Statistical Assessment of Physico-chemical Parameters of Water from Bore Holes and Shallow Wells in Agasteeswaram and Kalkulam Taluks of Kanyakumari District, India

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Abstract A systematic study has been carried out to explore physico-chemical parameters of drinking water from bore holes and shallow wells in five different stations (sites) of Agasteeswaram and Kalkulam Taluks in Kanyakumari District of South India. Water samples from bore holes and shallow wells in five stations were collected and analyzed for temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride, total dissolved solids, dissolved oxygen, BOD, electrical conductivity, total nitrogen, nitrate, sulphate, ammonia, phosphate, total phosphorus, sodium, potassium and oxidation & reduction potential. Comparative studies of parameters in different stations and in different Taluks were also carried out. The physico-chemical parameters were analyzed and the results were compared with water quality standards described by WHO. Statistical techniques, calculation of basic statistics, Correlation matrix, Hierarchical Cluster analysis were simultaneously applied to the physico-chemical parameters of water samples taken from in different stations and in different Taluks. The above study will be useful to know the water quality and their fitness for drinking purposes at various stations undertaken. Overall water quality was found satisfactory for drinking purpose without prior treatment.

Keywords Bore Hole, Shallow Well, Agasteeswaram Taluk, Kalkulam Taluk, Physico-chemical Parameters, Basic Statistics, Correlation Matrix, Hierarchical Cluster Analysis

1. Introduction

The life of living organism depends on water[1-4]. The main source of life for many people in the world is the ground water[5]. The pollution of surface and ground water is a major problem due to rapid urbanization and industrialization[6]. The water demand is continuously increasing mainly due to population growth and raising needs in agriculture, industrial uses and domestic services[7]. Several studies on the ground water quality have been carried out in different parts of India[8-11]. Kanyakumari district is divided into four Taluks. The district is part of the composite east flowing river basin “between Pazhayar and Tamirabarani” as per the irrigation Atlas of India[12]. People in Kanya Kumari district depends on bore holes and shallow wells for domestic purpose. The quality of water from bore holes and shallow wells are to be analyzed. The objective of this study is to investigate physico-chemical analysis and statistical analysis of parameters of water from bore holes and shallow wells in our study area. Study area consists of four Taluks namely Agasteeswaram, Kalkulam, Vilavamcode and Thovalai. But at present, we liberate the results of the Agasteeswaram and Kalkulam Taluks.

2. Material and Methods

Study Area (Figure 1).

Kanyakumari district is the southernmost district of the state of Tamil Nadu, and the southernmost tip of peninsular India. It is located between 77°15’ and 77° 36’of east of longitudes and 8° 03’and 8° 35’ north of latitudes. Agasteeswaram and Kalkulam Taluks are situated near to Thovalai and Vilavancode respectively.

Collection of samples

Bore hole water samples were collected from five stations namely Agasteeswaram, Kanyakumari, Nagercoil,
Suchindrum and Vadasery of Agasteeswaram Taluk. The above stations are hereafter referred as B1, B2, B3, B4, B5. Bore hole water samples were collected from five villages namely Colachel, Kurunthencode, Manavalakurich, Thukalay and Vellilmalai of Kalkulam Taluk. These stations are hereafter referred as B6, B7, B8, B9, B10. Similarly shallow well water samples were also collected from the above said villages and were labeled as Agasteeswaram (S1), Kanyakumari (S2), Nagercoil (S3), Suchindrum (S4) and Vadasery (S5) of Agasteeswaram Taluk and Colachel(S6), Kurunthencode(S7), Manavalakurich(S8), Thukalay (S9) and Vellilmalai (S10) of Kalkulam Taluk. Sample from all the above stations were collected in pre-cleaned to polyethylene bottles and labeled as said above.

**Physico-Chemical Analysis**

Samples collected from all the stations were analysed for physico-chemical analysis using standard methods\[13\]. The following physico-chemical parameters such as temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride, total dissolved solids, dissolved oxygen, BOD, electrical conductivity, total nitrogen, nitrate, sulphate, ammonia, phosphate, total phosphorus, sodium, potassium and oxidation & reduction potential have been analyzed. The temperature of the water samples was measured by mercury thermometer. The pH measurement of the water samples was carried out using digital pH meter (Elico pH-13 model). A conductivity meter was used to measure EC. Volumetric method using sulfuric acid as titrant and phenolphthalein and methyl orange as indicators was used to determine alkalinity. EDTA (complexometric) method was used to determine calcium, magnesium and total hardness titrimetrically. Flame photometer was used to identify sodium and potassium. Mohr’s method was used to measure chloride by titration with silver nitrate. UV-Vis Spectrophotometer was used to analyse nitrate. Salinity was estimated by Argentometric titration method. The dissolved oxygen was estimated by Winklers method. The findings of the present investigation were summarized and compared with standards\[14,15\].

**Reagents and Classware**

All reagents used in our work were of analytical grade. Double distilled water was used to prepare all the reagents and calibration standards.

**Statistical Analysis**

The correlation between various physico-chemical parameters of water samples analysed statistically conducting basic statistics (mean, standard deviation (SD), median, minimum, maximum, variance (V), Kurtosis (K), Skewness (S), Hierarchical cluster analysis, Pearson correlation analysis with the help of SPSS (Statistics Package for the Social Sciences) software (Windows version 19) and the relation between various parameters were also studied by Microsoft office Excel 2007.

### 2. Result and Discussion

The physical and chemical parameters such as temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride, total dissolved solids, dissolved oxygen, BOD, electrical conductivity, total nitrogen, nitrate, sulphate, ammonia, phosphate, total phosphorus, sodium, potassium and oxidation & reduction potential of the drinking water samples collected from five different stations in bore holes in Agasteeswaram Taluk, shallow wells in Agasteeswaram Taluk and shallow wells in Kalkulam Taluk were given in Tables: 1, 3, 5 and 7 respectively.

In this study the tools used for data analysis are mainly experimental aimed at defining possible trends, relationships or interactions among the measured parameters.

**Descriptive statistics** in the forms of mean, SD, median, minimum, maximum, variance (V), Kurtosis (K), Skewness(S), standard error of mean (SEM), standard error of kurtosis (SEK), standard error of skewness (SES) were calculated and summarized in Tabular form in Tables 2, 4, 6 and 8 respectively.

The physico-chemical parameters were also analysed through graphical representation using Microsoft office Excel 2007 to know the relation between the parameters for samples taken from bore hole of Agasteeswaram Taluk (Figures 2 to 7), for samples taken from bore hole of Kalkulam Taluk (Figures 8 to 13), for shallow well of Agasteeswaram Taluk (Figures 14 to 19), for samples taken from shallow well of Kalkulam Taluk (Figures 20 to 25).
Table 1. Physical and Chemical Parameters of bore hole water from Agasteeswaram Taluk (Stations B1 to B5)

| Stations | Parameters | Temp(°C) | pH     | Turbidity | EC (MicS/cm) | TDS (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Alkalinity (mg/L) |
|----------|------------|----------|--------|-----------|--------------|-------------|---------------|------------------|------------------|
| B1       |            | 26       | 6.8    | 7.92      | 721          | 62          | 19.85         | 14.75            | 180              |
| B2       |            | 27       | 6.2    | 7.7       | 720          | 61          | 18.2          | 13.71            | 183              |
| B3       |            | 28       | 7.6    | 7.7       | 680          | 64          | 18.7          | 14.72            | 180              |
| B4       |            | 26       | 6.3    | 7.7       | 730          | 62          | 19.7          | 12.92            | 189              |
| B5       |            | 27       | 7.7    | 7.6       | 625          | 63          | 19            | 12.98            | 191              |

| Stations | Hardness Ca (mg/L) | Hardness Mg (mg/L) | Fluoride (ppm) | Chloride (mg/L) | Total N (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) | Ammonia (mg/L) |
|----------|--------------------|--------------------|----------------|-----------------|----------------|----------------|----------------|----------------|
| B1       | 60                 | 1.5                | 0.8            | 250             | 4.2            | 0.6            | 5.8            | 5.85           |
| B2       | 65                 | 1.5                | 0.8            | 255             | 4              | 0.5            | 5.5            | 6              |
| B3       | 69                 | 1.4                | 0.7            | 265             | 4.3            | 0.5            | 5.4            | 8              |
| B4       | 62                 | 1.6                | 0.8            | 280             | 4.2            | 0.62           | 5.2            | 5.2            |
| B5       | 60                 | 1.5                | 0.7            | 260             | 4.3            | 0.8            | 5              | 5              |

| Stations | Phosphate (mg/L) | Total P (mg/L) | Salinity (ppm) | DO (mg/L) | BOD (mg/L) | OXREDPot (mV) |
|----------|-----------------|----------------|---------------|-----------|------------|---------------|
| B1       | 0.9             | 0.7            | 70            | 5.4       | 4.5        | 650           |
| B2       | 0.8             | 0.6            | 83            | 6         | 4.8        | 620           |
| B3       | 0.8             | 0.7            | 80            | 5.3       | 5          | 610           |
| B4       | 0.92            | 0.7            | 79            | 6         | 5.2        | 600           |
| B5       | 0.85            | 0.65           | 70            | 5.2       | 5          | 620           |

