with some simple methods, in this case the SPLOM after autoscaling. Unfortunately none evident data clouds can be obtained. After that, Hierarchical Cluster Analysis (HCA) [2] was calculated on the 2 matrices, using always average-linkage (UPGMA) as agglomerative method and City-Block as distance.

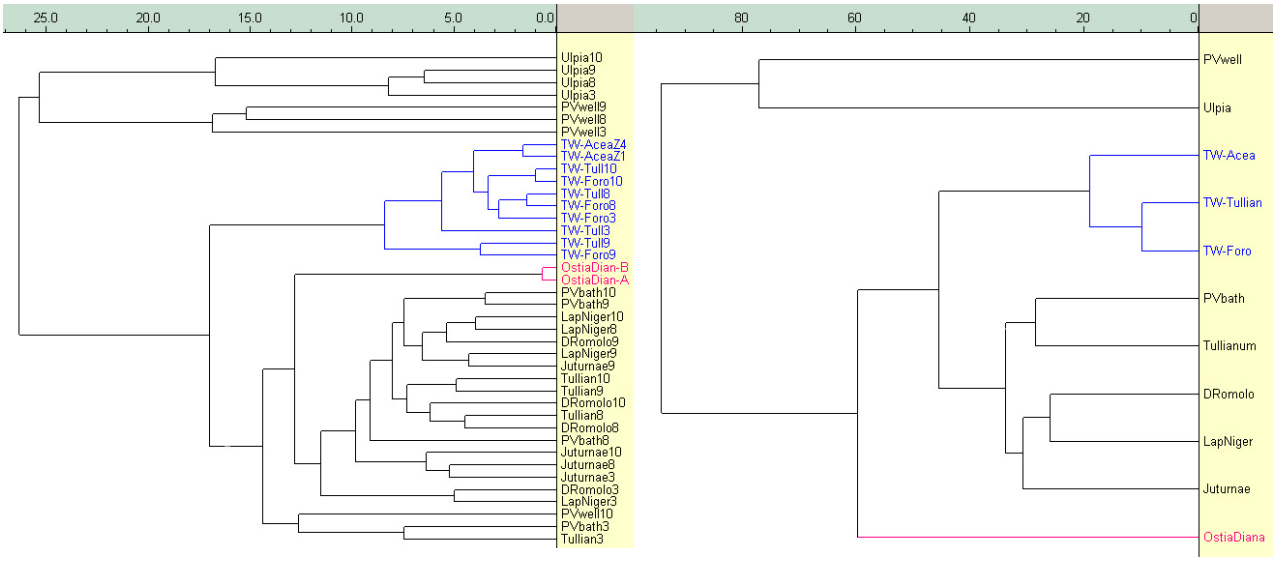

Fig. 1; Cluster analyses of the first (on the left) and of the second (on the right) matrices

On the left of the fig. 1 the dendrogram from matrix1 evidences: 4 groups including the Basilica Ulpia and the well of Palazzo Valentini; just below all the tap waters, the water from Ostia Antica and finally all the other sources of Romanum Fora. On the right using matrix2, we have a similar distribution.

Conclusions

In this study 2 standpipes of city water and data from the supplier have been used as a form of data validation and effectively we have got a group, blue in figure, with those waters. Consequently, we can state the presence of 2 different aquifers, 1 near the Traianus's Column and 1 for the others. Unfortunately, when we put all the sources together in a map, this statement resulted difficult to explain; so, further campaigns are needed to deepening the research.

References

1) R. Benami Amiel, T. Grodek, A. Frumkin; Characterization of the hydrogeology of the sacred Gihon Spring, Jerusalem: a deteriorating urban karst spring, *Hydrogeology Journal*, 18(6), 2010, 1465-1479

2) A. Michalik; The Use of Chemical and Cluster Analysis for Studying Spring Water Quality in Świętokrzyski National Park, *Polish J. of Environ. Stud.,* 17(3), 2008, 357-362