# DESIGN OF SMALL SCALE WASTE WATER (GREY WATER) TREATMENT PLANT

**A Thesis submitted to the**

**Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH**
**DAPOLI - 415 712**
**Maharashtra State (India)**

**In the partial fulfillment of the requirements for the degree of**

**MASTER OF TECHNOLOGY**
**(AGRICULTURAL ENGINEERING)**

**in**

**IRRIGATION AND DRAINAGE ENGINEERING**

**by**

**MS. JUVEKAR PRANATI RAMESH**
**B. Tech (Agril. Engg.)**

**DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING,**
**COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY**
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**DAPOLI- 415 712, DIST. RATNAGIRI, M. S. (INDIA).**

**SEPTEMBER, 2015**

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**Approved by the advisory committee**


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# CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted

by me or any other person to any other

University or Institute

for a Degree or

Diploma.

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**Date: / /2015** (Regd. No. ENDPM-74/2013)

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This is to certify that the thesis entitled "**Design of small scale waste water (grey water) treatment plant**", submitted to Faculty of Agricultural Engineering, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) in partial fulfillment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in **Irrigation and Drainage Engineering**, embodies the record of a piece of bonafied research work carried out by **Ms. Pranati Ramesh Juvekar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree, diploma or publication in any other form.

The assistance and help received during the course of this investigation and source of the literature have been duly acknowledged.

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The assistance and help received during the course of this investigation and source of the literature have been duly acknowledged.

**Place :** Dapoli

**Date:** / / 2015 **(U. S. Kadam)**

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**Place:** Dapoli

**Date:** / / 2015 **(N. J. Thakor)**

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**Place : Dapoli** **Date**

**: / /2015** **(Pranati Ramesh Juvekar)**

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# LIST OF SYMBOLS

| Symbols | Description |
|---|---|
| % | Per cent |
| @ | About |
| = | Equal to |
| + | Plus |
| - | Minus |
| * | Multiplication |
| / | Division |
| < | Less than |
| > | Greater than |
| Q | Discharge |

# LIST OF ABBREVIATIONS

| **Abbreviations** | **Meanings** |
|---|---|
| Agril. | Agricultural |
| Agril. Engg. | Agricultural Engineering |
| CAET | College of Agricultural Engineering and Technology |
| CD | Critical difference |
| Cm | Centimeter |
| Dr.BSKKV | Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth |
| Dept. | Department |
| $^{0}C$ | Degree Celsius |
| $^{0}$ | Degree |
| D.F. | Degrees of freedom |
| EC | Electrical Conductivity |
| dS/m | Deci - Sieman per meter |
| et al. | And others |
| etc. | Etcetera |
| FAO | Food and Agriculture Organization |
| Fig | Figure |
| g or gm | Gram |
| SE | Standard Error |
| Ha | Hectare |
| Hr | Hour |
| i.e. | That is |
| K | Potassium |
| Ltd. | Limited |
| Lit | Liter |
| Lph | Liter per hour |
| Mha | Million hectare |
| Mha-m | Million hectare meter |
| MT | Metric tones |
| $MT.ha^{-1}$ | Metric tons per hectare |
| $mm.ha^{-1}$ | Millimeter per hectare |

| | |
|---|---|
| M | Meter |
| $m^2$ | Meter square |
| $mm.day^{-1}$ | Millimeter per day |
| Mg | Milligram |
| Mm | Millimeter |
| min. | Minute |
| M.S. | Maharashtra State |
| M.Tech. | Master of Technology |
| N | Nitrogen |
| Mg | Magnesium |
| Ca | Calcium |
| TDS | Total Dissolved Solids |
| Na | Sodium |
| SAR | Sodium Adsorption Ratio |
| RSC | Residual Sodium Carbonate |
| No. or Nos. | Number or Numbers |
| COD | Chemical Oxygen Demand |
| BOD | Biological Oxygen Demand |
| E coli | Escherichia coli |
| GW | Grey Water |
| GWS | Grey Water System |
| GWT | Grey Water Treatment |
| T- N | Total Nitrogen |
| DO | Dissolve Oxygen |
| NTU | Nephelometric Turbidity unit |
| Cu | Uniformity coefficient |
| HLR | Hydraulic Loading Rate |
| HRT | Hydraulic Retention Time |
| OLR | Organic Loading Rate |
| O&G | Oil and Grease |
| ppm | Parts per million units |

# *ABSTRACT*

## "Design of small scale waste water (grey water) treatment plant"

BY

**Pranati Ramesh Juvekar**

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Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
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**Research Guide : Prof. S. T. Patil**

**Department : Irrigation and Drainage Engineering**

India is facing a water crisis and by 2025 it is estimated that India's population will be suffering from severe water scarcity. There is a great challenge ahead to produce more food for increasing population using less water as agriculture sector has to release fresh water to meet the enhanced requirement of other sectors such as domestic and industrial. Contrarily, increasing urbanization is resulting in increased domestic waste water generation, which is mainly disposed as untreated. Currently, partially treated and untreated waste water is discharged into rivers or on lands causing various environmental problems. On the other hand, waste water would be beneficial in case it is scientifically used for irrigation as it can act as an important source of water and nutrient (Pescod, 1992).

The present investigation was carried out on the grey water of Jayaprabha girl's hostel of DBSKKV, Dapoli. The capacity of Jayaprabha girl's hostel is 350 girl's in 150 rooms in two wings. The average daily consumption of water is around 10,000 liter per day for each wing. The grey water is carried through pipe drain up to disposal of natural drain. The elevation difference from Jayaprabha hostel and natural drain is 1.5m and length of pipe drain is 110 m, respectively. The present investigation was undertaken with view to study physical and chemical parameters of domestic grey water and to design small scale waste water treatment plant for Jayaprabha girl's hostel of Dr. BSKKV, Dapoli. The treated water can be used for irrigating horticultural crops as well as gardens. The grey water generated from bathrooms, basins and kitchen of the Jayaprabha hostel were analyzed by using different media during December to February, 2015.

Grey water sample filtered through individual filtration media which were easily available such as gravel, grit, sand and broken brick at the depth of 45cm, 30cm and 15 cm respectively. These results were analyzed for individual filtration media at the depth of 45cm, 30cm, and 15cm for selection of media and its efficient depth. After selection of efficient depth of layers installed small scale filtration unit. This grey water treatment plant is a combination of natural and physical operations. All the natural and easily available low cost materials were used for the treatment process. After that analyzed physical and chemical properties of treated grey water for combination of filtration media, along with charcoal, water quality was decided.

The physical and chemical properties of untreated and treated water were determined. Under physical properties, temperature, color, turbidity and odour were studied. The effect of media and depth on various chemical properties as pH, EC, TDS, potassium, calcium, carbonates and bicarbonates, magnesium, nitrogen, sodium, SAR, RSC, oil and grease, BOD and COD were fund out. The results of analysis were used for design of small scale waste water treatment plant.

The small scale grey water filtration model was designed by using engineering parameters as porosity (ɳ), voids ratio (e), dry bulk density ($\varrho_b$) and wet bulk density ($\varrho_w$), hydraulic conductivity and interstitial velocity ($V_a$). The media used were sand (0.42 mm), grit (6-8mm), gravel (15-25 mm), broken brick (25-30 mm) and charcoal (12-16 mm). As sand had fine particle size among all media. The particle size was decided on effective size $d_{10}$ i.e. 0.42 mm and uniformity coefficient ($C_u$) 2.2 for uniform filtration. The porosity of sand, grit, gravel, broken brick and charcoal were 39, 37, 32, 31 and 38 per cent respectively. The depth of the media were determined by filtering grey water through selected media at 15, 30 and 45 cm and its effect on physical and chemical properties of grey water were determined. The most effective combination of media found were 45 cm sand, 45 cm grit, 15 cm gravel, 30 cm broken brick and 30 cm charcoal respectively. The designed model was tested by gradient 0.83m. The estimated interstitial velocity of flow through combination of media considering particularly for sand was 9.7 m.day$^{-1}$. The capacity of designed model was 0.022 m$^3$.day$^{-1}$ for filtration area of 6.35×10$^{-3}$ m$^2$ and 1.8 m depth of media. The depth sequence and particle size of media will be constant for design of higher capacity filter. The only surface area will increase or decrease according to capacity.

This filtration unit or model showed the better and effective performance by the experiment and balances the advantages and disadvantages of the system. As per the

Indian Standards, the treated water can use for landscaping, gardening and irrigation on horticultural crops.

# VII. APPENDICES

## Appendix-I

**Statistical analysis of pH**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 6.62 | 6.22 | 6.18 | 19.02 | |
| **$M_1D_2$** | 6.5 | 6.15 | 6.13 | 18.78 | |
| **$M_1D_3$** | 6.21 | 6.1 | 6.09 | 18.4 | |
| **$M_2D_1$** | 6.79 | 6.46 | 6.34 | 19.59 | |
| **$M_2D_2$** | 6.67 | 6.35 | 6.29 | 19.31 | |
| **$M_2D_3$** | 6.45 | 6.3 | 6.2 | 18.95 | |
| **$M_3D_1$** | 7.54 | 6.74 | 7.5 | 21.78 | |
| **$M_3D_2$** | 7.36 | 6.67 | 7.45 | 21.48 | |
| **$M_3D_3$** | 7.2 | 6.6 | 7.43 | 21.23 | |
| **$M_4D_1$** | 6.56 | 6.48 | 6.5 | 19.54 | |
| **$M_4D_2$** | 6.49 | 6 | 6.43 | 18.92 | |
| **$M_4D_3$** | 6.38 | 5.89 | 6.35 | 18.62 | |
| **Inlet** | 6.56 | 6.76 | 6.15 | 19.47 | |
| **Total1** | 87.33 | 82.72 | 85.04 | 255.09 | |
| **Total2** | 80.77 | 75.96 | 78.89 | 235.62 | |
| **cf1 =** | 1668.48 | **TSS1 =** | 7.17 | **ESS1 =** | 1.25 |
| **cf2=** | 1542.13 | **TSs2 =** | 6.97 | **ESS2=** | 0.89 |
| **TrSS1 =** | 5.11 | **RSS 1=** | 0.81 | | |
| **TrSS2 =** | 5.10 | **RSS 2=** | 0.97 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 19.02 | 19.59 | 21.78 | 19.54 | 79.93 |
| **D2** | 18.78 | 19.31 | 21.48 | 18.92 | 78.49 |
| **D3** | 18.4 | 18.95 | 21.23 | 18.62 | 77.2 |
| **Total** | 56.2 | 57.85 | 64.49 | 57.08 | 235.62 |
| **DSS =** | 0.31 | **MSS =** | 4.77 | **Int SS =** | 0.02 |

**ANOVA**

| SV | Df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.97 | 0.48 | | |
| M | 3 | 4.77 | 1.59 | 39.17 | **Sig** |
| D | 2 | 0.31 | 0.15 | 3.82 | **Sig** |
| MXD | 6 | 0.02 | 0.003 | 0.083 | **NS** |
| Error | 22 | 0.89 | 0.040 | | |
| Total | 35 | 6.97 | | | |

# Appendix-II

**Statistical analysis of Electrical Conductivity (EC), µS/cm or micromhos/cm**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 109 | 120.5 | 34.56 | 264.06 | |
| **$M_1D_2$** | 135 | 122.2 | 110 | 367.2 | |

| | | | | | |
|---|---|---|---|---|---|
| **$M_1D_3$** | 229.4 | 135 | 130 | 494.4 | |
| **$M_2D_1$** | 33.5 | 33.8 | 48 | 115.3 | |
| **$M_2D_2$** | 129.5 | 110.5 | 149.6 | 389.6 | |
| **$M_2D_3$** | 185 | 127.7 | 187 | 499.7 | |
| **$M_3D_1$** | 107.5 | 136 | 211.5 | 455 | |
| **$M_3D_2$** | 131.4 | 136.5 | 230 | 497.9 | |
| **$M_3D_3$** | 220.7 | 185.4 | 312.3 | 718.4 | |
| **$M_4D_1$** | 78.4 | 100.5 | 119.6 | 298.5 | |
| **$M_4D_2$** | 123.2 | 102.6 | 125 | 350.8 | |
| **$M_4D_3$** | 206.6 | 108.3 | 130 | 444.9 | |
| **Inlet** | 323.1 | 268.6 | 302.7 | 894.4 | |
| **Total1** | 2012.3 | 1687.6 | 2090.26 | 5790.16 | |
| **Total2** | 1689.2 | 1419 | 1787.56 | 4895.76 | |
| **cf1 =** | 859639.8 | **TSS1 =** | 197949.59 | **ESS1 =** | 35621.11 |
| **cf2=** | 665790.7 | **TSs2 =** | 123631.8 | **ESS2=** | 35051.21 |
| **TrSS1 =** | 155312 | **RSS 1=** | 7016.48 | | |
| **TrSS2 =** | 82510.64 | **RSS 2=** | 6069.98 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 264.06 | 115.3 | 455 | 298.5 | 1132.86 |
| **D2** | 367.2 | 389.6 | 497.9 | 350.8 | 1605.5 |
| **D3** | 494.4 | 499.7 | 718.4 | 444.9 | 2157.4 |
| **Total** | 1125.66 | 1004.6 | 1671.3 | 1094.2 | 4895.76 |
| **DSS =** | 43824.01 | **MSS =** | 30525.82 | **Int SS =** | 8160.81 |

**ANOVA**

| SV | df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 6069.97 | 3034.98 | | |
| M | 3 | 30525.82 | 10175.27 | 6.38 | **Sig** |
| D | 2 | 43824.01 | 21912 | 13.75 | **Sig** |
| MXD | 6 | 8160.80 | 1360.13 | 0.85 | **NS** |
| Error | 22 | 35051.21 | 1593.24 | | |
| Total | 35 | 123631.83 | | | |

# Appendix-III

**Statistical analysis of Total Dissolved Solids (TDS), mg/l**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 69.76 | 78.20 | 22.11 | 170.07 | |
| **$M_1D_2$** | 86.4 | 77.12 | 70.4 | 233.92 | |
| **$M_1D_3$** | 146.82 | 86.4 | 83.2 | 316.42 | |
| **$M_2D_1$** | 21.44 | 21.63 | 30.72 | 73.79 | |
| **$M_2D_2$** | 82.88 | 70.12 | 95.74 | 248.74 | |

| | | | | | |
|---|---|---|---|---|---|
| **$M_2D_3$** | 118.4 | 78.5 | 119.68 | 316.58 | |
| **$M_3D_1$** | 84.09 | 87.04 | 135.36 | 306.49 | |
| **$M_3D_2$** | 107.2 | 105.92 | 147.2 | 360.32 | |
| **$M_3D_3$** | 140.8 | 118.56 | 199.87 | 459.23 | |
| **$M_4D_1$** | 50.17 | 64.32 | 76.54 | 191.03 | |
| **$M_4D_2$** | 78.85 | 65.66 | 80 | 224.51 | |
| **$M_4D_3$** | 132.24 | 69.31 | 83.2 | 284.75 | |
| **Inlet** | 206.78 | 171.90 | 193.72 | 572.41 | |
| **Total1** | 1325.84 | 1094.7 | 1337.75 | 3758.29 | |
| **Total2** | 1119.06 | 922.79 | 1144.02 | 3185.88 | |
| **cf1 =** | 362174.5 | **TSS1 =** | 80612.93 | **ESS1 =** | 12693.73 |
| **cf2=** | 281940.1 | **TSs2 =** | 51006.12 | **ESS2=** | 12514.12 |
| **TrSS1 =** | 65030.88 | **RSS 1=** | 2888.32 | | |
| **TrSS2 =** | 36045.19 | **RSS 2=** | 2446.81 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 170.07 | 73.79 | 306.49 | 191.03 | 741.40 |
| **D2** | 233.92 | 248.74 | 360.32 | 224.51 | 1067.49 |
| **D3** | 316.42 | 316.58 | 459.23 | 284.75 | 1376.98 |
| **Total** | 720.41 | 639.11 | 1126.04 | 700.30 | 3185.88 |
| **DSS =** | 16835.58 | **MSS =** | 16490.31 | **Int SS =** | 2719.30 |

**ANOVA**

| SV | df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 2446.81 | 1223.40 | | |
| M | 3 | 16490.31 | 5496.77 | 9.66 | **Sig** |
| D | 2 | 16835.58 | 8417.79 | 14.79 | **Sig** |
| MXD | 6 | 2719.30 | 453.21 | 0.79 | **NS** |
| Error | 22 | 12514.12 | 568.82 | | |
| Total | 35 | 51006.12 | | | |