Figure 2. Relation between Temperature, pH, Turbidity, Fluoride bore hole water of Agasteeswaram Taluk

Figure 3. Relation between Na, K, Ca, Mg of bore hole water from Agasteeswaram Taluk

Figure 4. Relation between Total N, Nitrate, Sulphate, Ammonia of bore hole water from Agasteeswaram Taluk

Figure 5. Relation between EC, TDS, Alkalinity of bore hole water of Agasteeswaram Taluk
Table 2. Statistics of Physico-Chemical parameters of water from Agateeswaram Taluk (Stations B1 to B5)
Figure 8. Relation between Temperature pH, Turbidity, Fluoride of bore hole water of Kalkulam Taluk

Figure 9. Relation between Na, K, Ca, Mg of bore hole water of Kalkulam Taluk

Figure 10. Relation between Total N, Nitrate, Sulphate, Ammonia of bore hole water of Kalkulam taluk

Figure 11. Relation between EC, TDS, Alkalinity of bore hole water of Kalkulam taluk

Figure 12. Relation between Phosphate, Total P, DO, BOD of bore hole water of Kalkulam Taluk

Figure 13. Relation between Chloride, Salinity, ORP of bore hole water of Kalkulam Taluk

Figure 14. Relation between Temperature, pH, Turbidity, Fluoride of shallow well water of Agateeswaram taluk

Figure 15. Relation between Na, K, Ca, Mg of shallow well water of Agateeswaram Taluk
Table 4. Statistics of Physico-Chemical Parameters of Bore Hole water from Kalkulam Taluk (Stations B6 to B10)

| Parameters    | Mean N | Std. Deviation | Median | SEM | Minimum | Maximum | Variance | Kurtosis | SEK | Skewness | SEK |
|---------------|--------|----------------|--------|-----|---------|---------|----------|----------|-----|-----------|-----|
| Temp          | 27.40  | 5 0.894        | 28.00  | 0.400 | 26.00   | 28.00   | .800     | 0.313    | 2.0 | -1.258    | 0.913|
| pH            | 7.38   | 5 0.363        | 7.20   | 0.162 | 7.00    | 7.90    | .132     | -0.940   | 2.0 | 0.736     | 0.913|
| Turbidity     | 7.20   | 5 0.216        | 7.30   | 0.096 | 7.00    | 7.60    | .047     | 1.435    | 2.0 | 0.422     | 0.913|
| EC            | 704.00 | 5 68.775       | 720.00 | 30.757 | 600.00  | 790.00  | 4730.000 | 1.602    | 2.0 | -0.619    | 0.913|
| TDS           | 72.60  | 5 7.266        | 74.00  | 3.249 | 62.00   | 80.00   | 52.800   | -0.537   | 2.0 | -0.730    | 0.913|
| Sodium        | 18.62  | 5 0.837        | 18.20  | 0.374 | 17.90   | 19.80   | .702     | -1.660   | 2.0 | 0.816     | 0.913|
| Potassium     | 14.61  | 5 0.682        | 14.70  | 0.305 | 13.90   | 15.50   | .466     | -1.851   | 2.0 | 0.160     | 0.913|
| Alkalinity    | 195.80 | 5 3.898        | 197.00 | 1.743 | 190.00  | 200.00  | 15.200   | 0.001    | 2.0 | -1.549    | 0.913|
| HardnessCa    | 68.20  | 5 3.114        | 69.00  | 1.392 | 63.00   | 71.00   | 9.700    | 2.675    | 2.0 | -0.730    | 0.913|
| HardnessMg    | 1.86   | 5 0.296        | 2.00   | 0.132 | 1.50    | 2.20    | .088     | -2.270   | 2.0 | -0.730    | 0.913|
| Fluoride      | 0.70   | 5 0.100        | 0.70   | 0.044 | .60     | .80     | .010     | -3.000   | 2.0 | 0.000     | 0.913|
| Chloride      | 232.00 | 5 5.700        | 230.00 | 2.549 | 225.00  | 240.00  | 32.500   | -0.178   | 2.0 | 0.405     | 0.913|
| TotalN        | 4.48   | 5 0.238        | 4.50   | 0.106 | 4.20    | 4.80    | .057     | -1.117   | 2.0 | 0.206     | 0.913|
| Nitrate       | 0.74   | 5 0.089        | 0.80   | 0.040 | .60     | .80     | .008     | 0.312    | 2.0 | -1.258    | 0.913|
| Chloride      | 6.56   | 5 0.336        | 6.20   | 0.150 | 5.90    | 6.70    | .113     | -1.913   | 2.0 | 0.379     | 0.913|
| Ammonia       | 0.93   | 5 0.120        | 0.90   | 0.053 | .79     | 1.10    | .014     | -0.595   | 2.0 | 0.460     | 0.913|
| TotalP        | 0.74   | 5 0.084        | 0.78   | 0.037 | .60     | .80     | .007     | 1.954    | 2.0 | -1.539    | 0.913|
| Salinity      | 74.60  | 5 6.308        | 70.00  | 2.821 | 70.00   | 82.00   | 39.800   | -3.250   | 2.0 | 0.623     | 0.913|
| DO            | 6.38   | 5 0.540        | 6.20   | 0.241 | 5.80    | 7.00    | .292     | -2.782   | 2.0 | 0.325     | 0.913|
| BOD           | 5.26   | 5 0.498        | 5.40   | 0.222 | 4.60    | 5.80    | .248     | -1.795   | 2.0 | -0.454    | 0.913|
| OXRED Pot     | 623.00 | 5 10.368       | 625.00 | 4.636 | 610.00  | 635.00  | 107.500  | -1.963   | 2.0 | -0.236    | 0.913|

Table 5. Physical and Chemical Parameters of Shallow well water from Agasteeswaram Taluk (Stations S1 to S5)

| Stations | Temp(°C) | pH | Turbidity | EC (MicS/cm) | TDS (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Alkalinity (mg/L) |
|----------|----------|----|-----------|--------------|------------|---------------|------------------|-------------------|
| S1       | 26       | 6.4| 5.4       | 650          | 36         | 15.2          | 12.2             | 140               |
| S2       | 26       | 6.3| 5.4       | 625          | 37         | 15.3          | 11.5             | 150               |
| S3       | 26       | 6.4| 5.4       | 600          | 36         | 13            | 11.8             | 142               |
| S4       | 27       | 6.5| 5.5       | 632          | 36.5       | 15.2          | 11.9             | 160               |
| S5       | 26       | 6.8| 5.8       | 635          | 37         | 16            | 11.8             | 143               |

| Stations | Hardness Ca (mg/L) | Hardness Mg (mg/L) | Fluoride (ppm) | Chloride (mg/L) | Total N (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) | Ammonia (mg/L) |
|----------|--------------------|--------------------|----------------|-----------------|----------------|----------------|----------------|----------------|
| S1       | 53                 | 1.3                | 0.5            | 230             | 3.8            | 0.5            | 4.42           | 5               |
| S2       | 50                 | 1.25               | 0.4            | 220             | 3.4            | 0.4            | 4.38           | 5               |
| S3       | 56                 | 1.3                | 0.5            | 210             | 4              | 0.5            | 4.48           | 5               |
| S4       | 53                 | 1.27               | 0.5            | 220             | 4.2            | 0.5            | 4.5            | 5               |
| S5       | 55                 | 1.25               | 0.6            | 209             | 4              | 0.5            | 4.6            | 5               |

| Stations | Phosphate (mg/L) | Total P (mg/L) | Salinity (ppm) | DO (mg/L) | BOD (mg/L) | OXRED Pot (mV) |
|----------|------------------|----------------|----------------|-----------|------------|----------------|
| S1       | 0.7              | 0.5            | 30             | 7.2       | 5          | 600            |
| S2       | 0.6              | 0.4            | 28             | 6.8       | 4          | 560            |
| S3       | 0.75             | 0.5            | 42             | 6.5       | 5.3        | 570            |
| S4       | 0.6              | 0.5            | 52             | 6.4       | 5.2        | 570            |
| S5       | 0.6              | 0.55           | 38             | 6.3       | 5          | 580            |
Figure 16. Relation between Total N, Nitrate, Sulphate, Ammonia of shallow well water of Agateeswaram taluk

Figure 17. Relation between EC, TDS, Alkalinity of shallow well water of Agateeswaram taluk

Figure 18. Relation between Phosphate, Total P, DO, BOD of shallow well water of Agateeswaram taluk

Figure 19. Relation between Chloride, Salinity, ORP of shallow well water of Agateeswaram taluk

