CHEMICAL STUDIES OF OCCUPATION SOILS IN INDIA

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Chemical analyses of occupation soils are useful aids to studies of abandoned human settlements. Human occupation increases concentrations of elements such as carbon, nitrogen and phosphorus, and this alteration is cumulative and measurable by chemical analysis.

The fertility of an occupation soil is usually higher than that of surrounding soils. In India, habitation mounds are often destroyed by farmers who use the soil to fertilize their fields. They are aware that these deposits are rich in essential plant nutrients which significantly increase crop production. This high fertility of occupational debris is due to the residue of chemical elements contained in plant food materials, human and animal excreta, urine, human burials, and food bones.

The chemical elements which are of greatest importance from an archaeological point of view are carbon, nitrogen and phosphorus. Average concentrations of these elements in various natural soils (agricultural and non-agricultural) are given in Table 1.

	pH	Organic Carbon %	Nitrogen %	Phosphorus %
Black soil	8.2	0.5	0.03	0.06
Alluvial soil	6.3	0.4	0.04	0.04
Red soil	5.4	0.2	0.002	0.006
Forest soil	6.6	1.5	0.25	0.09
Desert soil	8.8	0.2	0.02	0.009

Table 1: Average nutrient concentrations in some Indian soils (from Govinda Rajan and Gopala Rao 1978)

Carbon and nitrogen are added to inhabited areas in relatively large quantities as a result of human activity, but they are easily lost through leaching, oxidation and reduction. However, although the total quantity of phosphorus in any soil is small due to its low solubility and restricted movement, the possible loss by leaching is almost nil, except through erosion (Duma 1972; Eidt 1977).

Phosphorus fixation in soils occurs mainly through reaction with hydrolysed iron and aluminium oxides, and with calcium and magnesium compounds. It may also become adsorbed on the surface of clay particles or form complexes with clay minerals (Mizota 1977). Thus, of all the chemical elements introduced into soil through human activity, phosphorus is the most accurate index of the extent, intensity, duration and nature of human settlement.

With a view to testing the applicability of chemical analysis to the study of anthrosols in India, experiments were carried out at several sites, ranging in date from Stone Age to Early Historic. Nearly 500 soil samples were collected from archaeological sites situated in various parts of the country; 400 samples were from actual habitational areas, and about 100 were from non-habitational areas including adjacent fields as well as virgin soils underlying the archaeological deposits. All these samples were analysed for organic carbon, nitrogen and phosphorus by standard methods. Electrical conductivity and pH values were also determined to understand the nature of the salts present in the deposits.

Data on all the samples collected from vertical sections were computerized in order to investigate the behaviour of carbon, nitrogen and phosphorus. From the computer analysis it appears that the values of these elements vary from site to site, and even within layers of the same site (Deotare and Joshi 1981). Since carbon and nitrogen are relatively unstable, and subject to microbial activity and oxidation in arid and semi-arid conditions, no significant variations between habitation and non-habitation areas were observed (Table 2). However, phosphorus concentrations in habitation deposits range between 4 and 10 times more than those in adjacent non-habitation deposits.

From Table 2, the following observations can be made:

1. Almost all samples are alkaline with a pH above 7.0, except at Bhimbetka and Thebronggiri where the deposits are acid with a low electrical conductivity, owing to heavy rainfall.

2. For organic carbon and nitrogen no definite trends can be observed, and these two elements cannot be considered indicative of the character of a settlement.

3. Concerning phosphorus, all deposits from habitational areas contain more than 0.10%, while in non-habitational deposits it ranges from 0.02 to 0.10%. Thus, if a phosphorus content is more than 0.1% it is an indication of human habitation, and more positively so if the value is more than 0.2%.