# Appendix-IV

**Statistical analysis of Calcium (Ca), me/l**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 0.8 | 0.8 | 0.8 | 2.4 | |
| **$M_1D_2$** | 1 | 0.7 | 0.9 | 2.6 | |
| **$M_1D_3$** | 1 | 0.6 | 0.6 | 2.2 | |
| **$M_2D_1$** | 0.6 | 0.8 | 0.7 | 2.1 | |
| **$M_2D_2$** | 0.8 | 0.8 | 0.8 | 2.4 | |
| **$M_2D_3$** | 0.8 | 0.6 | 0.9 | 2.3 | |
| **$M_3D_1$** | 0.6 | 0.9 | 0.8 | 2.3 | |
| **$M_3D_2$** | 0.8 | 0.8 | 0.9 | 2.5 | |

| | | | | | |
|---|---|---|---|---|---|
| **$M_3D_3$** | 0.8 | 1 | 0.4 | 2.2 | |
| **$M_4D_1$** | 0.8 | 0.7 | 0.8 | 2.3 | |
| **$M_4D_2$** | 0.8 | 1 | 0.9 | 2.7 | |
| **$M_4D_3$** | 1.2 | 1.2 | 0.8 | 3.2 | |
| **Inlet** | 1.1 | 1.2 | 1 | 3.3 | |
| **Total1** | 11.1 | 11.1 | 10.3 | 32.5 | |
| **Total2** | 10 | 9.9 | 9.3 | 29.2 | |
| **cf1 =** | 27.08 | **TSS1 =** | 1.16 | **ESS1 =** | 0.58 |
| **cf2=** | 23.68 | **TSs2 =** | 0.91 | **ESS2=** | 0.56 |
| **TrSS1 =** | 0.55 | **RSS 1=** | 0.032 | | |
| **TrSS2 =** | 0.32 | **RSS 2=** | 0.02 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 2.4 | 2.1 | 2.3 | 2.3 | 9.1 |
| **D2** | 2.6 | 2.4 | 2.5 | 2.7 | 10.2 |
| **D3** | 2.2 | 2.3 | 2.2 | 3.2 | 9.9 |
| **Total** | 7.2 | 6.8 | 7 | 8.2 | 29.2 |
| **DSS =** | 0.05 | **MSS =** | 0.12 | **Int SS =** | 0.14 |

**ANOVA**

| **SV** | **df** | **SS** | **MSS** | **F cal** | **Result** |
|---|---|---|---|---|---|
| Rep | 2 | 0.02 | 0.01 | | |
| M | 3 | 0.12 | 0.042 | 1.66 | **NS** |
| D | 2 | 0.053 | 0.02 | 1.04 | **NS** |
| MXD | 6 | 0.13 | 0.023 | 0.89 | **NS** |
| Error | 22 | 0.56 | 0.025 | | |
| Total | 35 | 0.91 | | | |

# Appendix-V

**Statistical analysis of Bicarbonate ($HCO_3$), me/l**

| | **$R_1$** | **$R_2$** | **$R_3$** | **Total** | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 2.1 | 2 | 1.9 | 6 | |
| **$M_1D_2$** | 2.3 | 1.9 | 1.7 | 5.9 | |
| **$M_1D_3$** | 2.4 | 2.1 | 1.4 | 5.9 | |
| **$M_2D_1$** | 1.6 | 1.4 | 1.1 | 4.1 | |
| **$M_2D_2$** | 2.2 | 2.3 | 2.5 | 7 | |
| **$M_2D_3$** | 3.6 | 3.1 | 2.9 | 9.6 | |
| **$M_3D_1$** | 1.5 | 1.4 | 1.3 | 4.2 | |
| **$M_3D_2$** | 1.7 | 1.4 | 1.4 | 4.5 | |
| **$M_3D_3$** | 1.8 | 1.6 | 1.3 | 4.7 | |
| **$M_4D_1$** | 1.5 | 1.3 | 1.6 | 4.4 | |
| **$M_4D_2$** | 2.6 | 2.1 | 2.1 | 6.8 | |

| | | | | | |
|---|---|---|---|---|---|
| **$M_4D_3$** | 2.9 | 2.7 | 2.5 | 8.1 | |
| **Inlet** | 3.8 | 3.6 | 3.2 | 10.6 | |
| **Total1** | 30 | 26.9 | 24.9 | 81.8 | |
| **Total2** | 26.2 | 23.3 | 21.7 | 71.2 | |
| **cf1 =** | 171.57 | **TSS1 =** | 19.32 | **ESS1 =** | 0.84 |
| **cf2=** | 140.81 | **TSs2 =** | 12.44 | **ESS2=** | 0.79 |
| **TrSS1 =** | 17.47 | **RSS 1=** | 1.015 | | |
| **TrSS2 =** | 10.77 | **RSS 2=** | 0.86 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 6 | 4.1 | 4.2 | 4.4 | 18.7 |
| **D2** | 5.9 | 7 | 4.5 | 6.8 | 24.2 |
| **D3** | 5.9 | 9.6 | 4.7 | 8.1 | 28.3 |
| **Total** | 17.8 | 20.7 | 13.4 | 19.3 | 71.2 |
| **DSS =** | 3.86 | **MSS =** | 3.33 | **Int SS =** | 3.57 |

**ANOVA**

| SV | df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.86 | 0.43 | | |
| M | 3 | 3.33 | 1.11 | 30.59 | **Sig** |
| D | 2 | 3.86 | 1.93 | 53.21 | **Sig** |
| MXD | 6 | 3.57 | 0.59 | 16.38 | **Sig** |
| Error | 22 | 0.79 | 0.03 | | |
| Total | 35 | 12.44 | | | |

# Appendix-VI

**Statistical analysis of Potassium (K), mg/l**

| | **$R_1$** | **$R_2$** | **$R_3$** | **Total** | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 0.7 | 0.9 | 0.8 | 2.4 | |
| **$M_1D_2$** | 1 | 1.8 | 1.9 | 4.7 | |
| **$M_1D_3$** | 1.9 | 1.9 | 1.9 | 5.7 | |
| **$M_2D_1$** | 0.8 | 0.7 | 0.75 | 2.25 | |
| **$M_2D_2$** | 0.8 | 0.8 | 0.8 | 2.4 | |
| **$M_2D_3$** | 0.9 | 1 | 0.95 | 2.85 | |
| **$M_3D_1$** | 3.3 | 3.8 | 3.55 | 10.65 | |
| **$M_3D_2$** | 4.2 | 4 | 4.1 | 12.3 | |
| **$M_3D_3$** | 4.2 | 4.1 | 4.15 | 12.45 | |
| **$M_4D_1$** | 1 | 1.1 | 1.05 | 3.15 | |
| **$M_4D_2$** | 1.3 | 1.3 | 1.3 | 3.9 | |
| **$M_4D_3$** | 1.7 | 1.6 | 1.65 | 4.95 | |
| **Inlet** | 5 | 7.4 | 6.2 | 18.6 | |
| **Total1** | 26.8 | 30.4 | 29.1 | 86.3 | |

| | | | | | |
|---|---|---|---|---|---|
| **Total2** | 21.8 | 23 | 22.9 | 67.7 | |
| **cf1 =** | 190.96 | **TSS1 =** | 110.78 | **ESS1 =** | 3.04 |
| **cf2=** | 127.31 | **TSs2 =** | 56.24 | **ESS2=** | 0.60 |
| **TrSS1 =** | 107.23 | **RSS 1=** | 0.51 | | |
| **TrSS2 =** | 55.56 | **RSS 2=** | 0.07 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 2.4 | 2.25 | 10.65 | 3.15 | 18.45 |
| **D2** | 4.7 | 2.4 | 12.3 | 3.9 | 23.3 |
| **D3** | 5.7 | 2.85 | 12.45 | 4.95 | 25.95 |
| **Total** | 12.8 | 7.5 | 35.4 | 12 | 67.7 |
| **DSS =** | 2.41 | **MSS =** | 52.38 | **Int SS =** | 0.77 |

**ANOVA**

| **SV** | **Df** | **SS** | **MSS** | **F cal** | **Result** |
|---|---|---|---|---|---|
| Rep | 2 | 0.073 | 0.036 | | |
| M | 3 | 52.38 | 17.46 | 637.26 | **Sig** |
| D | 2 | 2.41 | 1.20 | 43.99 | **Sig** |
| MXD | 6 | 0.77 | 0.12 | 4.70 | **Sig** |
| Error | 22 | 0.60 | 0.027 | | |
| Total | 35 | 56.24 | | | |

## Appendix-VII

**Statistical analysis of Nitrogen (N), mg/l**

| | $R_1$ | $R_2$ | $R_3$ | **Total** | |
|---|---|---|---|---|---|
| $M_1D_1$ | 4.2 | 3.9 | 4.2 | 12.3 | |
| $M_1D_2$ | 2.8 | 2.2 | 2.6 | 7.6 | |
| $M_1D_3$ | 1.4 | 1.9 | 1.7 | 5 | |
| $M_2D_1$ | 2.8 | 2.8 | 2.1 | 7.7 | |
| $M_2D_2$ | 1.4 | 1.6 | 1.8 | 4.8 | |
| $M_2D_3$ | 2.8 | 2.1 | 2.3 | 7.2 | |
| $M_3D_1$ | 4.2 | 4.2 | 4.6 | 13 | |
| $M_3D_2$ | 1.4 | 1.7 | 1.4 | 4.5 | |
| $M_3D_3$ | 2.8 | 2.7 | 2.2 | 7.7 | |
| $M_4D_1$ | 3.9 | 4.1 | 3.7 | 11.7 | |
| $M_4D_2$ | 4.2 | 4.4 | 4.2 | 12.8 | |
| $M_4D_3$ | 4.1 | 4.3 | 3.8 | 12.2 | |
| **Inlet** | 8.4 | 7.3 | 6.9 | 22.6 | |
| **Total1** | 44.4 | 43.2 | 41.5 | 129.1 | |
| **Total2** | 36 | 35.9 | 34.6 | 106.5 | |
| **cf1 =** | 427.35 | **TSS1 =** | 101.19 | **ESS1 =** | 2.52 |
| **cf2=** | 315.06 | **TSs2 =** | 42.02 | **ESS2=** | 1.54 |

| | | | | | |
|---|---|---|---|---|---|
| **TrSS1 =** | 98.34 | **RSS 1=** | 0.32 | | |
| **TrSS2 =** | 40.38 | **RSS 2=** | 0.10 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 12.3 | 7.7 | 13 | 11.7 | 44.7 |
| **D2** | 7.6 | 4.8 | 4.5 | 12.8 | 29.7 |
| **D3** | 5 | 7.2 | 7.7 | 12.2 | 32.1 |
| **Total** | 24.9 | 19.7 | 25.2 | 36.7 | 106.5 |
| **DSS =** | 10.82 | **MSS =** | 17.16 | **Int SS =** | 12.39 |

**ANOVA**

| SV | df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.10 | 0.050 | | |
| M | 3 | 17.16 | 5.72 | 81.46 | **Sig** |
| D | 2 | 10.82 | 5.41 | 77.03 | **Sig** |
| MXD | 6 | 12.39 | 2.06 | 29.42 | **Sig** |
| Error | 22 | 1.54 | 0.07 | | |
| Total | 35 | 42.02 | | | |

# Appendix-VIII

**Statistical analysis of Magnesium (Mg), me/l**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| $M_1D_1$ | 0.35 | 0.1 | 0.25 | 0.7 | |
| $M_1D_2$ | 0.4 | 0.1 | 0.25 | 0.75 | |
| $M_1D_3$ | 0.4 | 0.05 | 0.25 | 0.7 | |
| $M_2D_1$ | 0.4 | 0.35 | 0.3 | 1.05 | |
| $M_2D_2$ | 0.4 | 0.4 | 0.5 | 1.3 | |
| $M_2D_3$ | 0.3 | 0.4 | 0.35 | 1.05 | |
| $M_3D_1$ | 0.6 | 0.15 | 0.3 | 1.05 | |
| $M_3D_2$ | 0.4 | 0.4 | 0.4 | 1.2 | |
| $M_3D_3$ | 0.4 | 0.1 | 0.2 | 0.7 | |
| $M_4D_1$ | 0.6 | 0.1 | 0.4 | 1.1 | |
| $M_4D_2$ | 0.8 | 0.4 | 0.5 | 1.7 | |
| $M_4D_3$ | 0.8 | 0.6 | 0.5 | 1.9 | |
| **Inlet** | 1.3 | 1.2 | 1.3 | 3.8 | |
| **Total1** | 7.15 | 4.35 | 5.5 | 17 | |
| **Total2** | 5.85 | 3.15 | 4.2 | 13.2 | |
| **cf1 =** | 7.41 | **TSS1 =** | 3.36 | **ESS1 =** | 0.26 |
| **cf2=** | 4.84 | **TSs2 =** | 1.12 | **ESS2=** | 0.25 |
| **TrSS1 =** | 2.79 | **RSS 1=** | 0.30 | | |
| **TrSS2 =** | 0.55 | **RSS 2=** | 0.30 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |

| | | | | | |
|---|---|---|---|---|---|
| **D1** | 0.7 | 1.05 | 1.05 | 1.1 | 3.9 |
| **D2** | 0.75 | 1.3 | 1.2 | 1.7 | 4.95 |
| **D3** | 0.7 | 1.05 | 0.7 | 1.9 | 4.35 |
| **Total** | 2.15 | 3.4 | 2.95 | 4.7 | 13.2 |
| **DSS =** | 0.046 | **MSS =** | 0.37 | **Int SS =** | 0.12 |

**ANOVA**

| SV | Df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.30 | 0.15 | | |
| M | 3 | 0.37 | 0.12 | 10.78 | **Sig** |
| D | 2 | 0.04 | 0.02 | 1.97 | **NS** |
| MXD | 6 | 0.12 | 0.021 | 1.81 | **NS** |
| Error | 22 | 0.25 | 0.011 | | |
| Total | 35 | 1.12 | | | |

# Appendix-IX

**Statistical analysis of Sodium (Na), me/l**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| $M_1D_1$ | 0.79 | 0.78 | 0.78 | 2.35 | |
| $M_1D_2$ | 0.79 | 0.78 | 0.76 | 2.33 | |
| $M_1D_3$ | 0.9 | 0.85 | 0.86 | 2.61 | |
| $M_2D_1$ | 0.44 | 0.45 | 0.49 | 1.38 | |
| $M_2D_2$ | 0.45 | 0.47 | 0.44 | 1.36 | |
| $M_2D_3$ | 0.79 | 0.77 | 0.72 | 2.28 | |
| $M_3D_1$ | 0.82 | 0.89 | 0.83 | 2.54 | |
| $M_3D_2$ | 0.79 | 0.79 | 0.77 | 2.35 | |
| $M_3D_3$ | 0.65 | 0.58 | 0.59 | 1.82 | |
| $M_4D_1$ | 0.26 | 0.37 | 0.28 | 0.91 | |
| $M_4D_2$ | 0.47 | 0.47 | 0.46 | 1.4 | |
| $M_4D_3$ | 0.56 | 0.58 | 0.52 | 1.66 | |
| **Inlet** | 1.41 | 1.45 | 1.48 | 4.34 | |
| **Total1** | 9.12 | 9.23 | 8.98 | 27.33 | |
| **Total2** | 7.71 | 7.78 | 7.5 | 22.99 | |
| **cf1 =** | 19.15 | **TSS1 =** | 2.99 | **ESS1 =** | 0.021 |
| **cf2=** | 14.68 | **TSs2 =** | 1.18 | **ESS2=** | 0.017 |
| **TrSS1 =** | 2.97 | **RSS 1=** | 0.002 | | |
| **TrSS2 =** | 1.16 | **RSS 2=** | 0.003 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 2.35 | 1.38 | 2.54 | 0.91 | 7.18 |
| **D2** | 2.33 | 1.36 | 2.35 | 1.4 | 7.44 |
| **D3** | 2.61 | 2.28 | 1.82 | 1.66 | 8.37 |

| | | | | | |
|---|---|---|---|---|---|
| **Total** | 7.29 | 5.02 | 6.71 | 3.97 | 22.99 |
| **DSS =** | 0.06 | **MSS =** | 0.77 | **Int SS =** | 0.32 |

**ANOVA**

| SV | df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.003 | 0.0017 | | |
| M | 3 | 0.78 | 0.25 | 322.69 | **Sig** |
| D | 2 | 0.06 | 0.03 | 40.63 | **Sig** |
| MXD | 6 | 0.32 | 0.05 | 67.39 | **Sig** |
| Error | 22 | 0.017 | 0.0008 | | |
| Total | 35 | 1.18 | | | |

# Appendix-X

**Statistical analysis of Sodium Adsorption Ratio (SAR)**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| $M_1D_1$ | 1.04 | 1.16 | 1.07 | 3.27 | |
| $M_1D_2$ | 0.94 | 1.23 | 1 | 3.17 | |
| $M_1D_3$ | 1.07 | 0.79 | 1.3 | 3.16 | |
| $M_2D_1$ | 0.67 | 0.68 | 0.69 | 2.04 | |
| $M_2D_2$ | 0.61 | 0.6 | 0.54 | 1.75 | |
| $M_2D_3$ | 1.06 | 1.08 | 0.91 | 3.05 | |
| $M_3D_1$ | 1.05 | 1.01 | 1.1 | 3.16 | |
| $M_3D_2$ | 1.01 | 1 | 0.95 | 2.96 | |
| $M_3D_3$ | 0.83 | 0.78 | 1.07 | 2.68 | |
| $M_4D_1$ | 0.31 | 0.58 | 0.36 | 1.25 | |
| $M_4D_2$ | 0.52 | 0.56 | 0.54 | 1.62 | |
| $M_4D_3$ | 0.56 | 0.63 | 0.64 | 1.83 | |
| **Inlet** | 1.23 | 1.33 | 1.38 | 3.94 | |
| **Total1** | 10.9 | 11.43 | 11.55 | 33.88 | |
| **Total2** | 9.67 | 10.1 | 10.17 | 29.94 | |
| **cf1 =** | 29.43 | **TSS1 =** | 2.96 | **ESS1 =** | 0.29 |
| **cf2=** | 24.90 | **TSS2 =** | 2.31 | **ESS2=** | 0.29 |
| **TrSS1 =** | 2.64 | **RSS 1=** | 0.018 | | |
| **TrSS2 =** | 2.006 | **RSS 2=** | 0.012 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 3.27 | 2.04 | 3.16 | 1.25 | 9.72 |
| **D2** | 3.17 | 1.75 | 2.96 | 1.62 | 9.5 |
| **D3** | 3.16 | 3.05 | 2.68 | 1.83 | 10.72 |
| **Total** | 9.6 | 6.84 | 8.8 | 4.7 | 29.94 |
| **DSS =** | 0.070 | **MSS =** | 1.59 | **Int SS =** | 0.33 |