Table 6. Statistics of Physico-Chemical parameters of shallow wells water from Agatesswaram Taluk (S1 to S5)

| Parameters | Mean  | SD   | Median | SEM  | Minimum | Maximum | Variance | Skewness | SEK  | Skewness |
|------------|-------|------|--------|------|---------|---------|----------|----------|------|----------|
| Temp       | 26.20 | 5    | 0.447  | 26.00| 26.00   | 27.00   | 0.200    | 2.236    | 0.913|
| pH         | 6.48  | 5    | 0.192  | 6.40 | 0.086   | 6.30    | 0.037    | 1.517    | 0.913|
| Turbidity  | 5.50  | 5    | 0.173  | 5.40 | 0.077   | 5.40    | 0.030    | 1.925    | 0.913|
| EC         | 628.40| 5    | 18.311 | 632.00| 8.189   | 650.00  | 335.300  | -0.851   | 0.913|
| TDS        | 36.50 | 5    | 0.500  | 36.50| 0.223   | 37.00   | 0.250    | -0.000   | 0.913|
| Sodium     | 14.94 | 5    | 1.134  | 15.20| 0.507   | 13.00   | 1.288    | -1.718   | 0.913|
| Potassium  | 11.84 | 5    | 0.251  | 11.80| 0.112   | 11.50   | 0.063    | 0.913    | 0.913|
| Alkalinity | 147.00| 5    | 8.185  | 143.00| 3.660   | 160.00  | 67.000   | 1.286    | 0.913|
| HardnessCa | 53.40 | 5    | 2.302  | 53.00| 1.029   | 56.00   | 5.300    | 0.196    | 0.913|
| HardnessMg | 1.27  | 5    | 0.025  | 1.27 | 0.011   | 1.25    | 0.001    | 0.196    | 0.913|
| Fluoride   | 0.50  | 5    | 0.070  | 0.50 | 0.031   | 0.40    | 0.005    | 0.000    | 0.913|
| Chloride   | 217.80| 5    | 8.613  | 220.00| 3.852   | 230.00  | 74.200   | 0.444    | 0.913|
| TotalN     | 3.88  | 5    | 0.303  | 4.00 | 0.135   | 4.20    | 0.092    | -1.118   | 0.913|
| Nitrate    | 0.48  | 5    | 0.044  | 0.50 | 0.020   | 0.50    | 0.002    | -2.236   | 0.913|
| Sulphate   | 4.47  | 5    | 0.084  | 4.48 | 0.037   | 4.48    | 0.007    | 0.602    | 0.913|
| Ammonia    | 5.12  | 5    | 0.178  | 5.00 | 0.080   | 5.00    | 0.032    | 1.258    | 0.913|
| Phosphorus | 0.65  | 5    | 0.070  | 0.60 | 0.031   | 0.75    | 0.005    | 0.884    | 0.913|
| TotalP     | 0.49  | 5    | 0.054  | 0.50 | 0.024   | 0.55    | 0.003    | -1.293   | 0.913|
| Salinity   | 38.00 | 5    | 9.695  | 38.00| 4.335   | 52.00   | 94.000   | -1.889   | 0.913|
| DO         | 6.64  | 5    | 0.364  | 6.50 | 0.163   | 6.30    | 0.133    | 1.064    | 0.913|
| BOD        | 4.90  | 5    | 0.519  | 5.00 | 0.232   | 5.00    | 0.270    | 0.692    | 0.913|
| OXREDPot   | 583.00| 5    | 23.345 | 570.00| 10.440  | 560.00  | 545.000  | -1.181   | 0.913|
### Table 7. Physical and Chemical Parameters of Shallow Well water from Kalkulam Taluk (Stations S6 to S10)

| Stations | Temp (°C) | pH  | Turbidity | EC (MicS/cm) | TDS (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Alkalinity (mg/L) |
|----------|----------|-----|-----------|--------------|------------|---------------|-----------------|------------------|
| S6       | 26       | 6.8 | 5         | 631          | 37         | 15            | 11.2            | 140              |
| S7       | 26       | 6.2 | 5.8       | 328          | 37.5       | 15.8          | 12.9            | 152              |
| S8       | 27       | 6.1 | 5.4       | 620          | 36.5       | 15.7          | 12.8            | 150              |
| S9       | 26       | 6   | 5         | 625          | 36         | 16            | 13.9            | 151              |
| S10      | 26       | 6   | 5.2       | 600          | 35.8       | 15.1          | 12.9            | 153              |

| Stations | Hardness Ca (mg/L) | Hardness Mg (mg/L) | Fluoride (ppm) | Chloride (mg/L) | Total N (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) | Ammonia (mg/L) |
|----------|-------------------|-------------------|---------------|----------------|----------------|---------------|----------------|----------------|
| S6       | 56                | 1.7               | 0.6           | 210            | 3.9            | 0.4           | 4.7            | 5              |
| S7       | 52                | 1.8               | 0.4           | 208            | 3.8            | 0.5           | 4.8            | 4.8            |
| S8       | 55                | 1.3               | 0.6           | 206            | 3.8            | 0.5           | 4.4            | 4.8            |
| S9       | 57                | 1.4               | 0.6           | 205            | 3.6            | 0.5           | 4.8            | 5.2            |
| S10      | 56                | 1.2               | 0.5           | 203            | 3.9            | 0.6           | 4.4            | 5.3            |

| Stations | Phosphate (mg/L) | Total P (mg/L) | Salinity (ppm) | DO (mg/L) | BOD (mg/L) | OXREDPot (mV) |
|----------|------------------|----------------|---------------|-----------|------------|---------------|
| S6       | 0.72             | 0.54           | 25            | 7         | 5.8        | 580           |
| S7       | 0.8              | 0.53           | 54            | 7.2       | 5.5        | 590           |
| S8       | 0.4              | 0.5            | 42            | 7.4       | 6          | 582           |
| S9       | 0.5              | 0.48           | 72            | 6.8       | 6.4        | 576           |
| S10      | 0.7              | 0.4            | 42            | 6         | 4.6        | 572           |

### Figures

**Figure 20.** Relation between Temperature, pH, turbidity, Fluoride of shallow well water of Kalkulam taluk

**Figure 21.** Relation between Na, K, Ca, Mg of shallow well water of Kalkulam taluk

**Figure 22.** Relation between Total N Nitrate, Sulphate, Ammonia of Shallow well water of Kalkulam taluk

**Figure 23.** Relation between EC, TDS, Alkalinity of shallow well water of Kalkulam taluk
Figure 24. Relation between Phosphate, Total P, DO, BOD of shallow well water of Kalkulam taluk

Figure 25. Relation between Chloride, Salinity, ORP of Shallow well water of Kalkulam taluk

Table 8. Statistics of Physico-Chemical Parameters of Shallow well water from Kalkulam Taluk (Stations S6 to S10)

| Parameters | Mean | N  | Std. Deviation | Median | SEM  | Minimum | Maximum | Variance | Kurtosis | SEK | Skewness | SEK |
|-----------|------|----|----------------|--------|------|---------|---------|----------|----------|-----|----------|-----|
| Temp      | 26.20| 5  | 0.447          | 26.00  | 0.200| 26.00   | 27.00   | 0.200    | 5.000    | 2.0 | 2.236    | 0.913 |
| pH        | 6.22 | 5  | 0.334          | 6.10   | 0.149| 6.00    | 6.80    | 0.112    | 3.764    | 2.0 | 1.913    | 0.913 |
| Turbidity | 5.28 | 5  | 0.334          | 5.20   | 0.149| 5.00    | 5.80    | 0.112    | .536     | 2.0 | 1.089    | 0.913 |
| EC        | 620.80| 5 | 12.316         | 625.00 | 6.508| 600.00  | 631.00  | 151.700  | 2.918    | 2.0 | -1.670   | 0.913 |
| TDS       | 36.56| 5  | 0.702          | 36.50  | 0.314| 35.80   | 37.50   | 0.493    | -1.570   | 2.0 | 0.362    | 0.913 |
| Sodium    | 15.52| 5  | 0.443          | 15.70  | 0.198| 15.00   | 16.00   | 0.197    | -2.701   | 2.0 | -0.364   | 0.913 |
| Potassium | 12.74| 5  | 0.971          | 12.90  | 0.434| 11.20   | 13.90   | 0.943    | 2.453    | 2.0 | -0.948   | 0.913 |
| Alkalinity| 149.20| 5 | 5.263          | 151.00 | 2.353| 140.00  | 153.00  | 27.700   | 4.128    | 2.0 | -1.988   | 0.913 |
| HardnessCa| 55.20| 5  | 1.923          | 56.00  | 0.860| 52.00   | 57.00   | 3.700    | 2.608    | 2.0 | -1.517   | 0.913 |
| HardnessMg| 1.48 | 5  | 0.258          | 1.40   | 0.115| 1.20    | 1.80    | 0.067    | -2.413   | 2.0 | 0.363    | 0.913 |
| Fluoride  | 0.54 | 5  | 0.089          | 0.60   | 0.040| 0.40    | 0.60    | 0.008    | 0.312    | 2.0 | -1.258   | 0.913 |
| Chloride  | 206.40| 5 | 2.701          | 206.00 | 1.208| 203.00  | 210.00  | 7.300    | -0.681   | 2.0 | 0.183    | 0.913 |
| TotalN    | 3.80 | 5  | 0.122          | 3.80   | 0.054| 3.60    | 3.90    | 0.015    | 2.000    | 2.0 | -1.361   | 0.913 |
| Nitrate   | 0.50 | 5  | 0.070          | 0.50   | 0.031| 0.40    | 0.60    | 0.005    | 2.000    | 2.0 | 0.000    | 0.913 |
| Sulphate  | 4.62 | 5  | 0.204          | 4.70   | 0.091| 4.40    | 4.80    | 0.042    | -3.163   | 2.0 | -0.441   | 0.913 |
| Ammonia   | 5.02 | 5  | 0.228          | 5.00   | 0.101| 4.80    | 5.30    | .052     | -2.507   | 2.0 | 0.228    | 0.913 |
| Phosphate | 0.62 | 5  | 0.166          | 0.70   | 0.074| 0.40    | 0.80    | 0.028    | -1.838   | 2.0 | -0.570   | 0.913 |
| TotalP    | 0.49 | 5  | 0.055          | 0.50   | 0.024| 0.40    | 0.54    | 0.003    | 1.683    | 2.0 | -1.304   | 0.913 |
| Salinity  | 47.00| 5  | 17.378         | 42.00  | 7.771| 25.00   | 72.00   | 302.000  | 614.0    | 2.0 | 0.403    | 0.913 |
| DO        | 6.88 | 5  | 0.540          | 7.00   | 0.241| 6.00    | 7.40    | .292     | 2.021    | 2.0 | -1.339   | 0.913 |
| BOD       | 5.66 | 5  | 0.676          | 5.80   | 0.302| 4.60    | 6.40    | .458     | 1.396    | 2.0 | -1.005   | 0.913 |
| OXREDPot  | 580.00| 5 | 6.782          | 580.00 | 3.033| 572.00  | 590.00  | 46.000   | 0.488    | 2.0 | 0.577    | 0.913 |
Temperature