4. At the protected Palaeolithic cave site of Betamcherla a phosphorus value of 0.35% was obtained, but the open-air

Cultural period	Site	Number of samples	pH	E.C.	O.C.%	N %	P %
Early Historic	Dangwada	8	8.9 (8.3)	0.50 (0.20)	0.31 (0.44)	0.06 (0.07)	0.28 (0.03)
	Nagdandi	2	7.6 (7.2)	0.16 (0.05)	1.18 (0.33)	0.15 (0.06)	0.31 (0.08)
	Semthan	4	8.3 (8.5)	6.1 (0.22)	0.56 (0.23)	0.09 (0.05)	0.32 (0.07)
	Satanikota	2	9.0 (7.6)	0.47 (0.23)	0.45 (0.44)	0.05 (0.06)	0.40 (0.04)
	Somnath	4	8.1 (8.8)	1.47 (0.50)	0.72 (0.46)	0.11 (0.01)	0.47 (0.06)
Megalithic	Mahurzari (Stone-circle)	8	(7.6)	(0.14)	(0.58)	(0.04)	(0.05)
	Satanikota (-do-)	9	(8.3)	(0.22)	(0.19)	(0.02)	(0.06)
	Naikund (-do-)	7	(7.7)	(0.23)	(0.35)	(0.02)	(0.05)
	Naikund	32	8.0 (8.2)	0.25 (0.21)	0.56 (0.26)	0.06 (0.03)	0.34 (0.06)
	Virapuram	2	9.3 (9.0)	1.1 (0.72)	0.21 (0.18)	0.02 (0.01)	0.51 (0.07)

Table 2. Mean percentages of carbon, nitrogen and phosphorus in deposits from Indian archaeological sites.

Cultural period	Site	Number of samples	pH	E.C.	O.C.%	N %	P %
Chalcolithic	Mandsaur	7	9.4	0.5	0.31	0.06	0.21
	Rupar	3	8.2 (8.8)	6.3 (1.8)	0.45 (0.21)	0.11 (0.06)	0.26 (0.03)
	Inamgaon	68	8.3 (8.8)	4.2 (0.3)	0.78 (0.35)	0.08 (0.02)	0.30 (0.06)
	Dangwada	6	8.6 (8.3)	1.6 (0.20)	0.34 (0.44)	0.06 (0.07)	0.31 (0.03)
	Apegaon	18	8.1 (8.0)	1.3 (0.8)	0.84 (0.58)	0.05 (0.03)	0.33 (0.10)
	Daimabad	85	8.5 (8.2)	2.6 (0.7)	0.68 (0.68)	0.06 (0.03)	0.35 (0.06)
	Ahar	11	9.4 (8.1)	24.2 (20.0)	0.34 (0.34)	0.03 (0.02)	0.37 (0.08)
	Somnath	2	8.8 (8.8)	0.9 (0.5)	0.53 (0.46)	0.29 (0.01)	0.57 (0.06)
	Jodhapura	8	8.1 (8.4)	15.0 (11.5)	0.41 (0.16)	0.17 (0.07)	0.65 (0.04)
Neolithic	Thebronggiri	1	4.2 (3.9)	0.05 (0.02)	0.94 (0.64)	0.05 (0.02)	0.19 (0.06)

Table 2 continued

Cultural period	Site	Number of samples	pH	E.C.	O.C.%	N %	P %
	Virapuram	3	8.6 (9.0)	1.68 (0.72)	0.19 (0.18)	0.03 (0.01)	0.20 (0.07)
	Burzahom	16	8.5 (8.1)	0.8 (0.4)	1.01 (0.44)	0.10 (0.07)	0.45 (0.07)
	Kudutini	3	8.8	0.5	0.47	0.07	0.55
	Kupgal	4	8.6	3.8	0.36	0.04	0.70
	Sangankallu	4	9.1	7.5	0.67	0.12	0.68
Harappan	Kalibangan - Residential area	5	8.4	13.5	0.24	0.11	0.29
	- Citadel	8	(8.0)	(1.5)	(0.29)	(0.07)	0.14 (0.07)
	Rupar	4	8.0 (8.8)	10.0 (1.8)	0.32 (0.21)	0.14 (0.06)	0.28 (0.03)
	Lothal	9	8.2 (8.4)	17.0 (0.2)	0.13 (0.32)	0.03 (0.03)	0.31 (0.06)
Mesolithic	Iddinda karai	2	7.7 (8.3)	0.7 (0.8)	0.32 (0.12)	0.06 (0.009)	0.14 (0.04)
Palaeolithic	Khandera	19	6.7	0.11	0.79	0.06	0.05
	Bhimbetaka	12	4.2	0.08	0.30	0.03	0.14