**ANOVA**

| SV | Df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.01 | 0.006 | | |
| M | 3 | 1.59 | 0.53 | 39.93 | **Sig** |
| D | 2 | 0.07 | 0.035 | 2.64 | **NS** |
| MXD | 6 | 0.33 | 0.056 | 4.23 | **Sig** |
| Error | 22 | 0.29 | 0.013 | | |
| Total | 35 | 2.31 | | | |

# Appendix-XI

**Statistical analysis of Residual Sodium Carbonate (RSC), me/l**

| | $R_1$ | $R_2$ | $R_3$ | Total | |
|---|---|---|---|---|---|
| **$M_1D_1$** | 0.95 | 1.1 | 0.85 | 2.9 | |
| **$M_1D_2$** | 0.9 | 1.1 | 0.55 | 2.55 | |
| **$M_1D_3$** | 1 | 1.45 | 0.55 | 3 | |
| **$M_2D_1$** | 0.6 | 0.25 | 0.1 | 0.95 | |
| **$M_2D_2$** | 1 | 1.1 | 1.2 | 3.3 | |
| **$M_2D_3$** | 2.5 | 2.1 | 1.65 | 6.25 | |
| **$M_3D_1$** | 0.3 | 0.35 | 0.2 | 0.85 | |
| **$M_3D_2$** | 0.5 | 0.2 | 0.6 | 1.3 | |
| **$M_3D_3$** | 0.6 | 0.5 | 0.7 | 1.8 | |
| **$M_4D_1$** | 0.1 | 0.5 | 0.4 | 1 | |
| **$M_4D_2$** | 1 | 0.7 | 0.7 | 2.4 | |
| **$M_4D_3$** | 0.9 | 1 | 1.2 | 3.1 | |
| **Inlet** | 1.4 | **1.4** | 1.6 | 4.4 | |
| **Total1** | 11.75 | 11.75 | 10.3 | 33.8 | |
| **Total2** | 10.35 | 10.35 | 8.7 | 29.4 | |
| **cf1 =** | 29.29 | **TSS1 =** | 10.86 | **ESS1 =** | 1.34 |
| **cf2=** | 24.01 | **TSs2 =** | 9.67 | **ESS2=** | 1.26 |
| **TrSS1 =** | 9.42 | **RSS 1=** | 0.10 | | |
| **TrSS2 =** | 8.25 | **RSS 2=** | 0.15 | | |
| | **M1** | **M2** | **M3** | **M4** | **Total** |
| **D1** | 2.9 | 0.95 | 0.85 | 1 | 5.7 |
| **D2** | 2.55 | 3.3 | 1.3 | 2.4 | 9.55 |
| **D3** | 3 | 6.25 | 1.8 | 3.1 | 14.15 |
| **Total** | 8.45 | 10.5 | 3.95 | 6.5 | 29.4 |
| **DSS =** | 2.98 | **MSS =** | 2.60 | **Int SS =** | 2.66 |

**ANAVA**

| SV | Df | SS | MSS | F cal | Result |
|---|---|---|---|---|---|
| Rep | 2 | 0.15 | 0.075 | | |
| M | 3 | 2.60 | 0.86 | 15.07 | **Sig** |

| | | | | | |
|---|---|---|---|---|---|
| D | 2 | 2.98 | 1.49 | 25.93 | **Sig** |
| MXD | 6 | 2.66 | 0.44 | 7.73 | **Sig** |
| Error | 22 | 1.26 | 0.057 | | |
| Total | 35 | 9.67 | | | |

# Appendix-XII

## Saponification value for oil and grease determination

Formula for determination of saponification value given as follows,

$$\text{Saponification value} = \frac{(X-Y)\times 28}{weight\ of\ sample}$$

Where,

X = Blank Reading

Y = Sample Reading

**1. For gravel**

$$\text{Saponification value} = \frac{(9.6-8.75)\times 28}{5}$$

$$= 4.76$$

**2. For grit**

$$\text{Saponification value} = \frac{(9.6-8.6)\times 28}{5}$$

$$= 5.6$$

**3. For Sand**

$$\text{Saponification value} = \frac{(9.6-7.3)\times 28}{5}$$

$$= 12.88$$

**4. For Broken brick**

$$\text{Saponification value} = \frac{(9.6-7.75)\times 28}{5}$$

$$= 10.36$$

**5. For Untreated or raw grey water**

$$\text{Saponification value} = \frac{(9.6-7.25)\times 28}{5}$$

$$= 13.16$$

# APPENDIX- XIII

## Determination of porosity of filtration media

**1. Determination of porosity of sand**

Porosity can be defined as the ratio of the volume of pores (voids) to the total volume of solids. It was determined by using following formula as,

$$\eta = \frac{Vw}{(Vs+Vw)}$$

$$= \frac{451}{(705+451)}$$

$$\eta = 39\%$$

Therefore, porosity (η) of sand is 39%

**2. Determination of porosity of grit**

$$\eta = \frac{394}{(658+394)}$$

$$\eta = 37\%$$

Therefore, porosity (η) of grit is 37%

**3. Determination of porosity of gravel**

$$\eta = \frac{270}{(568+270)}$$

$$\eta = 32\%$$

Therefore, porosity (η) of gravel is 32 %

**4. Determination of porosity of broken brick**

$$\eta = \frac{575}{(1250+575)}$$

$$\eta = 31\%$$

Therefore, porosity (η) of broken brick is 31%

**5. Determination of porosity of charcoal**

$$\eta = \frac{1520}{(2380+1520)}$$

$$\eta = 38\%$$

Therefore, porosity (η) of charcoal is 38%

# APPENDIX- XIV

## Determination of Voids Ratio of filtration media

**1. Determination of Voids ratio of sand**

$$e = \frac{Va+Vw}{Vs}$$

$$e = \frac{Vw}{Vs}$$

$$e = \frac{451}{705}$$

Therefore, Voids ratio of sand is (e) = 0.63

**2. Determination of Voids ratio of grit**

$$e = \frac{394}{658}$$

$$= 0.59$$

Therefore, Voids ratio of grit is (e) = 0.59

**3. Determination of Voids ratio of gravel**

$$e = \frac{250}{568}$$

$$= 0.44$$

Therefore, Voids ratio of gravel is (e) = 0.44

**4. Determination of Voids ratio of broken brick**

$$e = \frac{575}{1250}$$

$$= 0.46$$

Therefore, Voids ratio of broken brick is (e) = 0.46

**5. Determination of Voids ratio of charcoal**

$$e = \frac{1520}{2380}$$

$$= 0.63$$

Therefore, Voids ratio of charcoal is (e) = 0.63

# APPENDIX- XV

**1. Determination of Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for sand**

$$\varrho_b = \frac{Ms}{Vt} = \frac{Ms}{Vs+Va+Vw}$$

$$= \frac{Ms}{Vs+Vw} \quad \text{.......... (Va becomes negligible)}$$

$$\varrho_b = 0.86 \text{ gm/cc}$$

$$\varrho_w = \frac{Ms+Mw}{Vs+Va+Vw}$$

$$= \frac{Ms+Mw}{Vs+Vw}$$

$$= 1.16$$

$$\varrho_w = 1.16 \text{ gm/cc}$$

Therefore, Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for sand are 0.86gm/cc and 1.16 gm/cc respectively.

2. **Determination of Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for grit**

$$\varrho_b = \frac{Ms}{Vs+Vw}$$

$$\varrho_b = 0.95 \text{ gm/cc}$$

$$\varrho_w = \frac{Ms+Mw}{Vs+Va+Vw} = \frac{Ms+Mw}{Vs+Vw}$$

$$= 1.33 \text{ gm/cc}$$

$$\varrho_w = 1.33 \text{ gm/cc}$$

Therefore, Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for grit are 0.95gm/cc and 1.33 gm/cc respectively.

**3. Determination of Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for gravel**

$$\varrho_b = \frac{Ms}{Vs+Vw}$$

$$\varrho_b = 1.12 \text{ gm/cc}$$

$$\varrho_w = \frac{Ms+Mw}{Vs+Va+Vw} = \frac{Ms+Mw}{Vs+Vw}$$

$$= \frac{2759+835}{1600+800}$$

$$\varrho_w = 1.27 \text{ gm/cc}$$

Therefore, Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for gravel are 1.12gm/cc and 1.27 gm/cc respectively.

**4. Determination of Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for broken brick**

$$\varrho_b = \frac{Ms}{Vs+Vw}$$

$$\varrho_b = 0.54 \text{ gm/cc}$$

$$\varrho_w = \frac{Ms+Mw}{Vs+Va+Vw} = \frac{Ms+Mw}{Vs+Vw}$$

$$= 0.89 \text{ gm/cc}$$

$$\varrho_w = 0.89 \text{ gm/cc}$$

Therefore, Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for broken brick are 0.54gm/cc and 0.89 gm/cc respectively.

**5. Determination of Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for charcoal**

$$\varrho_b = \frac{Ms}{Vs+Vw}$$

$$\varrho_b = 0.25 \text{ gm/cc}$$

$$\varrho_w = \frac{Ms+Mw}{Vs+Va+Vw} = \frac{Ms+Mw}{Vs+Vw}$$

$$= 0.65 \text{ gm/cc}$$

$$\varrho_w = 0.65 \text{ gm/cc}$$

Therefore, Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$) for sand are 0.25gm/cc and 0.65 gm/cc respectively

# APPENDIX- XVI

**Determination of Hydraulic conductivity:**

From Darcy's law hydraulic conductivity was determined by using following formula as,

$$K = \frac{VL}{Ath}$$

**1. Determination of Hydraulic conductivity for sand**

$$K = \frac{(2\times10^{-3})\times0.45}{0.00866\times1.66\times0.925}$$

= 4.5 m/day

**2. Determination of Hydraulic conductivity for grit**

$$K = \frac{(2\times10^{-3})\times0.457}{0.00866\times0.067\times0.925}$$

= 53.50 m/day

**3. Determination of Hydraulic conductivity for gravel**

$$K = \frac{(2\times10^{-3})\times0.45}{0.00866\times(1.32\times10^{-3})\times0.925}$$

= 85.11 m/day

**4. Determination of Hydraulic conductivity for broken brick**

$$K = \frac{(2\times10^{-3})\times0.45}{0.00866\times(9.16\times10^{-4})\times0.925}$$

= 123 m/day

**5. Determination of Hydraulic conductivity charcoal**

$$K= \frac{(2\times10^{-3})\times0.45}{0.00866\times(6\times10^{-3})\times0.925}$$

= 19 m/day

# APPENDIX- XVII

**Design parameters of small scale filtration unit**

**1. Calculation of Discharge (Q)**

The discharge capacity of designed filtration unit was determined as from Darcy's law,

$$Q = Kia$$

$$= 4.5 \times 0.83 \times 6.35 \times 10^{-3}$$

$$= 24 \text{ lit/day}$$

**2. Determination of flow velocity (V)**

It was determined by using following formula as,

$$V = K \times i$$

$$= 4.5 \times 0.833$$

$$= 3.8 \text{ m.day}^{-1}$$

**3. Determination of surface area of filter bed (A)**

$$\text{Surface area (A)} = \frac{\pi D2}{4}$$

$$= \frac{\pi \times (0.09)2}{4}$$

$$= 6.35 \times 10^{-3}$$

**4. Determination of Hydraulic Loading Rate (HLR)**

$$HLR = \frac{Q}{A}$$

$$HLR = \frac{0.024}{6.35 \times 10-3}$$

$$= 3.77 \text{ m.day}^{-1}$$

**5. Determination of Volume of filter unit (V):**

The volume of the filter unit was determined by using following formula as,

$$V = A \times d$$

$$= 6.35 \times 10^{-3} \times 1.8$$

$$= 0.011 m^3$$

**6. Determination of Hydraulic Retention time (HRT)**

Therefore hydraulic retention time for 1.8 m depth of media had been found as 1.33 hr

**7. Determination of Average Interstitial Velocity considered for sand medium**

$$V_a = \frac{Q}{\alpha A}$$

$$V_a = \frac{0.024}{0.39 \times 6.35 \times 10-3}$$

$$= 9.7\ \text{m.day}^{-1}$$

**8. Determination of equivalent vertical hydraulic conductivity for a stratified material ($K_z$):**

$$K_z = \frac{z1+z2+z3+z4+z5}{\frac{z1}{k1}+\frac{z2}{k2}+\frac{z3}{k3}+\frac{z4}{k4}+\frac{z5}{k5}}$$

$$K_z = \frac{(0.15+0.3+0.45+0.15+0.45+0.3)}{(\frac{0.15}{85.11}+\frac{0.3}{19}+\frac{0.45}{53.5}+\frac{0.15}{85.11}+\frac{0.45}{123}+\frac{0.3}{1.62})}$$

$$= 8.18\ \text{m.day}^{-1}$$

**9. Determination of types of flow on the basis of Reynolds number in four filtration media**

Type of flow was decided based on Reynolds number and it was determined for five filtration media and the formula is given as follows,

$$N_R = \frac{\varrho v D}{\mu}$$

For sand Reynolds number,

$$N_R = \frac{1\times3.8\times0.00042}{0.9\times10^{-3}}$$

$$= 1.79$$

For grit Reynolds number,

$$N_R = \frac{1\times3.8\times0.007}{0.9\times10^{-3}}$$

$$= 29.5$$

For gravel Reynolds number,

$$N_R = \frac{1\times3.8\times0.02}{0.9\times10^{-3}}$$

$$= 84.44$$

For broken brick Reynolds number,

$$N_R = \frac{1\times3.8\times0.025}{0.9\times10^{-3}}$$

$$= 105.5$$

For charcoal Reynolds number,

$$N_R = \frac{1\times3.8\times0.014}{0.9\times10^{-3}}$$

$$= 59.11$$

**10. Frictional head loss through media**

Frictional head loss through media was found $1\times10^{-3}$m

# APPENDIX- XVIII

## Design parameters of media for waste water treatment plant for Jayaprabha hostel

**1. Calculation of Discharge (Q)**

The discharge capacity of designed filtration unit was determined as from Darcy's law,

$$Q = Kia$$
$$= 4.5 \times 0.83 \times 6$$
$$= 22000 \text{ lit/day}$$

**2. Determination of flow velocity (V)**

It was determined by using following formula as,

$$V = K \times i$$
$$= 4.5 \times 0.833$$
$$= 3.8 \text{ m.day}^{-1}$$

**3. Determination of surface area of filter bed (A)**

$$\text{Surface area (A)} = 3m \times 2m$$
$$= 6m^2$$

**4. Determination of Hydraulic Loading Rate (HLR)**

$$HLR = \frac{Q}{A}$$
$$HLR = \frac{22}{6}$$
$$= 3.7 \text{ m.day}^{-1}$$

**5. Determination of Volume of filter unit (V)**

$$V = A \times d$$
$$= 6 \times 1.8$$
$$= 11 \text{ m}^3$$

**6. Determination of Hydraulic Retention time (HRT)**

Therefore hydraulic retention time for 1.8 m depth of media had been found as 1.33 hr

**7. Determination of Average Interstitial Velocity considered for sand medium**

$$V_a = \frac{Q}{\alpha A}$$
$$V_a = \frac{22}{0.39 \times 6}$$
$$= 9.57 \text{ m.day}^{-1}$$

**8. Determination of equivalent vertical hydraulic conductivity for a stratified material ($K_z$):**

$$K_z = \frac{z1+z2+z3+z4}{\frac{z1}{k1}+\frac{z2}{k2}+\frac{z3}{k3}+\frac{z4}{k4}}$$

$$K_z = \frac{(0.15+0.3+0.45+0.15+0.45+0.3)}{(\frac{0.15}{85.11}+\frac{0.3}{19}+\frac{0.45}{53.5}+\frac{0.15}{85.11}+\frac{0.45}{123}+\frac{0.3}{1.62})}$$

$$= 8.18 \text{ m.day}^{-1}$$

**9. Determination of types of flow on the basis of Reynolds number in four filtration media**

For sand Reynolds number,

$$N_R = \frac{1\times9.57\times0.00042}{0.9\times10^{-3}}$$

$$= 4.52$$

For grit Reynolds number,

$$N_R = \frac{1\times9.57\times0.007}{0.9\times10^{-3}}$$

$$= 74.43$$

For gravel Reynolds number,

$$N_R = \frac{1\times9.57\times0.02}{0.9\times10^{-3}}$$

$$= 212.6$$

For broken brick Reynolds number,

$$N_R = \frac{1\times9.57\times0.025}{0.9\times10^{-3}}$$

$$= 265.8$$

For charcoal Reynolds number,

$$N_R = \frac{1\times9.57\times0.014}{0.9\times10^{-3}}$$

$$= 155$$

**10. Frictional head loss through media**

$$h_L = \frac{0.012\times1.8\times(9.57\times10-3)2}{2\times9.81\times5} \quad = 2\times10^{-8} \text{ m}$$

# I. INTRODUCTION

In many arid and semi-arid countries water is becoming an increasingly scarce resource and planners are forced to consider alternative sources of water which might be used economically and effectively to promote further development. At the same time, with population expanding at a high rate, the need for increased food production is apparent. Whenever good quality water is scarce, water of marginal quality will have to be considered for use in agriculture. It is an opportune time, to refocus on one of the ways to recycle the water through reuse of urban wastewater for irrigation and other purposes. This could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater viz. irrigation and other ecosystem services. In general wastewater comprises liquid wastes generated by households, industry, commercial sources, as a result of daily usage, production and consumption activities. The disposal of the wastewater is a major problem faced by municipalities, particularly in the case of large metropolitan areas, with limited space for land based treatment and disposal. On the other hand, waste water is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture, aquaculture and other activities.