The temperature was found to be range between 26 to 28°C during study.

pH

pH is an indicative of acidity or basicity of water. The pH values of bore holes water varied between 6.2 to 7.7 for B1 to B5, 7.0 to 7.9 for B6 to B10 (Tables 1, 3), 6.3 to 6.8 for S1 to S5, 6.0 to 6.8 for S6 to S10 (Tables 5, 7). The mean pH of bore hole water found to be 6.92 for B1 to B5 ad 7.38 for B6 to B10. This shows that water samples from bore hole of Agateeswaram Taluk is almost neutral but water samples from Kalkulam Taluk is slightly alkaline trend. The mean pH of shallow wells water found to be 6.48 for S1 to S5 and 6.42 for S6 to S10. This shows that water samples from shallow wells of both Taluks are slightly acidic trend. The pH of water is influenced by geology of catchments area and buffering capacity of water.

Turbidity

Turbidity is a measure of the light scattering potential of water caused by the presence of colloidal and suspended material. The turbidity values of bore holes water varied between 7.6 to 7.9 for B1 to B5, 7.0 to 7.6 for B6 to B10 (Tables 1, 3), 5.4 to 5.8 for S1 to S5, 5.0 to 5.8 for S6 to S10 (Tables 5, 7). The mean turbidity of bore hole water found to be 7.72 for B1 to B5 ad 7.20 for B6 to B10. The mean turbidity of shallow wells water found to be 5.50 for S1 to S5 and 5.28 for S6 to S10. The limit of turbidity value for drinking water is specified as 5 to 10 NTU. The observed turbidity values are within the permissible limits.

Electrical conductivity

The EC values of bore holes water varied between 625 to 730 for B1 to B5, 600 to 790 for B6 to B10 (Tables 1, 3), 600 to 650 for S1 to S5, 600 to 631 for S6 to S10 (Tables 5, 7). The mean EC of bore hole water found to be 695.20 for B1 to B5 and 704 for B6 to B10. The mean EC of shallow wells water found to be 628.40 for S1 to S5 and 620.80 for S6 to S10. The observed values are within the permissible limits.

Total dissolved solids (TDS)

ISI prescribed desirable limit of TDS is 500 mg/L. TDS values observed in B1 to B10 and S1 to S10 were low and with the desirable limit. The low value indicates that there is not much pollution by particles. The TDS values of bore holes water varied between 61 to 64 for B1 to B5, 62 to 80.0 for B6 to B10 (Tables 1, 3), 36 to 37 for S1 to S5, 35.80 to 37.50 for S6 to S10 (Tables 5, 7). The mean TDS of bore hole water found to be 62.4 for B1 to B5 and 72.60 for B6 to B10. The mean TDS of shallow wells water found to be 36.50 for S1 to S5 and 36.56 for S6 to S10.

Sodium (Na+) and potassium (K+)

The concentration of Na values of bore holes water varied between 18.2 to 19.8 for B1 to B5, 17.9 to 19.80 for B6 to B10 (Tables 1, 3), 13.00 to 16.00 for S1 to S5, 15.0 to 16.0 for S6 to S10 (Tables 5, 7). The mean concentration of Na of bore hole water found to be 19.09 for B1 to B5 and 18.62 for B6 to B10. The mean concentration of Na of shallow wells water found to be 14.94 for S1 to S5 and 15.52 for S6 to S10. The observed values are within the permissible limits.

The concentration of K values of bore holes water varied between 12.9 to 14.7 for B1 to B5, 13.90 to 15.50 for B6 to B10 (Tables 1, 3), 11.50 to 12.20 for S1 to S5, 11.20 to 13.90 for S6 to S10 (Tables 5, 7). The mean concentration of K of bore hole water found to be 13.81 for B1 to B5 and 14.61 for B6 to B10. The mean concentration of K of shallow wells water found to be 11.84 for S1 to S5 and 12.74 for S6 to S10. The observed values are within the permissible limits.

Alkalinity

Alkalinity of water is a measure of its capacity to neutralize acids and provides an index for the nature of slats present in the water samples. The standard desirable limit of alkalinity in drinking water is 120 mg/L. The maximum permissible level is 600 mg/L. The alkalinity values of bore holes water varied between 180 to 191 for B1 to B5, 190 to 200 for B6 to B10 (Tables 1, 3), 140 to 160 for S1 to S5, 140 to 153 for S6 to S10 (Tables 5, 7). The mean alkalinity of bore hole water found to be 184.6 for B1 to B5 and 195.80 for B6 to B10. The mean alkalinity of shallow wells water found to be 147 for S1 to S5 and 149.20 for S6 to S10. The observed alkalinity values are within the permissible limits.

Calcium and Magnesium

The upper limit of calcium concentration in drinking water is specified as 75 mg/L (ISI, 1983). The Ca values of bore holes water varied between 60.0 to 69.0 for B1 to B5, 63.0 to 71.0 for B6 to B10 (Tables 1, 3), 50 to 56 for S1 to S5, 52 to 57 for S6 to S10 (Tables 5, 7). The mean Ca of bore hole water found to be 63.20 for B1 to B5 and 68.20 for B6 to B10. The mean Ca of shallow wells water found to be 147 for S1 to S5 and 149.20 for S6 to S10. The observed calcium values are within the permissible limits.

The upper limit of magnesium concentration in drinking water is specified as 30 mg/L (ISI, 1983). The Mg values of bore holes water varied between 1.4 to 1.6 for B1 to B5, 1.5 to 2.20 for B6 to B10 (Tables 1, 3), 1.25 to 1.40 for S1 to S5, 1.20 to 1.80 for S6 to S10 (Tables 5, 7). The mean Mg of bore hole water found to be 1.50 for B1 to B5 and 1.86 for B6 to B10. The mean Mg of shallow wells water found to be 1.27 for S1 to S5 and 1.48 for S6 to S10. The observed magnesium values are within the permissible limits.

Fluoride

Fluoride content is an important factor in the development of normal bones and teeth. The desirable limit is 1 to 1.5 mg/L for drinking purpose. Fluoride values observed in B1 to B10 and S1 to S10 were low and with the desirable limit. The Fluoride values of bore holes water varied between 0.7
to 0.8 for B1 to B5, 0.6 to 0.80 for B6 to B10 (Tables 1, 3), 0.4 to 0.60 for S1 to S5, 0.4 to 0.60 for S6 to S10 (Tables 5, 7). The mean Fluoride of bore hole water found to be 0.76 for B1 to B5 and 0.70 for B6 to B10. The mean Fluoride of shallow wells water found to be 0.50 for S1 to S5 and 0.54 for S6 to S10.

**Chloride**

Chloride is a most common inorganic anion present in water to it through biogenic sources and indicates the state of contamination. The chloride values of bore holes water varied between 250 to 280 for B1 to B5, 225 to 240 for B6 to B10 (Tables 1, 3), 209 to 230 for S1 to S5, 203 to 210 for S6 to S10 (Tables 5, 7). The mean chloride of bore hole water found to be 262 for B1 to B5 and 232 for B6 to B10. The mean chloride of shallow wells water found to be 217.80 for S1 to S5 and 206.40 for S6 to S10. The observed values are within the permissible limits.

**Nitrate**

The nitrate values of bore holes water varied between 0.5 to 0.8 for B1 to B5, 0.6 to 0.8 for B6 to B10 (Tables 1, 3), 0.4 to 0.50 for S1 to S5, 0.4 to 0.6 for S6 to S10 (Tables 5, 7). The mean nitrate of bore hole water found to be 0.60 for B1 to B5 and 0.74 for B6 to B10. The mean nitrate of shallow wells water found to be 0.48 for S1 to S5 and 0.50 for S6 to S10. The observed values are within the permissible limits.