Table 2 continued

Cultural period	Site	Number of samples	pH	E.C.	O.C.%	N %	P %
	Hunsgi	2	8.5	0.6	0.28	0.04	0.14
	Betamcherla	11	7.7	0.8	0.62	0.09	0.35

E.C. = Electrical conductivity in millimhos/cm.

O.C. = Organic Carbon

Figures in brackets are for sterile or non-habitation deposits.

Table 2 continued

Acheulian site of Khandera gave a very low (0.05%) phosphorus reading, mostly due to loss through run-off and erosion.

5. The Harappan sites of Lothal, Kalibangan and Rupar respectively gave 0.31, 0.29 and 0.28% P. These values are almost identical and show a high intensity of cultural activity.

6. The Neolithic sites of Sangankallu, Burzahom, Virapuram and Thebronggiri gave readings of 0.68, 0.45, 0.20 and 0.19% P respectively. The high values at Sangankallu (and also Kupgal and Kudutini) result from ash mound formation.

7. The maximum numbers of samples from specific sites so far studied are from the Chalcolithic sites of Inamgaon and Daimabad, both with identical environmental conditions, where the average phosphorus contents are 0.30 and 0.35% respectively. At Inamgaon, the phosphorus content is relatively low (average of 0.26%) in the Malwa levels, but it is higher (0.34%) in the Early Jorwe levels (Table 3).

8. In Chalcolithic sites other than Inamgaon and Daimabad the percentage of P is much the same, as at Ahar, Apegaon, Dangwada and Rupar. It is high at Jodhapura and Somnath as a result of the higher intensity of occupation. By and large the values of P for all the Chalcolithic sites are similar and it may be assumed that settlement sizes differed little.

9. The Megalithic sites of Naikund and Virapuram gave 0.34 and 0.51% P. The Virapuram site is well preserved, and judging from the thickness of the deposit the occupation may have been more intensive than at Naikund.

10. The Early Historic sites of Semthan, Nagdandi and Dangwada gave 0.32, 0.31 and 0.28% P respectively, without much variation. The high P values for Satanikota and Somnath show a higher intensity and duration of habitation.

11. The samples of occupation soils from all sites averaged 0.33% P, while all the non-occupation soils averaged 0.06% P. This significant difference demonstrates the usefulness of phosphate analysis in archaeological investigations.

The method can also be applied to confirm a break in a habitation sequence. In this regard the results from Rupar, Virapuram and Dangwada are very interesting (Table 4). At Rupar, samples from the sterile layer between the Harappan and Painted Grey Ware periods contain only 0.06% P, which indicates abandonment of the site at this time. Similarly, in the profile of Virapuram a sterile layer between the Neolithic and Megalithic occupations gave readings of 0.07 and 0.08% P. These values are very close to those

Culture	Description	Layer	pH	Phosphorus %
Late Jorwe	House No. 63	8	7.6	0.32
	House No. 63	8	7.7	0.29
	Inside house No. 65	8	7.6	0.33
	Outside house No. 65	8	8.2	0.40
	House No. 67	8	8.0	0.38
	House No. 68	8	8.1	0.27
	House No. 69	8	8.3	0.49
	House No. 71	8	7.6	0.46
Early Jorwe	House No. 75	12	7.9	0.25
	Inside house No. 78	12	8.8	0.29
	Outside house No. 78	12	9.2	0.13
	House No. 79	12	9.4	0.29
	House No. 80	12	8.0	0.29
	House No. 85	12	8.5	0.43
	House No. 85	12	9.4	0.42
Malwa	House No. 91	14	8.1	0.41
	Sealing soil of house No. 91	14	7.6	0.17
	Sample of decomposed grass in house No. 75		8.4	0.16
	Sample of decomposed grass of roof or side wall		9.0	0.18

Table 3. Results of analyses of house deposits at Inamgaon.