In both developed and developing countries, the most prevalent practices are the application of municipal wastewater (both treated and untreated) to land. In developed countries where environmental standards are applied, much of the wastewater is treated prior to use for irrigation of fodder, fibre and seed crops and to a limited extent, for the irrigation of orchards, vineyards, and other crops (Hussain *et al*.2002). Grey water is defined as the urban waste water that includes water from baths, showers, hand wash basins, washing machines, dish washers and kitchen sinks, but excludes input from toilets (Jefferson et al. 2014; Eriksson et al. 2002)

Thus, wastewater can be considered as both challenge and opportunity. Wastewater and its nutrient content can be used extensively for irrigation and other ecosystem services. Its reuse can deliver positive benefits to the farming community, society and municipalities. In general, municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water and by groundwater seepage entering the municipal sewage network. Domestic waste water consists of effluent discharges from households, institutions and commercial buildings. Industrial waste water is the effluent discharged by manufacturing units and food processing plants. Discharge rate of waste water having variations on daily and seasonal basis. The peak flow obtained more in morning. This flow is low during the early morning hours and a first peak generally occurs in the late morning followed by second peak in the evening which was observed at our research place Jayaprabha girls hostel, Dapoli. Substitution of freshwater by treated wastewater is already seen as an important water conservation and environmental protection strategy, which is simultaneously contributing to the maintenance of agricultural production.

Waste water is a rich source of plant nutrients. Impact of waste water irrigation on yield varies from crop to crop. If the crops are undersupplied with essential plant food nutrients, waste water irrigation will act as a supplemental source of fertilizer thus increasing crop yields (Hussain *et al*.2002).Waste water is extensively used in agriculture because it is rich source of nutrients and provides all the moisture necessary for crop growth. Most of crops give higher yields with waste water irrigation reduce the need for chemical fertilizers. The most visible effect of waste water for irrigation is a productivity increase due to its contents of nutrients and organic matter (Mara 2003; U. S. EPA, 2002). In the absence of any chemical fertilizer application, wastewater nutrients will act as a sole of fertilizer, delivering saving in fertilizer cost. Thus, from an economic standpoint waste water irrigation may have a threefold effects on crops that are higher yields, source of irrigation water and fertilizer value (Hussain *et al*.2002).

Grey water is a waste water derived from kitchens, bathrooms (i.e., discharges from shower, hand basin, bath), and laundry water. Grey water does not include the waste water produced from toilet use, which is considered black water. The generated quantity of grey water can greatly vary between different households within one community and depends on different factors, such as availability of water and lifestyle of households. In general, the volume of grey water accounts between 50 per cent and 80 per cent of the domestic household water uses. The quality of grey water is highly variable due to the variability in household water use. Grey water contains the same contaminants (organic compounds, nutrients and pathogens) as raw sewage water. However, grey water contains low concentrations of contaminants compared to those in raw sewage water and black water. The potential risks, as there is some concern that the high levels of organic load produced in kitchens might pose an unacceptable risk of pathogenic contamination in gray water. Reuse of grey water systems as an opportunity to conserve potable quality water, generate locally sustainable water sources, and match the water supply quality with that required for the intended use. Grey water or sullage is defined as all wastewater streams generated from households or office buildings except for the wastewater from toilets. Sources of grey water include for example sinks, showers, baths, clothes washing machines or dish washers. As grey water contains many fewer pathogens than domestic wastewater, it is easier to treat and to recycle onsite for uses such as toilet flushing, landscape irrigation or even irrigation of crops. Application of grey water reuse in urban water system provides a substantial benefit for both water supply and wastewater subsystems by reducing the need for clean water in water distribution system as well as generated wastewater in sewer system.

Improving water quality and mitigating water scarcity are closely linked to gray water management. Reuse of treated gray water, generated by bath, laundry and kitchen, and amounting two thirds of the total domestic waste water produced, could have the limited sources of fresh water. Even if reuse of gray water is not considered a priority (for reasons of abundance of fresh water resources or cultural barriers), appropriate gray water treatment prior to its discharge could significantly reduce water pollution. Also gray water contributes to half of the total organic load and up to two thirds of the phosphorus load in domestic waste water.

There is a high amount of variability in the chemical and physical quality of grey water produced by any household, due to factors such as source of water the water use efficiency of appliances and fixtures, individual habits, product used (eg. Detergents, shampoos, soaps etc) and other site specific characteristics. The amount of salt (sodium, magnesium, potassium and other salts), oils, greases, fats, nutrients and chemicals in grey water can largely be managed by the types of product used within a household. Most cleaning agents contain sodium salts, which can cause excessive soil alkalinity, inhibit seed germination, and destroy the structure of soils by dispersing clay. Cleaning products containing ammonia are safe to use, as plants can use it to obtain nitrogen.

Black water contains pathogens that must decompose before they can be released safely into the environment. It is difficult to process black water if it contains a large quantity of excess water, or if it must be processed quickly, because of the high concentrations of organic material. However, if black water does not contain excess water, or if it receives primary treatment to de-water, then it is easily processed through composting.

A safe and convenient water supply is paramount importance to human health and well being of a society as a whole, although the field of water treatment offers a variety of technological choices, only a few of them fully meet the specific requirement of rural area. In the construction of the plant, locally available material is generally used and the skills for construction, operation and maintenance are usually available locally. Filtration plays a very important role in grey water treatment. The sand used in the filters must be hard and resistant to chemical attack and free from dirt such as clay or dust. Slow sand filter can also achieve 99.99% removal of cryptosporidium and more than 90% removal of total coli form bacteria in water (Agunwamba, 2000).The number of technologies available in market for grey water filtration such as Grewa-R-S, Grewa-R and Grewa-M, Grewa FLEET for waste water treatment and grey water treatment. Also, Grewa-O is ideal for residential and commercial complexes and industrial water and waste water treatment. (Jaldhara Technologies Pvt. Ltd.)

One such method is slow sand filtration is a simple, efficient and reliable technique for the treatment of waste water. The slow sand filtration process is expected to remove such biological particles as cysts, algae, bacteria, viruses. The design period will depend upon the local circumstances. The components of a filtration unit include intake, pre-treatment (if any), filter box, piping, disinfection and treated water storage. The layout should be site specific. The most important characteristic of the filter medium is diameter and their uniformity or size range of that particular media such as sand, gravel, grit and charcoal has been used for research. The sand must have low silt content. The filter medium should be of uniform grain size to make sure that the pores, or holes, between grains having the same size so that the filter efficiency should be equal over the bed.

The effectiveness of the slow sand filter depends on the conditions in which they operate; and on the degree of pollution in the water to be filtered. All parts of the filter must be kept clean- contamination can come from outside the filter. Slow sand filters are able to provide very good safe water free from biological pathogens. There are number of problems always occurs during the slow sand filtration as they require relatively non turbid water to function properly. And water must be added regularly also during the construction care must be taken to prevent air pockets from forming in sand –this will foul the filter and require removing the sand and removing all anaerobic bacteria and odours. Rapid sand filters have filtered rates forty times those of slow sand filters. The sand size used in rapid sand filter is larger than sand used in slow sand filter. The coarser sand in the rapid sand filters has larger voids that do not fill as easily. There are three major types of filter problems as they can be caused by chemical treatment before the filter and control of filter flow rate and backwashing of filters. Also if the filter is not backwashed effectively, problems may occur that may be impossible to correct without total replacing the filter media.

It is one of the focused investigations into the reuse of grey water on horticultural crop and also irrigation, which may become a vital survival strategy for residents of water scarce region in year to come. The present investigation was carried out on domestic grey water generated from Jayaprabha hostel of DBSKKV, Dapoli. The average daily grey water production is around 10,000 litre per day for each wing. The present work is an attempt to examine irrigation water quality of domestic grey water. The study has following objectives,

1. To quantify the discharge and to study physical & chemical properties of domestic grey water before and after treatment.
2. Design of small scale waste water treatment plant.

# III. MATERIALS AND METHODS

The details of experimental site, experimental set up, procedures adopted and material used for experimentation are described below.

## 3.1 Experimental Site

The present investigation was carried out on the grey water of Jayaprabha girls' hostel of DBSKKV, Dapoli. This is located in the humid and tropical region on the west coast of Maharashtra. It is situated at an altitude of 280 m MSL at $17^0$12' North latitude and $73^0$12' East longitudes. The average annual minimum and maximum temperature of Dapoli are $11.4^0$C and $40^0$C, respectively; whereas relative humidity ranges from 43.7 to 95.2 per cent. The average annual rainfall is 3500 mm, but less water holding capacity of lateritic soil causes scarcity of water during summer months.

### 3.1.1 Details of Jayaprabha hostel

The accommodation capacities of Jayaprabha girl's hostel is 350 girls in 150 rooms in both wings. The average daily grey water production is around 10,000 lit per day for each wing. The total grey water production from both wings was around 20000 lit per day. The black water is already separated from grey water. The grey water was carried through pipe drain up to disposal of natural drain. The elevation difference from Jayaprabha hostel and natural drain is 1.5 m and length of pipe drain is 110 m.

**Fig. 3.1 Experimental site of Jayaprabha Hostel**

### 3.1.2 Estimation of daily grey water production

The most accurate method for measuring small flows is the volumetric method. This was done by measuring the time taken to fill a container of known volume. The equipment required was a calibrated container and a stop watch. A container was calibrated by adding known volumes of water by increments. The observations were taken during 6.30 am to 6.30 pm consequently for seven days. The data collected were analyzed and hourly, daily discharge, peak flow rate, peak hours were determined.

**Fig. 3.2 Discharge mesurement**

### 3.1.3 Media selection and their characteristics

The locally and easily available media viz, gravel, grit, sand, broken bricks and charcoal were selected for study. These media had characteristics of filtration as well as adsorbent of pollutant in grey water.

**Gravel**

Gravel is a granular broken piece of any type of rock. Gravels are usually sized between 2 mm to 40 mm. Selected size of gravel was 15-25 mm. They may be rounded, when from marine or fluvial source or angular when quarried and crushed. It gives support to other media.

**Grit**

Grit is another granular material in transition stage between a coarse sand and small pebbles. Generally 2 to 8 mm in size, grit traditionally had limited uses in construction but now days it can also be used for filtration media also. The size of grit was used 6- 8 mm. Grit generally having platy structure.

**Sand**

Sand used in the filters must be hard and free from dust and clay. It should be resistant to chemical attack. It is insoluble, hard, silicious and should not have clay, silt and dust (IS 8419 (Parrl):1977). Locally available beach sand was screened properly and used as filtration media and size of sand were decided on the basis of effective size and uniformity coefficient (Cu). The effective sizes of sand and uniformity coefficient decided for efficient filtration were 0.42mm and 2.2, respectively (Zaidun, 2011). Grey water was allowed to pass through sand media of various depths. The effect of depths of sand on physical as well as chemical qualities of grey water was observed. Grading and screening of sand was done by using standard sieve analysis.

**Broken Brick**

Burnt bricks were used for filtration media. Broken bricks have high adsorption capacity. It also has high turbidity removal efficiency. Locally available bricks have been broken into small pieces. Size of broken brick was 25-30 mm. Screening was done for obtaining uniform size, removal of fine dust and foreign particles.

**Charcoal**

Charcoal in the granular form was used for study. It has good adsorption quality. It can trap carbon based impurities (organic compounds) as well as inorganic and odorous compounds. (Godfred, 2014). Size of charcoal used was 12-16mm with 30cm depth.

**Table 3.1 Different sizes of selected filtration media**

| Media | Size of particles (mm) |
|---|---|
| Gravel | 15 – 25 |
| Grit | 6.0 – 8.0 |
| Sand | 0.42 |
| Broken brick | 25 – 30 |
| Charcoal | 12-16 |

**Fig. 3.3 Selection of filtration media**


**Fig. 3.4 Flushing of filtration media**

**Plate 3.5 Washing of filtration medium sand**


**Plate 3.6 Depth adjustment of media**

**Fig. 3.7 Filtration media at the depth 15 cm**

**Fig. 3.8 Collection of grey water after treatment**

### 3.1.4 Analysis of particle size distribution of sand

The determination of particle size distribution of sand media is of prime importance in design of slow sand filter. The standard procedure for analyzing sand by the dry sieving method is adopted. A set of sieves confirmed to Indian Standard, IS: 460-1962 is used. The most important feature of granular media is not the grain properties, but rather the pore space in the media. The treatment of waste water occurs in the pores where suspended solids are trapped, microorganisms grow. Ball, 1997 illustrated how the particle size of a filter media is related to the size of the void or pore space between the particles by calculating surface area and void volume for packed spheres of various sizes. The standard procedure for analyzing sand samples by the dry sieving method is adopted as follows:

- The sample of 2.4 kg weight was added in sieve shaker. The weight of material retained on each sieve is recorded. These weights were expressed as percentage of the total weight of the sample and a graph was plotted of the cumulative percent of the sample retained verses the size of the sieves. The sieve sizes were expressed in mm.
- The "percent retained" is plotted on the y- axis and the size of the sieve opening or 'particle size' is plotted on the x- axis.
- It is common practice to plot the graph on semi-log paper with the x- axis on the logarithmic scale. The size of the opening is considered to be the diameter of the smallest particle retained by each sieve.

**Fig. 3.9 Standard Sieve shaker**

**Fig. 3.10 Arrangement of sieves**

The following terms were used for determining the size characteristics of the filtration media of sand as,

## 1. Effective size

The term effective size is defined as formation particle size, where 10 percent of sand is finer and 90 percent coarser. The effective size of the formation material is 0.42mm

## 2. Uniformity coefficient

It expresses the variation in grain size. It is usually measured by the sieve aperture that passes 60 per cent of the material, divided by sieve aperture that passes 10 per cent of the material. It is usually expressed as follows,

$$C_u = \frac{D_{60}}{D_{10}}$$

For heterogeneous sand, this value will be high. Generally, a material is classified as uniform, if uniformity coefficient (Cu) less than 2. A uniformity coefficient of 4 or less is recommended for all filter media. (Clearinghouse, 1997). The ideal sand for intermittent sand filters receiving domestic waste water is coarse sand with an effective size between 0.3 mm and 0.5 mm (Crites and Tchobanoglous, 1999). The uniformity coefficient of selected sand was 2.2. Uniformity coefficient for gravel, grit, broken brick and charcoal need not to be determined because these media are machine made, uniform size broken pieces of stones having platy structure. The Following flow chart was used for filtration of grey water as,

### 3.1.5 Filtration of grey water sample through various filtration media

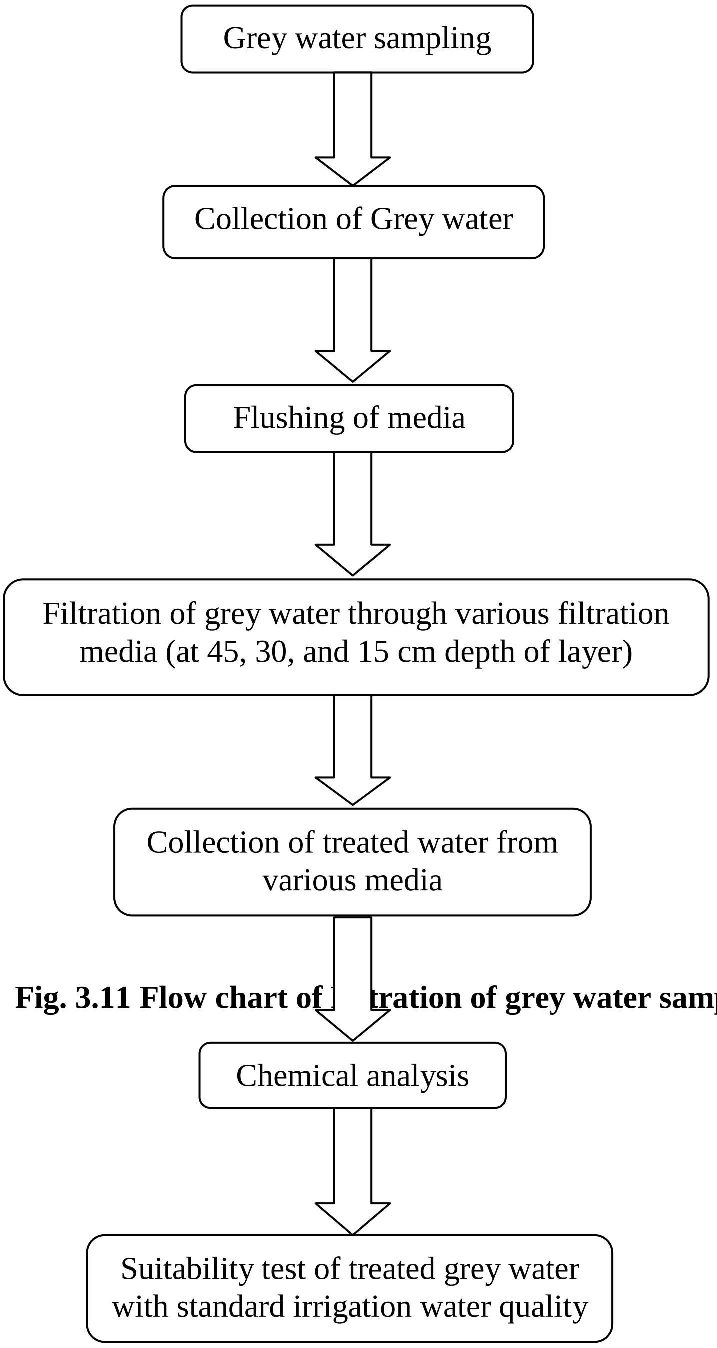


**Fig. 3.11 Flow chart of filtration of grey water sample**


**Fig. 3.12 Comparing appearance of grey water before and after treatment**


**Fig. 3.13 Grey water after filtration at 30 cm depth**

**Fig. 3.14 Grey water after filtration at 45 and 15 cm depth**

## 3.1.6 Physical properties of domestic grey water

### 3.1.6.1 Temperature

Grey water temperature is often higher than the temperature of water supply due to hot tap water used for personal hygiene and laundry. High temperature favours microbial growth and leads to precipitation of calcite in supersaturated waters. (Eriksson *et al*., 2002). Temperature of grey water after treatment was taken which was higher than before treatment and reported in Table 4.1

### 3.1.6.2 Colour

It is the cloudiness of grey water caused by large number of individual particles.