**Sulphate**

Sulphate is the major anion occurring in natural waters. The upper limit for sulphate concentration for drinking water is 150 mg/L. The Sulphate values of bore holes water varied between 5.0 to 5.8 for B1 to B5, 5.90 to 6.70 for B6 to B10 (Tables 1, 3), 4.38 to 4.60 for S1 to S5, 4.40 to 4.80 for S6 to S10 (Tables 7,10). The mean Sulphate of bore hole water found to be 5.38 for B1 to B5 and 6.26 for B6 to B10. The mean Sulphate of shallow wells water found to be 4.47 for S1 to S5 and 4.62 for S6 to S10. The observed values are within the permissible limits.

**Phosphate**

The phosphate ion in the water samples due to agriculture land composition of organic matter. The Phosphate values of bore holes water varied between 0.8 to 0.9 for B1 to B5, 0.79 to 1.10 for B6 to B10 (Tables 1, 3), 0.60 to 0.75 for S1 to S5, 0.40 to 0.80 for S6 to S10 (Tables 5, 7). The mean Phosphate of bore hole water found to be 0.85 for B1 to B5 and 0.93 for B6 to B10. The mean Phosphate of shallow wells water found to be 0.65 for S1 to S5 and 0.65 for S6 to S10. These values are within the permissible limits.

**Salinity**

The salinity values of bore holes water varied between 70.0 to 83.0 for B1 to B5, 70.0 to 82.0 for B6 to B10 (Tables 1, 3), 28 to 52 for S1 to S5, 25 to 72 for S6 to S10 (Tables 5, 7). The mean salinity of bore hole water found to be 76.4 for B1 to B5 and 74.6 for B6 to B10. This shows that water samples from bore holes of of both Taluks are slightly alkaline trend. The mean salinity of shallow wells water found to be 38 for S1 to S5 and 47 for S6 to S10. The observed values are within the permissible limits.

**Dissolved Oxygen**

It is one of the most fundamental parameters in water, as it is to the metabolism of all aerobic aquatic organisms. The permissible limit for DO for drinking water is 6 mg/L. DO values observed in B1 to B10 and S1 to S10 were low and with the desirable limit. The pH values of bore holes water varied between 5.2 to 6.0 for B1 to B5, 5.80 to 7.0 for B6 to B10 (Tables 1, 3), 6.3 to 7.2 for S1 to S5, 6.0 to 7.4 for S6 to S10 (Tables 5,7). The mean DO of bore hole water found to be 5.58 for B1 to B5 and 6.38 for B6 to B10. The mean DO of shallow wells water found to be 6.64 for S1 to S5 and 6.88 for S6 to S10.

**Biochemical oxygen demand**

The permissible limit for BOD as per WHO is 5 mg/L. The BOD values of bore holes water varied between 4.5 to 5.2 for B1 to B5, 4.60 to 5.80 for B6 to B10 (Tables 1, 3), 4.00 to 5.30 for S1 to S5, 4.60 to 6.4 for S6 to S10 (Tables 5, 7). The mean BOD of bore hole water found to be 4.90 for B1 to B5 and 5.26 for B6 to B10. The mean BOD of shallow wells water found to be 4.90 for S1 to S5 and 5.66 for S6 to S10.

**Oxidation Reduction potential**

The ORP values of bore holes water varied between 600 to 650 for B1 to B5, 610 to 635 for B6 to B10 (Tables 1, 3), 560 to 615 for S1 to S5, 572 to 590 for S6 to S10 (Tables 5, 7). The mean ORP of bore hole water found to be 620 for B1 to B5 and 623 for B6 to B10. The mean ORP of shallow wells water found to be 583 for S1 to S5 and 580 for S6 to S10. The shallow well water samples have less ORP value as compared to bore hole water samples. This indicates more oxygen present in bore hole water.

**Pearson correlation analysis**

The Pearson correlation analysis was performed for measured parameters to determine the relation between these variables and given in Tables 9, 10, 11, and 12 respectively. A correlation analysis is a bivariate method applied to describe the degree of relation between two hydro chemical parameters. A high correlation coefficient (near 1 or -1) means a good relationship between two variables and its value around zero means no relationship between them at a significant level of <0.05. More precisely it can be said that parameters showing coefficient >0.7 are considered to be strongly correlated where as coefficient between 0.5 and 0.7 shows moderate correlation.
### Table 9. Correlations status for the measured Physico-chemical parameters of water from bore holes in Agateeswaram Taluk.

|       | Temp  | pH    | Turbidity | EC    | TDS   | Sodium | Potassium | Alkalinity | Hardness Ca | Hardness Mg | Fluoride | Chloride | TotalN | Nitrate | Sulphate | Ammonia | Phosphate | Total P | Salinity | DO  | BOD  | OXRED Pot |
|-------|-------|-------|-----------|-------|-------|--------|-----------|------------|-------------|-------------|-----------|----------|--------|--------|---------|---------|-----------|---------|----------|------|-------|-----------|
| Temp  | .062  | .141  | .187      | .937  | .900  | -.084  | .118      | -.652      | -.945**     | .129       | .840**   | .426    | -.360  | .326   | -.303   | .262    | -.479    | -.935** | .107     | .038  | .226  | .361      |
| pH    | .141  | .303  | .027      | .466  | .937  | .643   | .425      | .117       | .008        | .418        | .237     | .276    | .296   | .310   | .333    | .357    | .357     | .300    | .142     | .057  | .476  | .467      |
| Turbidity | -.497 | .314  | 1.01     | .054  | .128  | .197   | .008      | .629       | -.688       | -.213      | .000     | .573   | -.450  | -.173  | -.354   | .912**  | .117     | .402    | .408     | -.270  | -.009 | -.786     |
| EC    | -.518 | .873* | .466     | .966  | .686  | .257   | .225      | -.429      | .085        | .404        | .891*    | .118    | -.630  | -.666  | .639    | .039    | .334     | .132    | .459     | .752   | .236  | .070      |
| Sodium | -.763 | .084  | .542      | .257  | .006  | 1      | -.008     | .129       | -.637       | .513        | .318     | .245   | .385   | .127   | .250    | .123    | .475     | .291    | .416     | .219   | .071  | .351      |
| Potassium | -.078 | .012  | .236      | .418  | .005  | .187   | .132      | .398       | .374        | .056       | .026     | .070   | .287   | .390   | .890*   | -.733   | -.109    | .367    | .066     | .293   | .352  | .551      |
| Alkalinity | .256  | -.684 | -.429     | -.051 | .129  | -.958**| .424      | -.711      | -.035       | -.539       | .640     | -.603   | .807*  | .756   | -.282   | .327    | -.197    | -.376   | .660     | -.551  | .467  | .213      |
| Hardness Ca | .318  | .379  | .101      | .358  | .334  | .495   | .005      | .239       | .089        | .478       | .174     | .459   | .141   | .049   | .069    | .323    | .295     | .488     | .267     | .113    | .685  | .469      |
| Hardness Mg | .054  | .425  | .366      | .446  | .266  | .124   | .239      | .187       | .120        | .399       | .466     | .070   | .443   | .022   | .079    | .481    | .066     | .455     | .345     | .222    | .232  | .255      |
| Fluoride | -.764 | .945** | .573      | .891* | -.881*| .318   | -.035     | -.160      | -.310       | .645        | .040     | -.745  | .342   | .376   | .477    | -.102   | .212     | .773     | -.345    | .244   | .285  | .346      |
| Chloride | -.078 | .450  | .118      | .210  | .224  | -.539  | .504      | .159       | .461        | -.040      | .266     | .064   | -.594  | -.084  | .337    | .389    | .364     | .373     | .903*    | -.871  | .068  | .213      |
| TotalN | .221  | .436  | .261      | .459  | .374  | .466   | .319      | .074        | .333        | .250       | .391    | .384   | .101   | .173   | .058    | .307    | .431     | .346     | .065     | .200   | .065  | .483      |
| Nitrate | -.267 | .380  | .141      | .056  | .070  | .285   | .459      | .196       | .128        | .089       | .243     | .483   | .068   | .237   | .373    | .458    | .065     | .321     | .273     | .373   | .346  | .483      |
| Sulphate | .221  | .360  | .912      | .639  | -.333 | .154   | .807*     | -.874*      | .090        | -.233      | .542    | -.628  | .1     | .347   | .021    | .129    | .019     | .080     | -.841**  | .705   | .257  | .273      |

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).
### Table 10. Correlations status for the measured Physico-chemical parameters of water from bore holes in Kalkulam Taluk.