Culture/Period	pH	Phosphorus %
Rupar		
Painted Grey Ware	8.6	0.30
Sterile layer	8.5	0.06
Sterile layer	8.1	0.06
Harappan	8.0	0.29
Virapuram		
Megalithic	9.1	0.62
Sterile layer	9.0	0.08
Sterile layer	9.1	0.07
Neolithic	8.4	0.23
Dangwada		
Shaka	9.0	0.23
Sterile layer	9.3	0.07
Shunga	9.5	0.17

Table 4. Results of chemical analysis of deposits from Rupar, Virapuram and Dangwada.

for the virgin and modern soils. A layer between the Shaka and Shunga occupations at Dangwada also has a very low (0.07%) phosphorus content.

In order to delimit the extent of habitation, a rapid phosphate field spot-test was applied at the Chalcolithic site of Inamgaon. By testing several samples on the site, significant values could be plotted until non-significant values were obtained. The extensive horizontal excavations at Inamgaon and Daimabad also gave opportunities to test samples collected from the different activity areas exposed. In Inamgaon, the horizontal distribution of phosphorus in the bottom layer of period III (Late Jorwe) gives some idea about the house-wise activities of the people. Phosphorus contents are 0.49 and 0.46% in houses 69 and 71 respectively, thus incidating high concentrations of occupation here (Table 4). In the Malwa levels, samples of decomposed grass from roofs or walls contain 0.16 and 0.18% P. However, a sample from house No. 91 contained 0.41% P, whereas the soil which overlay the same house gave only 0.17% P. This low phosphorus content in the overlying soil suggests that the sample might have come from a collapsed roof layer.

In layer 5 of the Malwa period at Daimabad the phosphorus content is higher than in the Jorwe layers, and ranges from 0.23 to 0.50%. These high phosphate contents are suggestive of a high density of population during the Malwa period. In layer 9 of the late Harappan period only slight variations in phosphorus content were observed, with one or two exceptions. Most samples are between 0.23 and 0.33% thus indicating a lesser intensity of occupation than in the Malwa period (Table 5). However, it should be stated that it is not possible to quantify actual population densities without comparisons with modern settlements with known values for human as well as animal populations.

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Culture	Layer	Depth in cm.	pH	Phosphorus %
Jorwe (Sector II)	top 2	20	8.1	0.28
" "	"	"	8.9	0.25
" "	"	"	8.3	0.31
" "	"	"	8.6	0.36
" "	"	"	8.8	0.25
" "	"	"	8.3	0.25
" "	"	"	8.3	0.33
" "	"	"	8.4	0.22
" "	"	"	8.6	0.14
" "	"	"	8.2	0.25
" "	"	28	8.5	0.34
" "	"	"	8.7	0.38
" "	"	"	8.4	0.39
" "	"	"	8.5	0.28
" "	"	"	9.1	0.31
Malwa (Sector II)	top 5	123	8.1	0.32
" "	"	"	8.0	0.39
" "	"	"	9.0	0.27
" "	"	"	8.1	0.23
" (Sector IV)	"	125	9.2	0.41
" "	"	"	8.6	0.36
" "	"	"	8.5	0.50
" "	"	"	8.8	0.41
" "	"	"	8.8	0.44
" "	"	130	8.8	0.46
" "	"	"	9.2	0.36
" "	"	"	8.4	0.41
" "	"	"	8.4	0.44
Late Harappan	top 9	205	8.5	0.29
" "	"	"	8.6	0.23
" "	"	"	8.9	0.26
" "	"	"	8.7	0.14
" "	"	"	8.7	0.32
" "	"	"	9.2	0.33
" "	"	"	8.9	0.22
" "	"	"	8.9	0.31
" "	"	"	9.2	0.58
" "	"	"	8.8	0.32

Table 5. Results of analysis of deposits from Daimabad.