### 3.1.6.3 Turbidity and contents of suspended solids

It is a measure of cloudiness of water, i.e. higher turbidity indicates greater murkiness, which is a result of the presence of suspended solids in the water, could potentially shield microbes and increase treatment loading. It has been measured by turbidity meter and results are reported in Table 4.1

**Fig. 3.15 Turbidity meter**

Turbidity meter is an instrument for measuring and comparing the turbidity of liquids by passing light through them and determining how much light is reflected by the particles in the liquid. The normal measuring range is 0 to 100 is expressed as Nephelometric Turbidity Units (NTU).

#### 3.1.6.4 Odour

The anaerobic condition leads to release of odorous compounds from the system. The odour of untreated grey water found was non-offensive.

## 3.2 Methods

### 3.2.1 Chemical parameters of domestic grey water

1. pH
2. Electrical conductivity (EC)
3. Total Dissolved Solids
4. Calcium
5. Carbonate and Bicarbonate
6. Potassium
7. Nitrogen
8. Magnesium
9. Sodium
10. SAR

11. RSC
12. Oil and grease
13. Chemical Oxygen Demand (COD)
14. Biological Oxygen Demand (BOD)

### 3.2.1 Standard procedure

The standard procedure used for chemical analysis is given below.

#### 3.2.1.1 Determination of pH

The effect of pH on the chemical and biological properties of liquids makes its determination very important. It is one of the most important parameter in water chemistry and is defined as -log [$H^+$], and measured as intensity of acidity or alkalinity on a scale ranging from 0-14. If free $H^+$ are more it is expressed acidic (i.e. pH<7), while more $OH^-$ions is expressed as alkaline (i.e. pH> 7). In natural water pH is governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions and ranges between 4.5 and 8.5, although mostly basic. It tends to increase during day largely due to the photosynthetic activity (consumption of carbon-di-oxide) and decreases during night due to respiratory activity. Waste water and polluted natural water have pH values lower or higher than 7 based on the nature of the pollutant.

pH is an indicator of the acidicity or basicity of water but is seldom a problem by itself. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is abnormal in quality. Normally, pH is a routine measurement in irrigation water quality assessment.

**Apparatus required:** pH meter.

**Electrometric method:** The pH is determined by measuring the Electro Motive Force (E.M.F) of a cell comprising an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and the reference electrode (usually a mercury/calomel electrode). Contact between the test solution and the reference electrode is usually got by means of a liquid junction, which forms a part of reference electrode. E.M.F of this cell is measured with pH meter that is a high impedance voltmeter calibrated in terms of pH. The electrode is allowed to stand for 2 minutes to stabilize before taking reading for reproducible results (at least 0.1 pH units).

**Fig. 3.16 pH meter**

### Practical suggestions

- Allow the pH meter to warm up for 10 minutes before recording the pH.
- Never allow the lower portion of glass electrode to touch the bottom of the beaker.
- Always put the switch to neutral, zero or release pH button whenever solution is changed.
- Ensured that the electrode is clean and filled with saturated KCℓ solution.
- After every 10 samples, check pH meter’s accuracy with the buffer solution.

### 3.2.1.2 Determination of Electrical Conductivity (EC)

Conductivity (specific conductance) is the numerical expression of the water's ability to conduct an electric current. It is measured in micro Siemens per cm and depends on the total concentration, mobility, valency and the temperature of the solution of ions. Electrolytes in a solution disassociate into positive (cations) and negative (anions) ions and impart conductivity. Most dissolved inorganic substances are in the ionised form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply. Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemen (s).

**Apparatus required:** Conductivity meter

### Procedure

1. Take the water sample in a clear beaker (100ml). Rinse the conductivity cell with distilled water and then with the sample.

2. Temperature and cell constant corrections are adjusted on the conductivity meter, if provided.

3. Connect conductivity cell to meter and dip in the sample.

4. Then read the conductivity value in $dSm^{-1}$ or $\mu Scm^{-1}$.

**Fig. 3.17 Conductivity meter**

### 3.2.1.3 Determination of Total Dissolved Solids

**Apparatus required:** Conductivity meter

**Procedure**

The electrode of the conductivity meter is dipped into the sample, and the readings are noted for stable value shown as µS/cm. Total Dissolve Solids for grey water sample derived by using following equation as,

$$\text{TDS (mg/l)} = \text{EC} \times 640 \quad \text{... (1)}$$

### 3.2.1.4 Determination of Calcium

The most common and reliable method of calcium determination in irrigation water's is by titration using disodium solution of ethylene diamine tetra acetic acid (EDTA) solution.

## Reagents

1. Standard calcium solution (0.01N): Weigh the 0.5g of pure $CaCO_3$ dried at 150˚C and dissolved in 10 ml of 0.2N HCl. Heat till the solution boils and $CO_2$ is completely driven off. Cool and make the volume accurately to 1 litre. This solution is used for standardizing EDTA.
2. EDTA solution (0.01N): Weigh 2.0g of versenate (disodium dihydrogen ethylene diamine tetra acetic acid). Dissolve it in distilled water and make the volume to 1 litre.
3. Ammonium perpurate (Murexide) powder. Weigh 0.2 g of ammonium perpurate and 40 g of potassium sulphate. Mix both the reagents thoroughly in a pestle and mortar and keep it as powder in a clean dark coloured bottle.
4. Sodium hydroxide (4N): Weigh 160 g of pure sodium hydroxide in water and make volume to 1 litre.

## Procedure

1. Pipette 5 mℓ water sample in a 100 ml clean conical flask and dilute by adding about 25 mℓ of distilled water.
2. Add 5 mℓ of NaOH and 25 mg of murexide powdered. Shake the contents well. Here original colour is orange red.
3. Start titration against EDTA till the colour changes to purple.

### Calculation

$$\text{Ca Concentration} = \frac{(\text{EDTA} \times 0.01 \times 1000)}{\text{aliquot(ml)}} \qquad ...(2)$$

### 3.2.1.5 Determination of Carbonates and Bicarbonates

Sum of the carbonate and bicarbonate ions constitutes the total alkalinity of the water as temporary hardness and raises its pH to more than 7.5. This alkalinity also causes corrosion in the boilers and other metallic pipes or containers. Hence, their determination is also important for agricultural as well as industrial purposes.

**Reagents**

1. Standard sulphuric acid (0.05N). Transfer 1.4 ml of concentrated $H_2SO_4$ in a 1 litre volumetric flask with distilled water. Standardize it against standard NaOH solution prepared separately.
2. Methyl orange indicator (0.5%). Dissolve 0.5 g dry methyl orange powder in 100 ml of 95% alcohol.
3. Phenolphthalein indicator (0.25%). Dissolve 0.25 g of pure phenolphthalein powder in 100 ml of 60% alcohol.

**Procedure**

1. Take a known volume (5 or 10 ml) of water sample in a clean porcelain dish or 100 ml conical flask and dilute it by adding about 25 ml of distilled water.
2. Add 2-3 drops of phenolphthalein. If red colour appears, titrate it against Standard $H_2SO_4$ till red colour disappears.
3. Record the titrate value.

4. Now add 2-3 drops of methyl orange to this colourless solution or in the original sample (if red colour was not noticed) and again titrate till the yellow colour changes into rosy red.

5. Record the volume of $H_2SO_4$ consumed.

**Calculation**

$$\text{Carbonates (me/l)} = \frac{\text{PR} \times 2 \times \text{normality of } H_2SO_4 \times 1000}{\text{aliquot(ml)}} \quad . \quad \ldots (3)$$

$$\text{Bicarbonates (me/l)} = \frac{[(\text{MR} - 2\text{PR}) \times \text{normality of } H_2SO_4 \times 1000}{\text{aliquot (ml)}} \quad \ldots (4)$$

### 3.2.1.6 Determination of potassium

Potassium generally constitutes a small fraction of cations present in surface as well as ground water. Being a plant nutrient, its presence in saline water counteracts the adverse effect of Na on crop growth. Hence, its determination is essential in saline waters along with that of Na. Flame photometry is the most rapid and reliable method of K determination.

### Procedure

Since concentration of potassium in irrigation waters in usually very low, the range of K in standard solutions is also kept low. Weigh 191mg of KCℓ and dissolve in distilled water. Make the volume to 1Liter. This is 100 mg/litre potassium stock solution. Prepare working standard solutions of 0, 2, 4, 6, 8, & 10mg/litre, in 100ml measuring flasks by dilution.

**Fig. 3.18 Determination of potassium**

### 3.2.1.7 Determination of Ammonium Nitrogen ($NH_4^+N$)

### Principle

Water sample is treated with a base, sometimes NaOH but usually MgO and mixture distilled. Ammonia is quantitatively expelled and absorbed in excess standard boric acid which is titrated directly with standard sulphuric acid.

### Required Reagents

1. Magnesium oxide (MgO):Heavy magnesium oxide was heated at 65˚C for 2 hours in an electric muffle furnace, allowed to cool in a desiccators over solid KCl and stored in a tightly stopper bottle. This was done to destroy $MgCO_3$ present as impurity.
2. Sodium hydroxide: Dissolve 420 gm of NaOH in distilled water and made a volume up to 1 liter, and allowed to stand for 2 days for any carbonate to settle.
3. Boric acid indicator solution: Weight and dissolved 20g of pure boric acid in about 900ml of hot distilled water. Cool and added 20 ml of mixed indicator and made the volume up to the mark.

4. Mixed indicator: Dissolved 0.066 g methyl red and 0.099 g bromocresol green in 100 ml alcohol.
5. Standard sulphuric acid (0.02N): Prepared and standardized for greater accuracy.

## Procedure

1. Pipette about 50 ml of water sample into the distillation flask and added about 100 ml distilled water. Then taken 20 ml of boric acid solution with mixed indicator in 150 or 250 ml conical flask and put beneath the condenser dipping the tip of the delivery tube in boric acid.
2. After that added 0.5 g of MgO or 10 ml of NaOH into distillation flask. Stopper the flask and distilled the ammonia into the boric acid solution till the distillate is about 30-35 ml.
3. Removed distillate first and then switched off the heating system. Then titrated the distillate against 0.02N sulphuric acid till the pinkish color reappeared. Blank has been also carried out simultaneously.

## Calculation

$$NH_4\text{-}N = \frac{(A - B) \times 280}{\text{Volume of sample (ml)}} \quad \text{... (5)}$$

Where,

A = Volume of $H_2SO_4$ used for sample (mℓ)

B = Volume of $H_2SO_4$ used for blank (mℓ)

### 3.2.1.8 Determination of Calcium +Magnesium for determination of Magnesium

## Required Reagents

1. EDTA Solution (0.01N)
2. Ammonium Perpurate
3. Sodium Hydroxide
4. Ammonium Chloride- Ammonium Hydroxide

## Procedure

1. 5 ml grey water sample taken in beaker after that added 25 ml distilled water.
2. Added 1 ml $NH_4Cl$ and $NH_4OH$ buffer solution.

3. Then added 3-4 drops of EBT indicator and then titrated this solution with 0.01 N EDTA solution.

4. End point: vine red to blue green.

$$Ca + Mg = \frac{EDTA\ used\ (BR) \times 0.01 \times 1000}{Volume\ of\ sanple}$$

… (6)

### 3.2.1.9 Determination of Sodium

Sodium has been determined flame photometrically. It is common method which is rapid and reliable. In this method, suspended particles were removed by filtration process using filter paper of what man no.42.

**Fig. 3.19 Filtration of grey water sample by what man filter paper**


**Fig. 3.20 Determination of Sodium by Flame Photo meter**

## Procedure

1. For preparing a stock solution of 100me/lit Na, weighted and dissolved 5.845g of sodium chloride in distilled water and made volume up to 1 liter for making working standards of 0, 2,4,6,8,10,20 me/lit of Na, pipette 0,2,4,6,8,10 ml of stock solution into 100 ml round bottom flask and made the volume with distilled water up to the mark.
2. Started the flame photo meter and first atomized distilled water and then adjusted galvanometer reading to zero. Then feed 10 me/lit standard solution and again adjusted galvanometer reading to 100 or any highest value displayed on the dial.
3. After that feed 2, 4, 6, 8, 10, 20 me/lit standards and noted the galvanometer readings.
4. Then drawn a curve by plotted flame photometer readings on Y- axis and sodium (me/lit) on X- axis. This should be straight line. If it is not, then reduce the working standards of Na. and again drawn the curve.
5. After that determined sodium concentration from the graph and multiplied by graph factor to get final value of sodium.

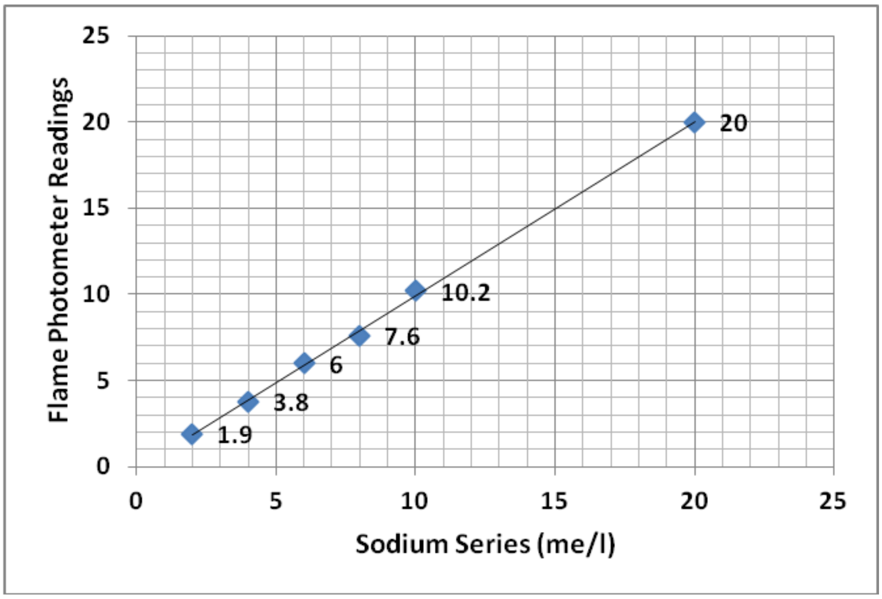


**Fig.3.21 Graph of Series vs. Flame photometer readings**

### 3.2.1.10 Determination of Sodium Adsorption Ratio (SAR)

This is an expression of the sodium hazard of irrigation water. It is the measure of the proportion of sodium to calcium and magnesium in water. The SAR is also as the index of the sodium permeability hazard as water moves through the soil. The main problem with high sodium concentration is its effect on the physical properties of soil. This breakdown disperses the soil clay and causes the soil to become hard and compact when dry and reduces the rate of water penetration when wet. A breakdown in the physical structure of the soil can occur with continued use of water with a high SAR value. The effect of high SAR on infiltration of irrigation water is dependent on the EC of water.

SAR value has been determined by using following formula as,

$$SAR = \frac{Na+}{\sqrt{\frac{(Ca+Mg)++}{2}}}$$

... (7)

### 3.2.1.11 Determination of Residual Sodium Carbonate (RSC)

The Residual Sodium Carbonate index of irrigation water or soil water indicates the alkalinity hazard for the soil. The RSC index is used to find the suitability of the soil swells or undergoes dispersion which drastically reduces its infiltration capacity.

RSC index has been determined by using following formula as,

$$RSC\ Index = [HCO_3+CO_3]- [Ca+Mg] \quad ...(8)$$

### 3.2.1.12 Determination of oil and grease in grey water by saponification value

The number of milligrams of KOH required for neutralizing the fatty acids resulting from the complete hydrolysis of 5 mℓ of fat or oil is called its saponification value.

**Principle**

When a fat or oil is heated with excess of alcoholic KOH, oil is hydrolysed to glycerol and the potassium salts of fatty acids (soaps.)

**Required Reagents**

1. Alcohol- ether mixture (1:1), (v/v): Mix 20 ml of alcohol and 20 mℓ ether.
2. Alcoholic KOH: (0.5 mol/0.5 N): Dissolve 7 g KOH in 250 mℓ of alcohol.
3. Hydrochloric acid: (0.5N): Measure 45 mℓ concentrated hydrochloric acid into a 250 mℓ flask. Dilute with water to 1000 mℓ.
4. Phenolphthalein indicator.

**Procedure**

1. Pipette out about 5mℓ of water sample contained in oil or grease into a 250 ml conical flask.
2. Then add 10 mℓ of alcoholic KOH and 25 mℓ alcohol- ether mixture to the flask.
3. Reflux on hot plate for 30 minutes.
4. Then cool the contents of the flask.
5. Simultaneously process was carried out another flask used in all the reagents without oil and grease containing grey water sample for blank.
6. Titrate the contents of both the flasks with 0.5 N HCL used in phenolphthalein indicator.
7. Titrated value of the flask contained oil or grease should be less than that for blank experiment.