|                | Temp | pH   | Turbidity | EC   | TDS  | Sodium | Potassium | Alkalinity | Hardness Ca | Hardness Mg | Fluoride | Chloride | Total N | Nitrate | Sulphate | Ammonia | Phosphate | TotalP | Salinity | DO   | BOD | OXREDPot |
|----------------|------|------|-----------|------|------|--------|-----------|------------|-------------|-------------|-----------|----------|---------|---------|---------|---------|----------|--------|---------|------|------|----------|
| **Ammonia**    |      |      |           |      |      |        |           |            |             |             |          |         |         |         |         |         |         |         |       |       |          |
|                | 0.363| 0.276| 0.015     | 0.123| 0.292| 0.402  | 0.049     | 0.026      | 0.443       | 0.353       | 0.145     | 0.250    | 0.128   | 0.284   | 0.487   | 0.418   | 0.488   | 0.449   | 0.037   | 0.092  |        |        |          |
| **Phosphate**  |      |      |           |      |      |        |           |            |             |             |          |         |         |         |         |         |         |         |       |       |          |
|                | -0.743| 0.326| 0.117     | 0.039| 0.549| -0.394 | -0.756    | -0.755     | -0.890*     | -0.832*     | -0.376   | -0.084  | -0.172 | -0.712 | -0.347  | 1       | -0.620  | -0.242  | -0.435  | -0.264  | -0.064  | -0.095  |        |        |          |
| **TotalP**     | -0.075| 0.296| 0.425     | 0.475| 0.169| 0.256  | 0.069     | 0.070      | 0.022       | 0.040       | 0.266    | 0.447   | 0.391   | 0.089   | 0.284   | 0.132   | 0.347   | 0.232   | 0.334   | 0.460   | 0.439   |        |        |          |
|                | -0.894*| 0.303| 0.402     | -0.229| 0.945**| -0.282 | -0.733    | -0.764     | -0.477      | -0.337      | 0.184    | 0.415   | 0.021   | -0.620 | 1       | 0.564   | -0.484  | 0.155   | 0.017   | 0.144   |        |        |          |
| **Salinity**   | 0.020| 0.310| 0.251     | 0.291| 0.355| 0.008  | 0.323     | 0.287      | -0.079      | 0.066       | 0.208    | 0.290   | 0.384   | 0.243   | 0.487   | 0.132   | 0.161   | 0.204   | 0.402   | -0.489  | 0.408   |        |        |          |
|                | -0.200| 0.262| 0.408     | 0.132| 0.339| 0.758  | 0.327     | -0.174     | -0.029      | 0.000       | -0.102   | 0.389   | 0.685   | 0.1 -315 | 0.330   | 0.106   | 0.000   |        |        |        |        |          |
|                | -0.376| 0.497| 0.370     | 0.123| 0.058| 0.351  | 0.044     | 0.024      | 0.267       | 0.455       | 0.125    | 0.063   | 0.268   | 0.058   | 0.237   | 0.449   | 0.334   | 0.402   | 0.294   | 0.433   | 0.500   |        |        |          |
| **DO**         | -0.253| 0.010| 0.494     | 0.071| 0.066| 0.434  | 0.267     | 0.432      | 0.455       | 0.125       | 0.063    | 0.268   | 0.058   | 0.237   | 0.449   | 0.334   | 0.402   | 0.294   | 0.101   | 0.362   | 0.266   |        |        |          |
|                | -0.226| 0.107| -0.786    | -0.236| 0.331| -0.110 | -0.660    | 0.645      | 0.246       | 0.267       | -0.345   | 0.903*  | 0.309   | 0.200   | 0.841*  | -0.644  | 0.017   | 0.106   | 0.376   | -0.218  | -0.960* | 1       |        |        |          |
|                | -0.357| 0.432| 0.057     | 0.351| 0.293 | 0.430   | 0.432     | 0.339      | 0.345       | 0.285      | 0.018    | 0.307   | 0.373   | 0.037   | 0.460   | 0.489   | 0.433   | 0.362   | 0.005   |        |        |          |
| **BOD**        | -0.319| 0.038| 0.749     | 0.070| -0.234| 0.281  | 0.551     | -0.469     | -0.453      | -0.189     | -0.244   | -0.871* | -0.109  | -0.065 | 0.705   | -0.095  | 0.144   | 0.000   | -0.621  | -0.377  | -0.960* | 1       |        |        |          |
|                | -0.300| 0.476| 0.073     | 0.455| 0.352| 0.323  | 0.168     | 0.213      | 0.222       | 0.380       | 0.346    | 0.431   | 0.458   | 0.092   | 0.439   | 0.408   | 0.500   | 0.132   | 0.266   | 0.005   |        |        |          |

*Correlation is significant at the 0.05 level (1-tailed).

**Correlation is significant at the 0.01 level (1-tailed).

C. Listwise N=5

* Correlation is significant at the 0.05 level (1-tailed).

** Correlation is significant at the 0.01 level (1-tailed).
# Statistical Assessment of Physico-chemical Parameters of Water from Bore Holes and Shallow Wells in Agateeswaram and Kalkulam Taluks of Kanyakumari District, India

| Parameter | Value 1 | Value 2 | Value 3 | Value 4 | Value 5 | Value 6 | Value 7 | Value 8 | Value 9 | Value 10 | Value 11 | Value 12 | Value 13 | Value 14 | Value 15 | Value 16 | Value 17 | Value 18 | Value 19 | Value 20 |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Alkalinity | .40    | .32    | -.68    | -.21    | .95    | .88    | .71    | .16    | .79    | .69    | .18    | .86    | .48    | .48    | .89    | .10    | .06    | .55    | .92    | .72    |
| Hardness  | .02    | .12    | .10    | .36    | .00    | .37    | .17    | .01    | .38    | .39    | .04    | .50    | .12    | .38    | .20    | .20    | .08    | .33    | .05    | .23    |
| Fluoride  | .19    | .32    | .09    | .14    | .18    | .19    | .18    | .16    | .01    | .01    | .37    | .18    | .16    | .39    | .17    | .16    | .16    | .01    | .45    | .43    |
| Chloride  | .49    | .88    | .46    | .61    | .93    | .32    | .38    | .21    | .34    | .28    | .35    | .38    | .35    | .41    | .29    | .10    | .35    | .16    | .16    | .01    |
| TotalN    | .73    | .38    | -.57    | .68    | .31    | .51    | .63    | .20    | .51    | .52    | .23    | .51    | .57    | .98    | .54    | .29    | .73    | .17    | .17    | .01    |
| Nitrate   | .30    | .23    | .18    | .10    | .01    | .12    | .13    | .36    | .18    | .18    | .34    | .32    | .18    | .16    | .16    | .01    | .17    | .17    | .17    | .01    |
| Sulphate  | .39    | .31    | .22    | .44    | .62    | .12    | .63    | .48    | .18    | .30    | .16    | .16    | .16    | .16    | .00    | .21    | .73    | .17    | .17    | .01    |
| Ammonia   | .36    | .31    | .22    | .44    | .62    | .12    | .63    | .48    | .18    | .30    | .16    | .16    | .16    | .16    | .00    | .21    | .73    | .17    | .17    | .01    |
| Phosphate | .72    | .21    | -.65    | .11    | .50    | .46    | .46    | .10    | .37    | .42    | .29    | .29    | .29    | .29    | .00    | .21    | .73    | .17    | .17    | .01    |
| TotalP    | .87    | .63    | -.57    | .68    | .31    | .51    | .63    | .20    | .51    | .52    | .23    | .51    | .57    | .98    | .54    | .29    | .73    | .17    | .17    | .01    |
| Salinity  | .89    | .71    | -.57    | .68    | .31    | .51    | .63    | .20    | .51    | .52    | .23    | .51    | .57    | .98    | .54    | .29    | .73    | .17    | .17    | .01    |
| DO        | .69    | .31    | .59    | .79    | .14    | .36    | .29    | .40    | .39    | .39    | .15    | .13    | .47    | .03    | .69    | .62    | .62    | .18    | .33    | .66    |
| BOD       | .09    | .07    | .14    | .03    | .41    | .39    | .39    | .15    | .42    | .21    | .48    | .48    | .07    | .12    | .12    | .12    | .12    | .12    | .12    | .12    |
| OXREDP    | .64    | .07    | .46    | .33    | .70    | .50    | .88    | .79    | .17    | .43    | .72    | .19    | .08    | .29    | .40    | .40    | .15    | .65    | .62    | .45    |

*Correlation is significant at the 0.05 level (1-tailed).
**Correlation is significant at the 0.01 level (1-tailed).
c. Listwise N=5
Table 11. Correlations status for the measured Physico-chemical parameters of water from shallow wells in Agateeswaram Taluk.

|       | Temp | pH  | Turbidity | EC   | TDS  | Sodium | Potassium | Alkalinity | Hardness Ca | Hardness Mg | Fluoride | Chloride | Total N | Nitrate | Sulphate | Ammonia | Phosphate | TotalP | Salinity | DO | BOD | OXREDPot |
|-------|------|-----|-----------|------|------|--------|-----------|------------|-------------|-------------|-----------|----------|---------|--------|---------|---------|----------|--------|---------|----|-----|---------|
| Temp  |      | .058| .000      | .110 | .000 | .128   | .134      | .888       | -.097       | -.089       | .000      | .143    | .590    | .250   | .159    | -.375   | -.395    | .102   | .807    | -.368 | .323 | -.311   |
| pH    | .463 | .500 | .430      | .500 | .419 | .415   | .022      | .438       | .443        | .500        | .409     | .148    | .343    | .399    | .267    | .255     | .435    | .049    | .271   | .298   | .305    |
| Turbidity | .058 | .975 | .237      | .390 | .474 | .124   | -.095     | .531       | -.394       | .919        | -.531    | .548    | .523    | .951    | -.494   | -.368    | .807    | .322    | -.627  | .400   | .768    |
| EC    | .463 | .002 | .351      | .258 | .210 | .421   | .439      | .179       | .256        | .014        | .179     | .169    | .183    | .006    | .199    | .271     | .049    | .299    | .129   | .252   | .065    |
| TDS   | .009 | .975 | .236      | .577 | .572 | .058   | .036      | .376       | -.575       | .816        | -.553    | .381    | .323    | .892    | -.484   | -.510    | .659    | .208    | -.633  | .194   | .711    |
| Sodium| .128 | .474 | .512      | .811 | .683 | .019   | .218      | -.457      | -.692       | .218        | -.264    | -.157   | .212    | -.867   | .826    | .068     | -.223   | .031    | -.377  | .490    | .466    |
| Potassium | .419 | .210 | .157      | .048 | .102 | .488   | .362      | .219       | .098        | .362        | .401    | .388    | .366    | .029    | .043     | .457    | .359    | .480    | .260   | .201    | .466    |
| Alkalinity | .134 | .124 | .058      | .545 | .697 | .019   | .292      | .355       | .683        | .423        | .513    | .473    | .757    | .104    | -.468    | .423    | .582    | .123    | .415   | .652    | .529    |
| Hardness Ca | .415 | .421 | .171      | .095 | .488 | .317   | .279      | .102       | .239        | .188        | .211    | .069    | .434    | .213    | .239     | .152    | .422    | .244    | .117   | .180    | .366    |
| Hardness Mg | .888 | -.095 | .053      | .002 | .336 | .218   | -.292     | 1          | -.425       | -.414       | -.302    | .225    | -.036   | .239    | -.626    | -.279   | .592    | -.377  | -.112  | -.549   | .169    |
| Fluoride | .907 | .531 | .376      | -.366 | -.434 | -.457 | .355      | -.425      | 1           | .441        | .768    | -.600   | .730    | .826    | .707    | .219     | .538    | .833    | .470   | -.470  | .857    | .437    |
| Chloride | .438 | .179 | .266      | .272 | .232 | .219   | .279      | .238       | .228        | .065        | .142    | .081    | .043    | .091    | .362     | .175    | .040    | .212   | .032   | .231    | .367    |
| Total N | .443 | .256 | .155      | .408 | .000 | .098   | .102      | .244       | .228        | .500        | .309    | .327    | .177    | .342    | .305     | .015    | .362    | .448   | .145   | .484    | .500    |
| Nitrate | .000 | .919 | .816      | .193 | .000 | .218   | .423      | -.302      | .768        | .000        | .651    | .791    | .924    | -.395   | .000     | .968    | .365    | -.485  | -.680  | .833    | .197    |
| Sulphate | .500 | .014 | .046      | .378 | .500 | .362   | .239      | .310       | .065        | .500        | .223    | .094    | .056    | .012    | .255     | .500    | .003    | .273   | .204   | .103   | .040    | .049    | .345   | .327    | .539    | .776   | .583   | .619    |
Table 12. Correlations status for the measured Physico-chemical parameters of water from shallow wells in Kalkulam Taluk.

|          | Temp | pH    | Turbidity | EC    | TDS   | Sodium | Potassium | Alkalinity | Hardness Ca | Hardness Mg | Fluoride | Chloride | Total N | Nitrate | Sulphate | Ammonia | Phosphate | TotalP | Salinity | DO | BOD | OXREDPot |
|----------|------|-------|-----------|-------|-------|--------|-----------|------------|-------------|-------------|-----------|----------|---------|---------|----------|---------|-----------|--------|----------|----|------|----------|
| Temp     | 1    | -200  | 0.200     | 0.086 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| pH      |      | 0.200 | 1         | 0.086 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| Turbidity| 0.200| 1     | 0.086     | 0.068 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| EC      | 0.200| 1     | 0.086     | 0.068 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| TDS     | 0.200| 1     | 0.086     | 0.068 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| Sodium  | 0.200| 1     | 0.086     | 0.068 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |
| Potassium| 0.200| 1     | 0.086     | 0.068 | 0.068 | 0.227  | 0.055     | 0.289      | 0.357       | 0.475       | 0.375     | 0.315   | 0.490   | 0.356   | 0.457    | 0.125   | 0.200     | 0.086  | 0.142    | 0.373 | 0.387 | 0.475    |

42 Statistical Assessment of Physico-chemical Parameters of Water from Bore Holes and Shallow Wells in Agateeswaram and Kalkulam Taluks of Kanyakumari District, India
| Property  | 0.085  | 0.471 | -0.562 | -0.363 | 0.533 | 0.849* | 1 | -0.252 | -0.455 | -0.499 | -0.781 | -0.349 | 0.873* | -0.213 | 0.162 | -0.143 | -0.597 | 0.667 | -0.288 | -0.292 | -0.056 |
|-----------|-------|-------|--------|--------|-------|--------|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Alkalinity |       |       |        |        |       |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Ca        | -0.058 | -0.963** | -0.251 | -0.789 | -0.240 | 0.062 | -0.252 | 1 | -0.592 | -0.814* | -0.356 | -0.212 | 0.000 | -0.203 | 0.730 | -0.470 | -0.420 | 0.015 | -0.452 | 0.200 | -0.881* |
| Mg        | -0.389 | -0.641 | -0.369 | -0.798 | 0.916* | 0.048 | -0.434 | -0.455 | -0.592 | 1 | -0.389 | 0.872* | 0.078 | -0.683 | -0.763 | -0.542 | -0.615 | 0.833* | -0.128 | -0.515 | 0.223 | -0.769 |
| Fluoride  | -0.375 | -0.217 | -0.802 | -0.145 | -0.466 | -0.088 | -0.138 | -0.499 | 0.814* | -0.389 | 1 | -0.228 | -0.395 | -0.191 | -0.196 | -0.716 | -0.505 | -0.145 | -0.124 | -0.570 | -0.495 |
| Chloride  | -0.267 | -0.363 | -0.051 | -0.408 | -0.226 | 0.444 | -0.412 | 0.196 | 0.047 | 0.259 | -0.487 | 0.356 | 0.255 | 0.379 | 0.376 | 0.087 | 0.468 | 0.408 | 0.421 | 0.158 | 0.199 |
| Nitrate   |       |       |        |        |       |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Sulphate  | -0.600 | 0.284 | 0.044 | 0.755 | -0.493 | 0.407 | 0.083 | -0.213 | -0.203 | 0.763 | -0.191 | 0.524 | -0.498 | -0.518 | 1 | -0.118 | 0.362 | 0.592 | 0.435 | 0.298 | 0.494 | 0.432 |
| Ammonia   | -0.142 | 0.321 | 0.472 | 0.070 | 0.199 | 0.248 | 0.444 | -0.365 | 0.372 | 0.067 | 0.379 | 0.183 | 0.197 | 0.186 | 0.425 | 0.274 | 0.147 | 0.232 | 0.139 | 0.234 |
| Phosphate | -0.539 | 0.269 | -0.681 | 0.595 | -0.806* | -0.301 | -0.266 | 0.162 | 0.730 | -0.542 | -0.196 | 0.625 | -0.090 | -0.465 | -0.118 | 1 | 0.050 | 0.768 | 0.196 | 0.909* | -0.334 | 0.905* |
| TotalP    | -0.174 | 0.331 | 0.103 | 0.145 | 0.050 | 0.311 | 0.332 | 0.397 | 0.081 | 0.173 | 0.376 | 0.130 | 0.443 | 0.215 | 0.425 | 0.468 | 0.065 | 0.376 | 0.016 | 0.292 | 0.217 |
| Salinity  |       |       |        |        |       |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| DO        | 0.100 | 0.657 | 0.242 | 0.955* | 0.851* | 0.202 | -0.444 | -0.597 | -0.420 | 0.833* | 0.050 | 0.931* | -0.073 | -0.889* | 0.592 | -0.768 | 0.108 | 1 | -0.173 | 0.864* | 0.610 | 0.781 |
| BOD       | -0.436 | 0.114 | 0.348 | 0.006 | 0.034 | 0.372 | 0.227 | 0.144 | 0.241 | -0.040 | 0.468 | -0.011 | 0.453 | -0.022 | 0.147 | 0.065 | 0.432 | -0.390 | 0.029 | 0.137 | 0.059 |
| OXREDPot  | 0.398 | 0.086 | 0.429 | 0.471 | 0.332 | 0.030 | 0.011 | 0.109 | 0.490 | 0.419 | 0.408 | 0.225 | 0.017 | 0.284 | 0.232 | 0.376 | 0.325 | 0.390 | 0.490 | -0.264 | 0.500 |
| Others    | 0.538 | 0.293 | 0.398 | 0.792 | 0.683 | 0.471 | -0.160 | -0.288 | -0.452 | 0.515 | 0.124 | 0.658 | -0.227 | -0.654 | 0.298 | -0.990* | -0.293 | 0.864* | -0.016 | 1 | 0.695 | 0.791 |
|           | 0.512 | 0.175 | 0.316 | 0.253 | 0.055 | 0.102 | 0.212 | 0.399 | 0.310 | 0.322 | 0.213 | 0.418 | -0.078 | 0.115 | 0.313 | 0.016 | 0.316 | 0.029 | 0.490 | 0.097 | 0.055 |
|           | -0.324 | 0.420 | 0.358 | 0.070 | 0.406 | 0.133 | 0.387 | 0.317 | 0.374 | 0.359 | 0.158 | 0.272 | 0.083 | 0.129 | 0.199 | 0.292 | 0.151 | 0.137 | 0.264 | 0.097 | 0.342 |
|           | -0.165 | 0.242 | 0.793 | 0.658 | 0.924* | -0.382 | -0.159 | -0.056 | -0.881* | -0.769 | 0.495 | 0.655 | 0.000 | -0.417 | 0.432 | -0.905* | 0.265 | 0.781 | 0.000 | 0.791 | 0.251 |
|           |       | 0.396 | 0.347 | 0.055 | 0.113 | 0.012 | 0.263 | 0.399 | 0.464 | 0.024 | 0.064 | 0.199 | 0.115 | 0.500 | 0.242 | 0.234 | 0.017 | 0.333 | 0.059 | 0.500 | 0.055 | 0.342 |
Cluster analysis (CA) was used for multivariate modeling of the input data\cite{16}. The main goal of the Hierarchical Agglomerative cluster analysis is to spontaneously classify data into groups of similarity (cluster) searching objects in the n-dimensional space located in closest neighbourhood and to separate a stable cluster from other clusters.