**Fig. 3.22 Determination of oil and grease in grey water sample**

### Calculations

$$\text{Saponification value} = \frac{(X - Y) \times 28}{\text{Weight of sample}}$$

.... (9)

Where,

X =Volume of 0.5 N HCL required to titrate the blank experiment flask (ml)

Y = Volume of 0.5 N HCL required to titrate the flask containing oil and grease experiment (ml)

## 3.2.1.13 Determination of Chemical Oxygen Demand (COD)

In the COD test, the oxidizing bacteria of the BOD test are replaced by a strong oxidizing agent under acidic condition.COD describes how much oxygen is required to oxidize all organic and inorganic matter found in waste water sample.

### Required Chemical Reagents

1. 0.25N Potassium Dichromate solution ($K_2Cr_2O_7$)
2. Standard 0.1 N Ferrous Ammonium Sulphate (FAS)
3. Mercuric Sulphate ($HgSO_4$)
4. Sulphuric acid solution ($H_2SO_4$)
5. Ferroin indicator

### Analysis Procedure

1. Take 3 COD bottles washed them with distilled water. Take samples in three bottles for blank, inlet and outlet.

2. For blank sample, take 20 ml distilled water, 10 ml $K_2Cr_2O_7$, 30 ml $H_2SO_4$ and pinch of $HgSO_4$. For inlet sample, take 10 ml untreated sample, 10 ml $K_2Cr_2O_7$, 10 ml distilled water, 30ml $H_2SO_4$, pinch of $HgSO_4$.
3. For outlet sample, take 20ml treated sample, 10ml $K_2Cr_2O_7$, 30ml $H_2SO_4$, and pinch of $HgSO_4$.
4. Those three COD bottles put into holes of digestion block which has attained $150^0$ c temperature. Also put air condenser on the reaction vessels. Reflux the contents for two hours.
5. Cool the contents and titrated the excess potassium dichromate with standard Ferrous Ammonium Sulphate using 4 to 5 drops of Ferroin indicator. Color changes from yellow to reddish brown.

**Calculation**

$$\text{COD in ppm} = \frac{(\text{Blank reading - Sample reading}) \times \text{N of FAS} \times 8000}{\text{Volume of sanple}} \quad \ldots (10)$$

**Fig. 3.23 Preparation of solutions for COD test**


**Fig. 3.24 COD Digester Unit**

### 3.2.1.14 Determination of Biological Oxygen Demand (BOD)

It measures the strength of polluted water based on the amount of oxygen required to stabilize the organic material present; defined as the oxygen demand for a mixed population of microbes in aerobic oxidation.

**Required chemical reagents for laboratory analysis**

1. Phosphate buffer solution
2. $MgSO_4$ solution
3. $CaCl_2$ solution
4. $FeCl_3$ solution
5. Conc. $H_2SO_4$ acid
6. $MnSO_4$ solution
7. Alkali –Azide solution
8. Starch indicator
9. Std. $Na_2S_2O_3$

**Preparation of dilution (arated) water**

1. Take 2 liter distilled water then add 1 ml Phosphate Buffer solution. Add 2 mℓ of $MgSO_4$ solution, 2mℓ $CaCl_2$ solution, 2 mℓ $FeCl_3$ solution. Aerate this water in a container by bubbling compressed air for 45 minutes.

**Fig. 3.25 Preparation of dilution water**

**Fig. 3.26 BOD bottles for blank, inlet and outlet**


**Fig. 3.27 BOD Incubator** **Fig 3.28 BOD bottles put for 5 days**



**Fig. 3.29 PPT dissolve after adding $H_2SO_4$   Fig. 3.30 Solution after adding starch solution**

**Analysis procedure**

1. First sample pH maintains 7 pH on digital pH meter. After 7 pH is maintained take sample in BOD bottle according to its range as follows:

**Table 3.2 Determination of Dilution factor**

| Range of BOD values to be determined | Sample volume (ml) | Dilution water Volume (ml) | Dilution factor |
|---|---|---|---|
| 0-6 | Undiluted | 0 | 1 |
| 4-12 | 500 | 500 | 2 |
| 10-30 | 200 | 800 | 5 |
| 20-60 | 100 | 900 | 10 |
| 40-120 | 50 | 950 | 20 |

| | | | |
|---|---|---|---|
| 100-300 | 20 | 980 | 50 |
| 200-600 | 10 | 990 | 100 |
| 400-1200 | 5 | 995 | 200 |

2. Take 300 mlℓ dilution or aerated water in two bottles, 6 mℓ inlet sample out of 300 mℓ aerated water in two bottles, 16 mℓ outlet sample out of 300ml aerated water in two bottles for blank, inlet and outlet, respectively. Then final 3 bottles put into BOD incubator for 5 days (26°$c$) and titrate after 5 days.
3. Take initial sample bottles blank, inlet and outlet, respectively.
4. Then add 2 mℓ $MnSO_4$, 2mℓ alkali-azide solution, Stirring and then settled it. After that add 2 mℓ Conc. $H_2SO_4$ to dissolve the ppt.
5. If the color is white then dissolved oxygen is zero. If color yellow then take 200 mℓ sample in 500 mℓ conical flask and titrate against $Na_2S_2O_3$(0.025N). Then add starch indicator into that sample and end point is yellow to colorless.

**Calculation**

Analysis of Dissolve Oxygen,

$$\text{DO (ppm)} = \frac{\text{BR} \times \text{N of } Na_2SO_3 \times 8 \times 100 \times 10000}{1000 \times \text{Taken sample}} \quad \text{... (11)}$$

6. After 5 days take final BOD sample bottles and titrate against $Na_2S_2O_3$ solution as above procedure.

**Calculation**

$$\text{BOD (ppm)} = \frac{\text{Final reading - Initial reading}}{\text{Dilution factor}} \quad \text{... (12)}$$

$$\text{Dilution factor} = \frac{\text{Volume of sample}}{\text{Total volume of diluent water}} \quad \text{... (13)}$$

## 3.3 Filter Design

### 3.3.1 Determination of porosity of filtration media

Porosity can be defined as the ratio of the volume of pores (voids) to the total volume of solids. (Michael, 1978). It determined by using following formula as,

$$\eta = \frac{(Va + Vw))}{(Vs + Va + Vw)}$$

… (14)

Where,

$V_a$ = Volume of air

$V_w$ = Volume of water

$V_s$ = Volume of solids

The porosity of media depends on several factors, including packing density, the particle size distribution and shape of particles. The volume of water contained in a saturated sample of known volume can indicate porosity. The mass of saturated material less the oven dry mass of solids, divided by density of water gives the volume of water. This divided by original sample volume gives porosity. (Nimmo, 2004)

Laboratory test was conducted to determine porosity of various filtration media. Porosity is an index of the relative volume of pores. It is influenced by the textural and structural characteristics of the solid media. For the experimentation taken measuring cylinder of two litres. Then added filtration media of gravel, grit, sand and broken brick and charcoal alternately. After that added water in required quantity up to saturation capacity of that particular media. Then by using above equation determined porosity for above filtration media. Also one thing which is very important that, while adding the water in solids or media the volume of air ($V_a$) becomes less or negligible. Therefore $V_a$ was not considered while determination of porosity.

### 3.3.2 Determination of voids ratio for filtration media (e)

The quantity expressing the ratio of the volume of pores to the volume of solids is termed as void ratio or relative porosity. While adding the water in solids or media the volume of pores ($V_a$) becomes less or negligible. Therefore $V_a$ was not considered while determination of porosity. The voids ratio determined by using following formula as,

$$e = \frac{Va + Vw}{Vs}$$

… (15)

### 3.3.3 Determination of dry bulk density ($\varrho_b$) and wet bulk density ($\varrho_w$) for filtration media

The dry bulk density of solid is defined as the ratio of mass of dried particles to the total volume of solids (including particles and pores). Here also $V_a$ was not considered while determination of porosity. It has been determined by using following formula as,

$$\rho b = \frac{Ms}{vt} = \frac{Ms}{Vs + Va + Vw}$$

... (16)

Where,

$M_s$ = Mass of solid

$V_t$ = Total volume

Wet bulk density is the mass of moist solids per unit volume of solids. It has been determined by using following formula as,

$$\rho w = \frac{Ms + Mw}{Vs + Va + Vw} \quad \text{... (17)}$$

### 3.3.4 Determination of hydraulic conductivity by constant head method

In laboratory, hydraulic conductivity was determined by using permeameter, in which flow was maintained through a sample of material. The constant head permeameter can measure hydraulic conductivities of consolidated or unconsolidated formations under low heads. In this method, water entered the medium cylinder from the bottom and was collected as overflow after passing upward through the material. From Darcy's law, hydraulic conductivity was determined by using following formula as,

$$K = \frac{VL}{Ath}$$

... (18)

Where,

'K' hydraulic conductivity of porous media, $m.day^{-1}$

'L' Length of material bed (m)

'V' flow volume ($m^3$)

't' time of discharge (sec)

'A' Cross sectional area of permeameter ($m^2$)

'h' hydraulic head difference (m)

It is important that the medium be thoroughly saturated to remove entrapped air. This method is restricted to test on media having high hydraulic conductivity.

## 3.4 Construction of model of small scale filtration unit

- Grey water treatment plant was designed for capacity of 24 lit per day. The source of grey water was collected from bathrooms, basins and kitchen in residential area of Jayaprabha girl's hostel. The raw grey water was collected in storage tank having capacity of 100 liter which can act as settling tank. The gravitational force was used for the flow of grey water.
- The flow rate of feed raw water was controlled by the manual control valve of size 16 mm. Selected media were used as filter beds in the filtration unit. The bed height of each material was determined and finalized by the experimentation.
- The two PVC candles of diameter 90 mm and height of 1200 mm were used. The first candle contains 15 cm, 30 cm and 45 cm for gravel, charcoal and grit, respectively set from bottom to top in the filtration unit of first column. Also depth of each bed were selected 15cm, 30cm and 45 cm for gravel, broken brick and sand, respectively set from bottom to top in filtration unit of second column.
- Supply pipe, connecting pipe and delivery pipe used were of 16 mm diameter. Also, air vent of 16 mm diameter was installed at the top of both candles. Drain valve of 16 mm diameter were installed at the bottom of both the candles.
- The head difference between outlet of storage tank and waste water treatment plant was 1.5 m.
- The screen filter of 1 inch (32mm) having capacity of $7m^3$/hr was installed after second candle. Filtered water was collected in separate tank.
- Then treated water samples were analyzed by standard method for water and waste water analyzed at the laboratory of Soil Science and Agricultural Chemistry. The parameters such as pH, EC, TDS, calcium, carbonate and bicarbonate, potassium, nitrogen, magnesium, SAR, RSC, oil and grease, COD and BOD of raw and treated grey water sample were tested for analyzing the performance study of the filtration unit. The layout of small scale waste water treatment plant is shown in fig. 3.31.

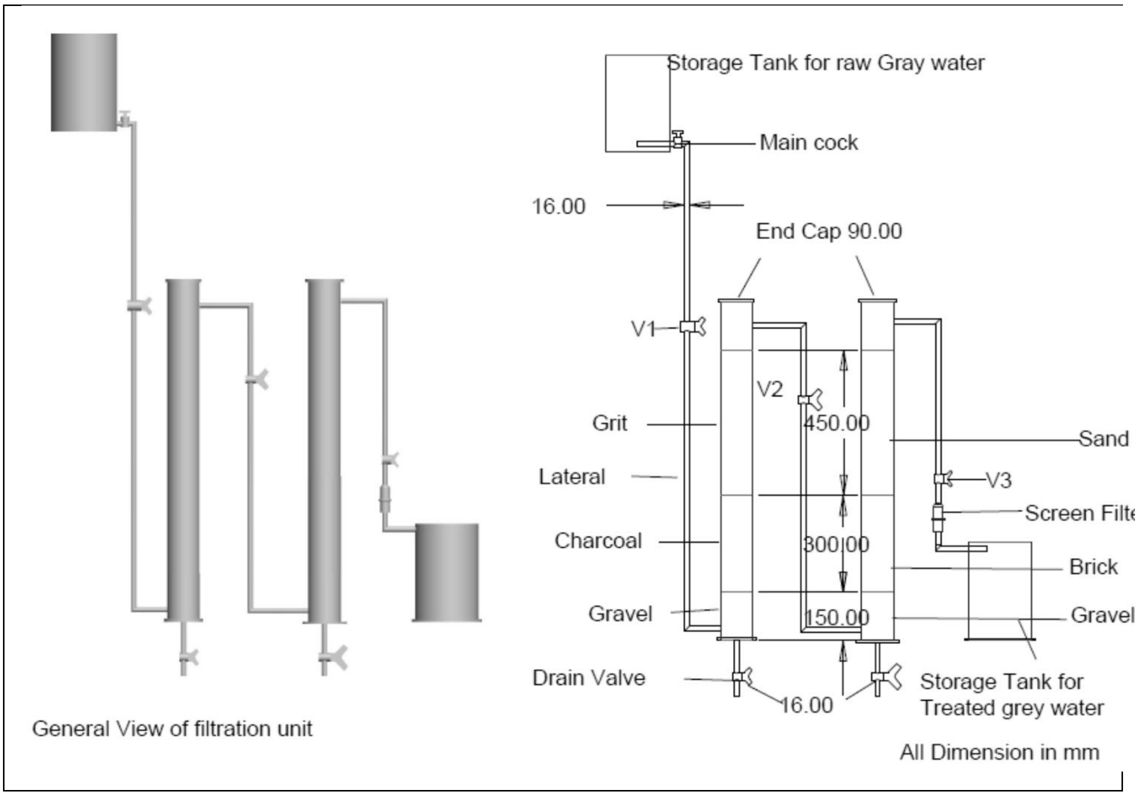


**Fig. 3.31 Layout of small scale waste water treatment plant**

## 3.5 Design parameters of media for small scale filtration unit

**3.5.1 Calculation of Discharge (Q)**: For four filtration media 'Q' can be determined from Darcy's law,

$$Q = Kia \qquad \text{... (19)}$$

Where,

'Q' discharge or flow rate, $m^3.day^{-1}$

'K' hydraulic conductivity of the fluid through porous media, $m.day^{-1}$

' i' hydraulic gradient, m/m

'a' is filter bed area, $m^2$

### 3.5.2 Determination of flow velocity

The velocity of drop of water at any point along its flow path depends upon the size of the pore and its position inside the pores. It can be determined as follows,

$$V = Ki \qquad \text{... (20)}$$

### 3.5.3 Determination of surface area of filter bed (A)

$$\text{Surface area (A)} = \frac{\Pi\ D2}{4}$$

... (21)

Where,

'D' the diameter of filtration pipe, mm

### 3.5.4 Determination of Hydraulic Loading Rate (HLR)

Hydraulic Loading Rate (HLR) expressed as expected flow divided by plan filter bed area. It has been calculated by using following formula as,

$$HLR = \frac{Q}{A} \qquad \text{… (22)}$$

Where,

HLR hydraulic Loading Rate, m/hr

'Q' expected flow, $m^3$/hr

'A' filter bed area, $m^2$

### 3.5.5 Dimensions of filter bed

The depth of bed of various filtration media had been decided by experimentation. The area of bed as width, length or diameter was worked out from design capacity of filter unit considering hydraulic retention time. The one step which is important in design is to determine the size the bed; bed area and depth of the beds are the basic dimensions that drive the rest of the design. The depth of the bed affects the time available for treatment and so its efficiency. Total depth for all beds (multilayer filter) in filter unit is, 180 cm which is required for the proper functioning of bed.

### 3.5.6 Determination of Volume of filter unit (V)

The volume of the filter unit has been determined by using following formula as,

$$V = A \times d \qquad \text{... (23)}$$

### 3.5.7Determination of Hydraulic Retention Time (HRT)

The water retention is greater with sands that have a higher uniformity coefficient due to smaller pore volumes and higher bulk densities. These conditions run counter to the objective for a good filter media, which should have sufficiently large pore spaces to allow ample oxygenation and unsaturated flow around the sand particles. The

Hydraulic retention time (HRT) is measured by the average length of time that a soluble compound remains in a constructed filtration beds.

### 3.5.8 Determination of Average Interstitial Velocity

$$V = \frac{Q}{A} \qquad \text{... (24)}$$

The velocity in above equation is referred to the Darcy's velocity because it assumes that flow occurs through the entire cross section of the material without regard to solids and pores. (Todd, 1980)

Actually, the flow is limited to the pores space only so that the average interstitial velocity was determined by using below formula as,

$$V_a = \frac{Q}{\alpha A} \qquad \text{… (25)}$$

Where, 'α' is porosity in percent. The actual velocity depends on specifying a precise point location within the medium.

### 3.5.9 Determination of equivalent vertical hydraulic conductivity for a stratified material ($K_z$)

The equivalent vertical hydraulic conductivity for a stratified material for four layers was determined by using below formula as,

$$Kz = \frac{Z1 + Z2 + Z3 + Z4 + Z5}{\frac{Z1}{K1} + \frac{Z2}{K2} + \frac{Z3}{K3} + \frac{Z4}{K4} + \frac{Z5}{K5}} \qquad \text{... (26)}$$

Where, z1, z2, z3 and z4 are depths of filtration media and k1, k2, k3 and k4 are hydraulic conductivities of filtration media respectively. (Todd, 1980)

### 3.5.10 Determination of types of flow on the basis of Reynolds number in four filtration media

Reynolds number is expressed as follows,

$$N_R = \frac{\rho v D}{\mu} \qquad \text{… (27)}$$

Where,

'ϱ' fluid density, $kg/m^3$

'V' velocity (m/s) or (m/day)

'D' diameter of sand (effective size $d_{10}$)

'μ' viscosity of fluid ($0.9\times10^{-3}$ $N\text{-}s/m^2$) (Barrett, 1991)

### 3.5.11 Frictional head loss through media

Head loss within a slow sand filter is caused by flow through the schmutzdecke and the sand bed. As the filter is operated, the schmutzdecke develops and its hydraulic resistance increases, causing most of the head loss. Darcy law can be applied to flow in laminar range through any porous medium. For homogeneous porous media Darcy law usually expressed in finite terms,

$$V = -K \frac{hL}{\Delta Z}$$

… (28)

Where,

V = Superficial velocity also called hydraulic loading rate, Q/A, (m/hr)

$h_L$= Head loss available across the filter bed from head water to tail water(m)

z = Flow distance through porous media (m)

K= Hydraulic conductivity of porous media (m/hr)

dh/dz= Hydraulic gradient (loss of head/unit length of flow, m/m)

For homogeneous porous media Darcy law usually expressed in finite terms,

$$V = -K \frac{hL}{\Delta Z}$$

… (29)

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# IV. RESULTS AND DISCUSSION

The present investigation was undertaken with view to study physical and chemical parameters of domestic waste or grey water and to design small scale waste water treatment plant for Jayaprabha girls' hostel of Dr. BSKKV, Dapoli. The treated water can be used for irrigating horticultural crops as well as gardens. The grey water generated from bathrooms, basins and kitchen of the Jayaprabha hostel were analysed by using different media during December to February, 2015. Grey water sample was filtered through individual filtration media which were easily available. These filtration media filled in four tanks included gravel, grit, sand and broken brick and the waste water sample filtered individually through those media at the depth of 45 cm, 30 cm and 15 cm respectively.

These results were analysed for individual filtration medium at the depth of 45 cm, 30 cm, and 15 cm for selection of medium and its efficient depth. After selection of efficient depth of layers, a small scale filtration unit was fabricated. This grey water treatment plant is a combination of natural and physical operations. All the natural and easily available low cost materials were used for the treatment process. After that, analysis of physical and chemical properties of treated grey water for combination of filtration media, along with charcoal, water quality was decided.

The physical and chemical properties of untreated and treated grey water were determined. Under physical properties, temperature, colour, turbidity and odour were studied. The effect of media and depth on various chemical properties such as pH, EC, TDS, potassium, calcium, carbonates and bicarbonates, magnesium, nitrogen, sodium, SAR, RSC, oil and grease, BOD and COD were found out. The results of analysis were used for design of small scale waste water treatment plant.

This filtration unit or model showed better and effective performance by the experiment and balances the advantages and disadvantages of the system. As per the Indian Standards, the treated grey water can be used for landscaping, gardening and irrigation which is aim of this research. Hence, on the large scale grey water treatment plant is more beneficial and economical for the Jayaprabha hostel as well as college campus development. The results presented in this study establish the potential applicability of the developed methodology. The observations were taken during 6.30 am to 6.30 pm consequently for seven days. The data collected were analyzed and hourly, daily discharge, peak flow rate, peak hours were determined.

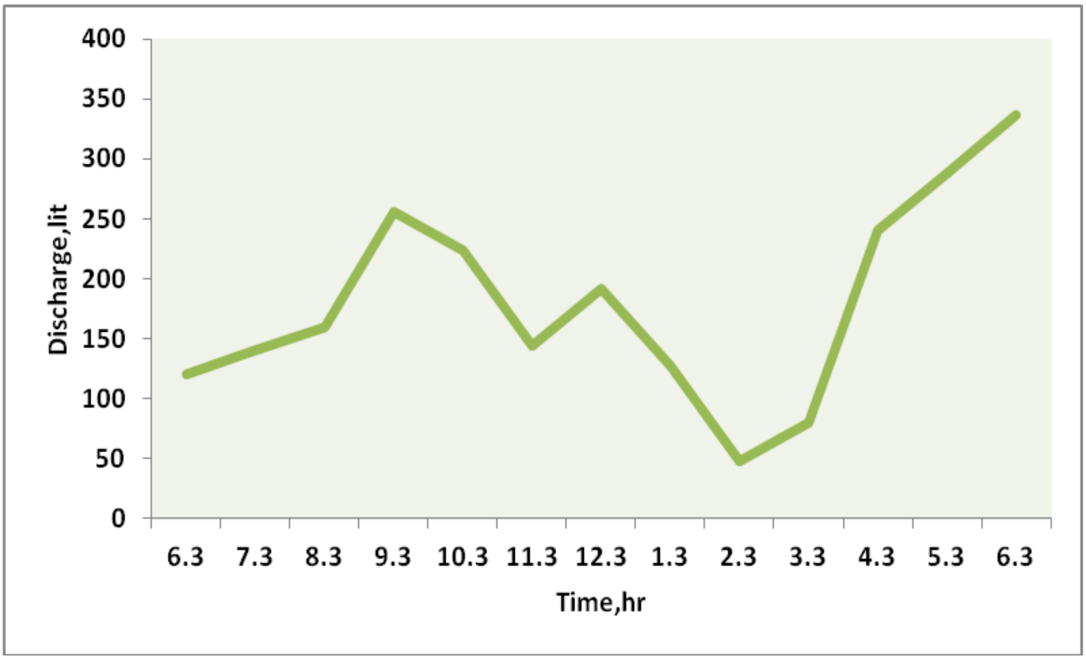


**Fig. 4.1 Graph of discharge Vs Time**

## 4.1 Physical properties of grey water after treatment

### 4.1.1 Temperature

Grey water temperature is often higher than the temperature of raw water supply due to hot tap water used for personal hygiene and laundry. Temperature of treated grey water was higher than untreated grey water. The study shows that untreated and treated grey water have 27˚C and 28˚C temperature, respectively at peak flow time of morning.

### 4.1.2 Colour

The cloudiness of grey water is caused by large number of individual particles. Removal efficiency of colour was found by using designed small scale waste water treatment plant.

### 4.1.3 Turbidity

The measurement of turbidity is a key test of water quality. It is a measure of cloudiness of water, i.e. higher turbidity indicates greater murkiness, which is a result of the presence of suspended solids in the water, could potentially shield microbes and increase treatment loading. The untreated grey water obtained 80 NTU and was reduced by filtration process up to 30 NTU. Results are matching with previous research (Uveges, *et al*. 2013).

### 4.1.4 Odour

The odour of untreated grey water found was non-offensive at all times. The odour of treated grey water was reduced substantially. Individual brick showed good results due to higher adsorption capacity.

**Table 4.1Physical properties of untreated and treated grey water**

| Sr. No. | Properties | Untreated | Treated |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1. | Temperature | 27˚C | 28˚C |
| 2. | Colour | Cloudy | Clear |
| 3. | Turbidity | 80 NTU | 30 NTU |
| 4. | Odour | Non offensive | Reduced |

## 4.2 Results of Chemical properties of grey water before and after treatment for individual filtration media

The chemical analysis of grey water was done at the laboratory of Department of Agricultural Chemistry and Soil Science, College of Agriculture, Dapoli. Also analysis for turbidity, BOD and COD was done at Department of Chemical Engineering, Gharda Institute of Technology, Lavel, Tal. Khed, Dist. Ratnagiri. The combine results of all chemical parameters are presented in Table 4.2.

**Table 4.2 Chemical parameters concentration of domestic grey water on the basis of depth and media**

| Depths | pH | EC (microm -hos/cm) | TDS (mg/ℓ) | Ca (me/ℓ) | $HCO_3$ (me/ℓ) | K (me/ℓ) | N (mg/ℓ) | Mg (me/ℓ) | Na (me/ℓ) | SAR | RSC (me/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $D_1$ | 6.66 | 94.4 | 61.78 | 0.76 | 1.56 | 1.54 | 3.72 | 0.32 | 0.59 | 0.81 | 0.47 |
| $D_2$ | 6.54 | 133.79 | 88.95 | 0.85 | 2.01 | 1.94 | 2.51 | 0.41 | 0.62 | 0.79 | 0.79 |
| $D_3$ | 6.43 | 179.78 | 114.75 | 0.82 | 2.36 | 2.16 | 2.39 | 0.36 | 0.69 | 0.89 | 1.17 |
| Inlet | 6.49 | 298.13 | 190.8 | 1.1 | 3.53 | 6.2 | 7.53 | 1.26 | 1.44 | 1.31 | 1.46 |
| SE | 0.06 | 11.52 | 6.88 | 0.04 | 0.05 | 0.047 | 0.07 | 0.031 | 0.008 | 0.03 | 0.069 |
| CD | 0.17 | 33.79 | 20.19 | NS | 0.16 | 0.14 | 0.2 | 0.09 | 0.02 | 0.09 | 0.2 |
| | | | | | | | | | | | |
| **Media** | **pH** | **EC (microm -hos/cm)** | **TDS (mg/ℓ)** | **Ca (me/ℓ)** | **$HCO_3$ (me/ℓ)** | **K (me/ℓ)** | **N (mg/ℓ)** | **Mg (me/ℓ)** | **Na (me/ℓ)** | **SAR** | **RSC (me/ℓ)** |
| $M_1$ | 6.24 | 125.07 | 80.04 | 0.8 | 1.98 | 1.42 | 2.81 | 0.24 | 0.81 | 1.06 | 0.93 |
| $M_2$ | 6.42 | 111.62 | 71.01 | 0.76 | 2.3 | 0.83 | 2.18 | 0.38 | 0.55 | 0.76 | 1.16 |
| $M_3$ | 7.16 | 185.7 | 125.12 | 0.78 | 1.48 | 3.93 | 2.8 | 0.33 | 0.74 | 0.97 | 0.43 |
| $M_4$ | 6.34 | 121.57 | 77.81 | 0.91 | 2.14 | 1.33 | 3.7 | 0.52 | 0.44 | 0.52 | 0.72 |
| Inlet | 6.49 | 298.13 | 190.81 | 1.1 | 3.53 | 6.2 | 7.53 | 1.26 | 1.45 | 1.31 | 1.46 |
| SE | 0.067 | 13.3 | 7.95 | 0.05 | 0.06 | 0.05 | 0.08 | 0.03 | 0.009 | 0.03 | 0.07 |
| CD | 0.23 | 39.02 | 23.32 | NS | 0.18 | 0.16 | 0.24 | 0.1 | 0.02 | 0.11 | 0.23 |

### 4.2.1Effect of depth and media on pH

The Table 4.2 shows quality parameters concentration of domestic grey water the basis of depth and media. It is clear from the table, the pH values varied with different depths of media. The maximum pH was observed in depth $D_1$ (6.66) which was significantly more than $D_3$ (6.43) but at par with $D_2$. While considering media, the pH values varied with different media. The maximum pH was observed in media $M_3$ (7.16) which was significantly more than remaining media $M_1$, $M_2$ and $M_4$.

Acidic water can also have detrimental effects on plant growth, particularly causing nutritional problem, pH less than 6 indicating corrosiveness which can lead to damage to metal pipes, tanks and fittings. Waste water alkalinity maintains original soil pH. Therefore selected maximum value of pH for deciding efficient depth of layer.

**Table 4.3 Interaction effect of depth and media on pH**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 6.34 | 6.53 | 7.26 | 6.51 | 6.56 |
| **$D_2$** | 6.26 | 6.44 | 7.16 | 6.31 | 6.54 |
| **$D_3$** | 6.13 | 6.32 | 7.08 | 6.21 | 6.43 |
| **Mean** | 6.24 | 6.43 | 7.17 | 6.34 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 0.06 | 0.067 | 0.11 | | |
| **CD** | 0.17 | 0.23 | NS | | |

The interaction effect of media on pH of treated water was found to be non significant. It indicates that as depth increased in all the media, pH is decreased. However maximum pH was obtained in media $M_3$ at the depth $D_1$ or combination of $M_3D_1$ followed by $M_3D_2$ whereas minimum was obtained in media $M_1D_3$. Graphical representation of effect of depth and media on pH is shown in Fig. 4.2.

### 4.2.2Effect of depth and media on electrical conductivity (micromhos/cm)

The effect of depth and media on EC was shown in Table 4.2. In general waters with conductivity values less than 750 micromhos/cm are satisfactory for irrigation. Waters in the range of 750 to 2250 micromhos/cm are widely used and satisfactory for crop growth. (Allison *et al*., 1953). All the values of EC obtained in Table 4.2, which are below the range of above mentioned permissible limit. Therefore all are safe for irrigation. However, minimum value of EC for deciding efficient depth of media for filtration unit was selected. As regards, effect of depth on EC, it was observed that, the minimum EC was found in $D_1$ (94.40), followed by $D_2$ (133.79) and $D_3$ (179.78). The EC due to depth $D_1$ was significantly less than $D_2$. Also EC due to $D_2$ was significantly less than $D_3$. However, EC due to medium $M_2$ was significantly less than $M_3$ (185.7) but at par with M1 and $M_4$.

**Table 4.4 Interaction effect of depth and media on EC (micromhos/cm) or µ**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 88.02 | 38.43 | 151.66 | 99.5 | 94.4 |

| | | | | | |
|---|---|---|---|---|---|
| **$D_2$** | 122.4 | 129.86 | 165.96 | 116.93 | 133.79 |
| **$D_3$** | 164.8 | 166.56 | 239.46 | 148.3 | 179.78 |
| **Mean** | 125.07 | 111.62 | 185.7 | 121.57 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 11.52 | 13.3 | 23.04 | | |
| **CD** | 33.79 | 39.02 | NS | | |

The interaction effect of media and depth on EC of treated water was found non significant, indicating that as depth decreased in all the media, EC increased. However minimum EC obtained in media $M_2$ at depth $D_1$ or combination of $M_2D_1$. Graphical representation of effect of depth and media on EC is shown in Fig. 4.3

### 4.2.3 Effect of depth and media on Total Dissolved Solids (mg/ℓ)

It is clear from Table 4.2 that mean TDS was affected by different depths of media. High concentration of dissolved solids adversely affects on crop growth and can also cause salt problems. TDS level for irrigation water is in the range of 500 to 2000 mg/lit (Rowe and Abdel, 1995). Therefore minimum values were selected for deciding efficient depth of media. The minimum TDS was observed in depth $D_1$ (61.78) which was significantly less than $D_3$ (114.75). However, based on values presented in Table 4.2 it was not at par with $D_2$ (88.95). Also, minimum TDS was observed in medium $M_2$ (71.01) which was significantly less than $M_3$ (125.12) but at par with $M_1$ and $M_4$.

**Table 4.5 Interaction effect of depth and media on TDS (mg/ℓ)**

| Depth | **Media** | | | | |
|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 56.69 | 24.59 | 102.16 | 63.67 | 61.78 |
| **$D_2$** | 77.97 | 82.91 | 120.1 | 74.83 | 88.95 |
| **$D_3$** | 105.47 | 105.52 | 153.07 | 94.91 | 114.74 |
| **Mean** | 80.04 | 71.01 | 125.12 | 77.81 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 6.88 | 7.95 | 13.76 | | |
| **CD** | 20.19 | 23.32 | NS | | |

The interaction effect of media and depth on TDS of treated water was found non significant, indicating that as depth decreased, TDS increased. However minimum TDS was obtained in medium $M_2$ at depth $D_1$ or combination of $M_2D_1$. Graphical representation of effect of depth and media on TDS is shown in Fig. 4.4

### 4.2.4 Effect of depth and media on Calcium (me/ℓ)

As regards, effect of depth on calcium, it was seen that, calcium values varied with different depths of media. Irrigation water contains ample amount of calcium is most desirable. The maximum Ca was observed in depth $D_2$ and medium $M_4$.

**Table 4.6 Interaction effect of depth and media on Calcium (me/ℓ)**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | $M_1$ | $M_2$ | $M_3$ | $M_4$ | Mean |
| $D_1$ | 0.8 | 0.7 | 0.76 | 0.76 | 0.76 |
| $D_2$ | 0.87 | 0.8 | 0.83 | 0.9 | 0.85 |
| $D_3$ | 0.73 | 0.76 | 0.73 | 1.06 | 0.83 |
| Mean | 0.8 | 0.75 | 0.77 | 0.91 | |
| | Depth | Media | Interaction | | |
| SE | 0.04 | 0.05 | | | |
| CD | NS | NS | | | |

The interaction effect of media and depth on Ca of treated water was found non significant. However, maximum Ca was observed in medium $M_4$ at the depth $D_3$ or combination of $M_4D_3$ followed by $M_4D_2$. Graphical representation of effect of depth and media on Ca is shown in Fig. 4.5

### 4.2.5 Effect of depth and media on Bicarbonate (me/ℓ)

The mean bicarbonate values were affected by different depths of media as reported in Table 4.2. The over use of high concentration of bicarbonate in irrigation water can contribute to a soil dominant in sodium, result in low infiltration rate. The minimum value of bicarbonate observed in depth $D_1$ (1.56) which was significantly lower than $D_2$ and $D_3$. Considering media, the minimum bicarbonate 1.48 was observed in medium $M_3$ followed by $M_1$ (1.98), $M_4$ (2.1) and $M_2$ (2.3). Also, $M_1$ and $M_4$ were at par with each other.