In figure 26, the hierarchical dendrogram for the clustering of determined physical and chemical parameters for all the studied stations is plotted (Ward’s method of linkage, squared Euclidean distance as similarity measure, standardization of the input data). For clustering altogether 22 physical and chemical parameters were chosen (indicated in Table 1). It could be concluded that the one big cluster and three small clusters are formed. Additionally sub clusters are also formed.

Cluster 1 (fifteen parameters are included)
- Fluoride, Phosphate, Nitrate, Total N, hardness Mg, pH, turbidity, sulphate, DO, BOD, Total N, Ammonia, Sodium, Potassium, temperature.
- Sub cluster 1: DO, Hardness Ca
- Sub cluster 2: Sodium, alkalinity

Cluster 2 (three parameters are included): TDS, hardness Ca, Salinity
- Sub cluster 2: Sodium, alkalinity

Cluster 3 (two parameters are included): Alkalinity, Chloride
- Sub cluster 3: EC, Hardness Ca

Cluster 4 (two parameters are included): EC and OXREDPOt

In figure 27, the hierarchical dendrogram for the clustering of determined physical and chemical parameters for all the studied stations is plotted (Ward’s method of linkage, squared Euclidean distance as similarity measure, standardization of the input data). For clustering altogether 22 physical and chemical parameters were chosen (indicated in Table 3). It could be concluded that the one big cluster and two small clusters are formed. Additionally sub clusters are also formed.

Cluster 1 (Eighteen parameters are included)
- Sulphate, Ammonia, DO, pH, turbidity, Total N, BOD, Fluoride, Total P, Nitrate, Phosphate, hardness Mg, Sodium, Potassium, temperature, TDS, Salinity, hardness Ca.
- Sub cluster 1: Sodium, alkalinity

Cluster 2 (two parameters are included): Alkalinity, chloride
- Sub cluster 2: EC, TDS
Cluster 3 (two parameters are included): EC, OXREDPot.

In figure 28, the hierarchical dendrogram for the clustering of determined physical and chemical parameters for all the studied stations is plotted (Ward’s method of linkage, squared Euclidean distance assimilarity measure, standardization of the input data). For clustering altogether 22 physical and chemical parameters were chosen (indicated in Table 5). It could be concluded that the one big cluster and three small clusters are formed. Additionally sub clusters are also formed. Cluster 1 (fourteen parameters are included)

Fluoride, Total P, Nitrate, Phosphate, hardness Mg, Sodium, Potassium, pH, DO, turbidity, Ammonia, Sulphate, BOD, Total N.

Sub cluster 1: Hardness Mg, temperature

Cluster 2 (four parameters are included): TDS, Salinity, Temperature, hardness Ca

Sub cluster 2: Ammonia, alkalinity

Cluster 3 (two parameters are included): Alkalinity, Chloride,

Sub cluster 3: EC, TDS

Cluster 4 (two parameters are included): EC, OXREDPot

In figure 29, the hierarchical dendrogram for the clustering of determined physical and chemical parameters for all the studied stations is plotted (Ward’s method of linkage, squared Euclidean distance assimilarity measure, standardization of the input data). For clustering altogether 22 physical and chemical parameters were chosen (indicated in Table 7). It could be concluded that the one big cluster and three small clusters are formed. Additionally sub clusters are also formed.

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**Figure 27.** Dendrogram for Physico-chemical parameters of bore hole water of Kalkulam Taluk.
Figure 28. Dendrogram for physico-chemical parameters of shallow hole water of Agateeswaram Taluk.

Figure 29. Dendrogram for physico-chemical parameters of shallow hole water of Kalkulam Taluk.
3. Conclusions

The physio-chemical analysis of borewell water samples from five different stations in Agasteeswaram and Kalkulam Taluk, shallow well water samples from five different stations in Agasteeswaram and Kalkulam Taluk were carried out. Also the statistical assessment is also carried out for the Physico-chemical parameter. Most of the parameters are well within the permissible limits. It is concluded that from the results of the present study, it may be said that the borewell water from both Taluks and shallow well water from both Taluks fits for domestic purpose. Statistical analysis results showed that the CA technique is useful in classification of water samples in the study region and the number of parameters.

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REFERENCES

[1] M.K.Gupta, Anjani Gupta, G.S.Gupta, Rajesh and Dubey, “Bio- Chemical, Physical and statistical analysis of hand pump’s water quality in Banida, Uttar Pradesh”, International Journal of Innovative research in Science, Engineering and technology, Vol. 3, No.3, 10220-10229, 2014.

[2] B.Vyankataesh, Yannawar, Arjun B.Bhosle, Praveen R.Shaikh and Sureka R.Gaikwad,”Water quality of hot water unkeshwar spring of Maharasthra, India”, International Journal of Innovation and Applied Studies, Vol. 3, No.2, 541-551, 2013.

[3] A.Papaioannou, K.Kavavas,P.Plageras, A.Minas, Z.Roupa, A.G.Paliatsos, P.T Nastos and A.Minas, “Ground water quality and location of productive activities in the region of Thessaly,Greece,” Desalination, Vol. 213, 209-217, 2007.

[4] M. Ramesh and K.Elam Valuthi, water quality parameter of ground water samplesin Tamilnadu, Kerala and Pondicherry, Der Chemica Sinica, Vol. 3, No5, 1272-1275, 2012.

[5] G.V.ShylaSree and B.Indirani, “Physico-Chemical parameters of ground water and pond water samples in and around Nagarecoil town, Kanyakumari District”. Journal of Chemical and Pharmaceutical research, Vol. 5, No.2, 202-207, 2013.

[6] K.Mophin Kani and A.G.Murugesan, “Evaluation and classification of water quality of Perennial River Tamirabarani through Aggregation of water quality index”. International journal of environmental protection, Vol. 1, No.2, 24-33, 2011.

[7] Agelos Papaioannou, Eleni Devriki and Nikolaos Rigas,” Assessment and modeling of ground water quality data by Environmetric methods in the context of public health”, Water resource management, Vol. 10, 965-9626, 2010.

[8] P.D.SreeDevi, “Ground water quality of Pageru river basic Cuddapah District, Andrapradesh”, Journal of Geological society of India, Vol. 64, No.5, 619-636, 2004.

[9] N.Subbha Rao and D.John Devadas, “Quality criteria for ground water use for development of an area”, J.Appl. GeoChem, Vol. 7, No.1, 9-23, 2005.

[10] S.Srinivas Gowd, “Assessment of ground water quality for drinking and irrigation purposes. A case study of Peddavanka water shed, Anantapur district, Andrapradesh, India.” Environ.Geol, Vol. 48, 702-712, 2005.

[11] Indrani Gupta, Shivani Dhage and Rakesh Kumar, “Study of variations in water quality of Mumbai coast through multivariate analysis technique”, Indian journal of Marine Sciences, Vol. 38,No.2, 170-177, 2009.

[12] A.Blachandran, “District ground water Brochure, Kanyakumari District, Tamilnadu”, Technical Report series, September 2008.

[13] American Public Health Association (APHA) 1998. Standard methods for the Examinations of water and waste water, 17th Edn; Washington, DC

[14] WHO, 1984. Guideline for drinking water quality Geneva.

[15] ISI, 1964. Indian standard specification for drinking water ISI 10500.

[16] D. L. Masart and L. Kauman L. “ The interpretation of chemical Data by the use of Cluster Analysis”, J.Wiley, New York.