**Table 4.7 Interaction effect of depth and media on Bicarbonate (me/ℓ)**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | $M_1$ | $M_2$ | $M_3$ | $M_4$ | Mean |
| $D_1$ | 2 | 1.37 | 1.4 | 1.46 | 1.55 |
| $D_2$ | 1.97 | 2.33 | 1.5 | 2.26 | 2.01 |
| $D_3$ | 1.97 | 3.2 | 1.56 | 2.7 | 2.36 |
| Mean | 1.98 | 2.3 | 1.48 | 2.14 | |
| | Depth | Media | Interaction | | |
| SE | 0.05 | 0.06 | 0.11 | | |
| CD | 0.16 | 0.18 | 0.32 | | |

It is clear from Table 4.7, with respect to the interaction effect of media and depth on bicarbonate, minimum value of 1.37 was obtained in treatment combination $M_2D_1$ followed by $M_3D_1$. Graphical representation of effect of depth and media on bicarbonate is shown in Fig. 4.6

### 4.2.6 Effect of depth and media on Potassium (me/ℓ)

From Table 4.2 it was found mean K value was affected by different depth of media. Also, mean value of K was increased with decrease in depth of media. Potassium considered nutrient for plant growth. As regards effect of depth on K, it was observed that, the maximum K was found in $D_3$ (2.16) followed by $D_2$ (1.94) and $D_1$ (1.54). The potassium due to depth $D_3$ was significantly more than $D_1$ and $D_2$. They were also at par with each other. The maximum mean value of potassium obtained in media $M_3$ (3.93), which was significantly more than remaining media. Also, $M_1$ and $M_4$ were at par with each other.

**Table 4.8 Interaction effect of depth and media on Potassium (me/ℓ)**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 0.8 | 0.75 | 3.55 | 1.05 | 1.53 |
| **$D_2$** | 1.56 | 0.8 | 4.1 | 1.3 | 1.94 |
| **$D_3$** | 1.9 | 0.95 | 4.15 | 1.65 | 2.16 |
| **Mean** | 1.42 | 0.83 | 3.93 | 1.33 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 0.047 | 0.05 | 0.09 | | |
| **CD** | 0.14 | 0.16 | 0.28 | | |

It is clear from Table 4.8, the interaction effect of media and depth on K, it observed that the maximum value was obtained in medium $M_3$ at depth $D_3$ or treatment combination $M_3D_3$ followed by $M_3D_2$. Graphical representation of effect of depth and media on K is shown in Fig.4.7

### 4.2.7 Effect of depth and media on Nitrogen (mg/ℓ)

The Table 4.2 concluded that the mean nitrogen values were affected by different depth of media. Also N values decreases with decrease in depth of media. Nitrogen promotes succulence in forage crops and leafy vegetables. However it considered beneficial nutrient for plant growth. Ammonium nitrogen constituted 61 per cent of the total nitrogen. The nitrogen in grey water mainly originates from protein contained in food residues, household cleaning products, and personal care products (Del Porto Steinfeld, 2000).When use at recommended rates, nitrogen improves the overall quality of crops and stimulates the utilization of P, K and other essential nutrients. As regards, effect of depth on N, it was observed that, the maximum mean value of N was found in $D_1$ (3.72) followed by $D_2$ (2.51) and $D_3$ (2.39). The N due to depth $D_1$ was significantly more than $D_2$ and $D_3$. Also $D_2$ and $D_3$ were at par with each other. Similarly, the maximum N was obtained in medium $M_4$ (3.7) followed by $M_3$ (2.81). Also, $M_1$ and $M_3$ were at par with each other.

**Table 4.9 Interaction effect of depth and media on Nitrogen (mg/ℓ)**

| Depth | Media | | | | |
|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| **$D_1$** | 4.1 | 2.56 | 4.33 | 3.9 | 3.72 |
| **$D_2$** | 2.66 | 1.6 | 1.5 | 4.26 | 2.5 |
| **$D_3$** | 1.66 | 2.4 | 2.56 | 2.93 | 2.39 |
| **Mean** | 2.81 | 2.18 | 2.8 | 3.7 |  |
|  | **Depth** | **Media** | **Interaction** |  |  |
| **SE** | 0.07 | 0.08 | 0.14 |  |  |
| **CD** | 0.2 | 0.24 | 0.41 |  |  |

It is clear from Table 4.9 that the interaction effect of depth and media on nitrogen of treated water was found to be significant. However, maximum N was obtained in media $M_4$ at depth $D_2$ or combination of $M_4D_2$, followed by $M_4D_1$. Graphical representation of effect of depth and media on N is shown in Fig. 4.8

### 4.2.8Effect of depth and media on Magnesium (me/ℓ)

The mean Mg values were affected by different depths of media estimated in Table 4.2. The magnesium is considered as a plant nutrient and it is essential for plant growth and soil physical properties. Therefore maximum value of Mg was selected for deciding efficient depth of media which contributed in determination of Residual Sodium Carbonate (RSC). As regards the maximum mean Mg was observed in depth $D_2$ (0.41) at par with $D_1$ and $D_3$. Similarly, the maximum Mg was obtained in media $M_4$. The Mg of medium $M_2$ and $M_3$ were at par with each other but significantly less than $M_4$.

**Table 4.10 Interaction effect of depth and media on Magnesium (me/ℓ)**

| **Depth** | **Media** |  |  |  |  |
|---|---|---|---|---|---|
|  | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 0.23 | 0.35 | 0.35 | 0.37 | 0.32 |
| **$D_2$** | 0.25 | 0.43 | 0.4 | 0.56 | 0.41 |
| **$D_3$** | 0.23 | 0.35 | 0.23 | 0.63 | 0.36 |
| **Mean** | 0.24 | 0.38 | 0.33 | 0.52 |  |
|  | **Depth** | **Media** | **Interaction** |  |  |
| **SE** | 0.03 | 0.03 | 0.06 |  |  |
| **CD** | 0.09 | 0.1 | NS |  |  |

The interaction effect of media and depth on Mg of treated water was found to be non significant, indicating that various depth and media affected on Mg of treated water. However, maximum Mg was obtained in medium $M_4$ at the depth $D_3$ or combination of $M_4D_3$ followed by $M_4D_2$, whereas minimum value was obtained in $M_1D_1$. Graphical representation of effect of depth and media on Mg is shown in Fig. 4.9

### 4.2.9Effect of depth and media on Sodium (me/ℓ)

The mean sodium values were affected by different depths of media as reported in Table 4.2. Sodicity refers specially to the amount of sodium present in irrigation water. Irrigation with water that has excess amounts of sodium can adversely impact soil structure, making plant growth difficult. Highly saline and sodic water qualities can cause problems for irrigation, depending on the type and amount of salt present. (Krista *et al.* 2003). The three main problems caused by sodium induced dispersion are reduced infiltration, reduced hydraulic conductivity and surface crusting. The minimum mean sodium was observed in depth $D_1$ (0.59). $D_1$ and $D_2$ were at par with each other but there is significant difference between $D_1$ and $D_3$.However, the minimum sodium was obtained in $M_2$ (0.55) which was significantly less than all media.

**Table 4.11 Interaction effect of depth and media on Sodium (me/ℓ)**

| | Media | | | | |
|---|---|---|---|---|---|
| **Depth** | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 0.78 | 0.46 | 0.85 | 0.3 | 0.59 |
| **$D_2$** | 0.77 | 0.45 | 0.78 | 0.46 | 0.62 |
| **$D_3$** | 0.87 | 0.76 | 0.61 | 0.55 | 0.69 |
| **Mean** | 0.81 | 0.55 | 0.75 | 0.44 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 0.06 | 0.07 | 0.01 | | |
| **CD** | 0.2 | 0.23 | 0.04 | | |

The interaction effect of media and depth on Na of treated water was found to be significant. However, minimum Na was obtained in medium $M_4$ at the depth $D_1$ or combination of $M_4D_1$ and maximum Na was obtained at medium $M_1$ at the depth $D_3$ or combination of $M_1D_3$. Graphical representation of effect of depth and media on Na is shown in Fig. 4.10

### 4.2.10 Effect of depth and media on Sodium Adsorption Ratio (SAR)

The mean SAR values were affected by different depths of media estimated in table 4.2. If the proportion of sodium is high, the alkali hazard is high, and, conversely, if calcium and magnesium predominate, the hazard is low. As per classification of irrigation water on the basis of EC (micromhos/cm) and SAR, the estimated values of EC and SAR were 155 micromhos/cm and 0.92, respectively. The estimated values were classified in class $C_1S_1$ (Allison et al., 1953). $C_1$ refers conductivity of low salinity water. It can be used for irrigation with most crops. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. Also $S_1$ refers low sodium water. It can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

The mean SAR values were fluctuated by different depths of media estimated in table 4.2. As regards effect of depth on SAR observed that the minimum SAR was found in $D_1$ (0.59). The SAR due to depth $D_1$ was significantly less than $D_3$ but at par with $D_2$.

**Table 4.12 Interaction effect of depth and media on SAR**

| | Media | | | | |
|---|---|---|---|---|---|
| **Depth** | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 1.09 | 0.68 | 1.05 | 0.42 | 0.81 |
| **$D_2$** | 1.05 | 0.58 | 0.98 | 0.54 | 0.79 |
| **$D_3$** | 1.05 | 1.01 | 0.89 | 0.61 | 0.89 |
| **Mean** | 1.06 | 0.76 | 0.98 | 0.52 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 0.03 | 0.03 | 0.06 | | |
| **CD** | 0.09 | 0.11 | 0.19 | | |

The interaction effect of media and depth on Na of treated water was found to be significant, indicating that various depth and media affected on SAR of treated water. However, minimum SAR was obtained in medium $M_4$ at the depth $D_1$ or combination of $M_4D_1$ followed by $M_4D_2$ and maximum SAR was obtained at medium $M_1$ at the depth $D_1$ or combination of $M_1D_1$. Graphical representation of effect of depth and media on SAR is shown in Fig. 4.11

### 4.2.11 Effect of depth and media on Residual Sodium Carbonate (RSC), me/ℓ

The mean SAR values were affected by different depths of media as reported in Table 4.2. The sodium permeability hazard for irrigation water is usually assessed when bicarbonate and carbonate levels are greater than 120 and 15mg/ℓ, respectively. RSC is a common means of assessing the sodium permeability hazard, and takes into account that the bicarbonate/carbonate and calcium or magnesium concentrations in irrigation water. Water with RSC value of 1.25 me/ℓ or lower is safe for irrigation. RSC values between 1.25 and 2.5 me/ℓ considered marginal and above 2.5 me/ ℓ is considered excessive. (Guidelines for saline sodic water quality suitable for irrigation, Ayers and Tanji, 1981)

As regards, the effect of depth on RSC, it was observed that, the minimum mean RSC was found in depth $D_1$ (0.47) followed by $D_2$ (0.79) and $D_3$ (1.17). The RSC due to depth $D_3$ was significantly more than $D_1$ and $D_2$.The minimum RSC was obtained in medium $M_3$ (0.43) followed by $M_4$ (0.72). Also RSC of medium $M_1$ and $M_2$, also $M_1$ and $M_4$ were at par with each other.

**Table 4.13 Interaction effect of depth and media on RSC (me/ℓ)**

| | Media | | | | |
|---|---|---|---|---|---|
| **Depth** | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **Mean** |
| **$D_1$** | 0.96 | 0.32 | 0.28 | 0.33 | 0.47 |
| **$D_2$** | 0.85 | 1.1 | 0.43 | 0.8 | 0.79 |
| **$D_3$** | 1 | 2.08 | 0.6 | 1.03 | 1.18 |
| **Mean** | 0.94 | 1.16 | 0.44 | 0.72 | |
| | **Depth** | **Media** | **Interaction** | | |
| **SE** | 0.06 | 0.07 | 0.14 | | |
| **CD** | 0.2 | 0.23 | 0.4 | | |

The interaction effect of media and depth on RSC of treated water was found to be significant, indicating that various depth and media affected on RSC of treated water. However, minimum RSC was obtained in medium $M_3$ at the depth $D_1$ or combination of $M_3D_1$ followed by $M_4D_1$ and maximum RSC was obtained at medium $M_2$ at the depth $D_3$ or combination of $M_2D_3$. Graphical representation of effect of depth and media on RSC is shown in Fig. 4.12

### 4.2.12 Saponification value for oil and grease

**Table 4.14 Results of Saponification values for oil and grease**

| Sr.No. | Media | Saponification value |
|---|---|---|
| 1. | Gravel | 4.76 |
| 2. | Grit | 5.6 |

| | | |
|---|---|---|
| 3. | Sand | 12.88 |
| 4. | Broken brick | 10.36 |

Saponification value describes the number of milligrams of KOH required to neutralize the fatty acids resulting from the complete hydrolysis of 5 ml of fat or oil and grease. In present study, saponification values were determined for four filtration media such as gravel, grit, sand and broken bricks. From the results it observed that, the saponification value for untreated grey water reduced up to 4.76. It means that, 4.76 milligrams of KOH required to neutralize the fatty acids resulting from the complete hydrolysis of 5 ml of fat or oil if media $M_1$ i.e. gravel is used up to the depth of 45 cm. Also it observed that, the determined saponification values for various filtration media which are less than the saponification value of untreated or unfiltered water. It means that the saponification values can be reduced up to certain level by using these various types of filtration media. From the results obtained, saponification values for various filtration media such as gravel, grit, sand and broken bricks were 4.76, 5.6, 12.88 and 10.36, respectively.

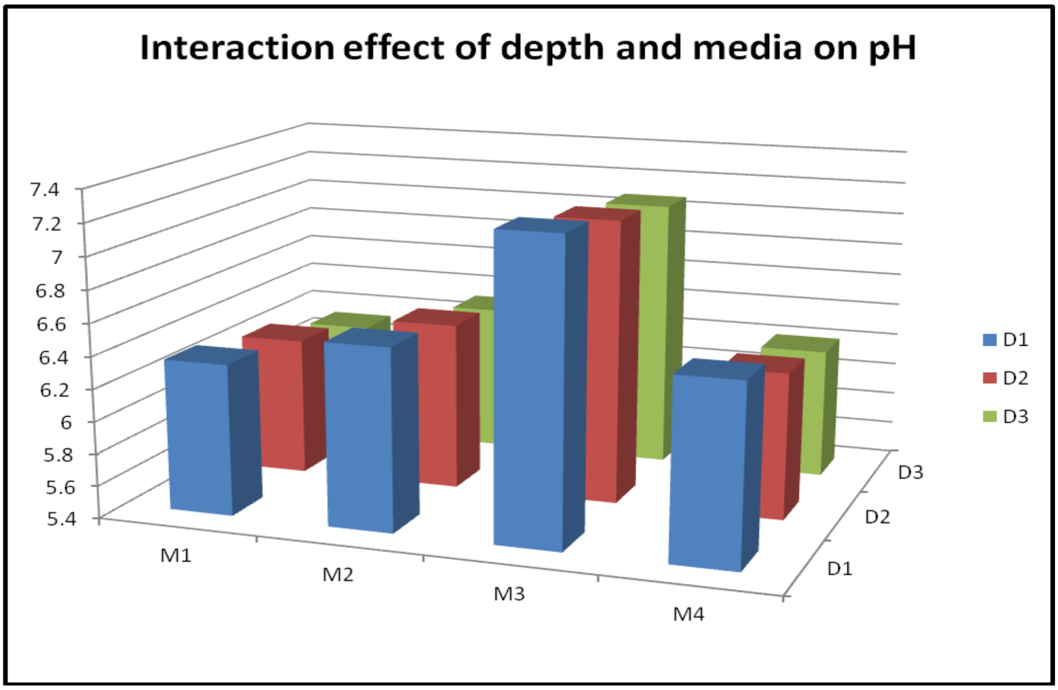


**Fig. 4.2 Interaction effect of depth and media on pH**

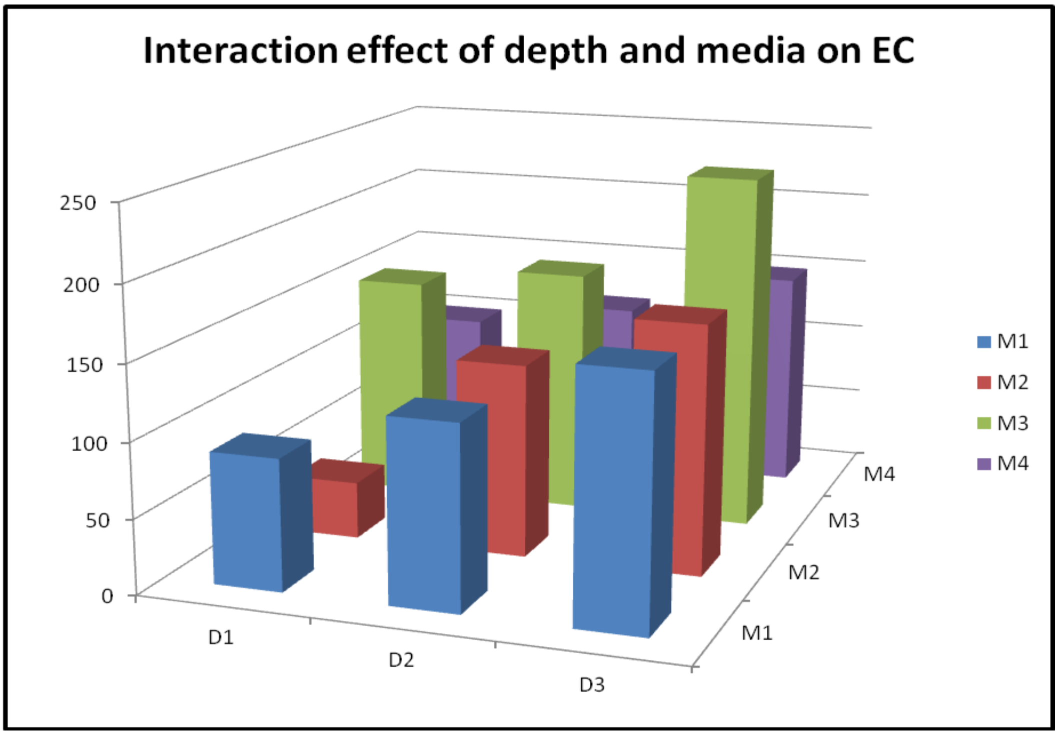


**Fig. 4.3 Interaction effect of depth and media on EC**

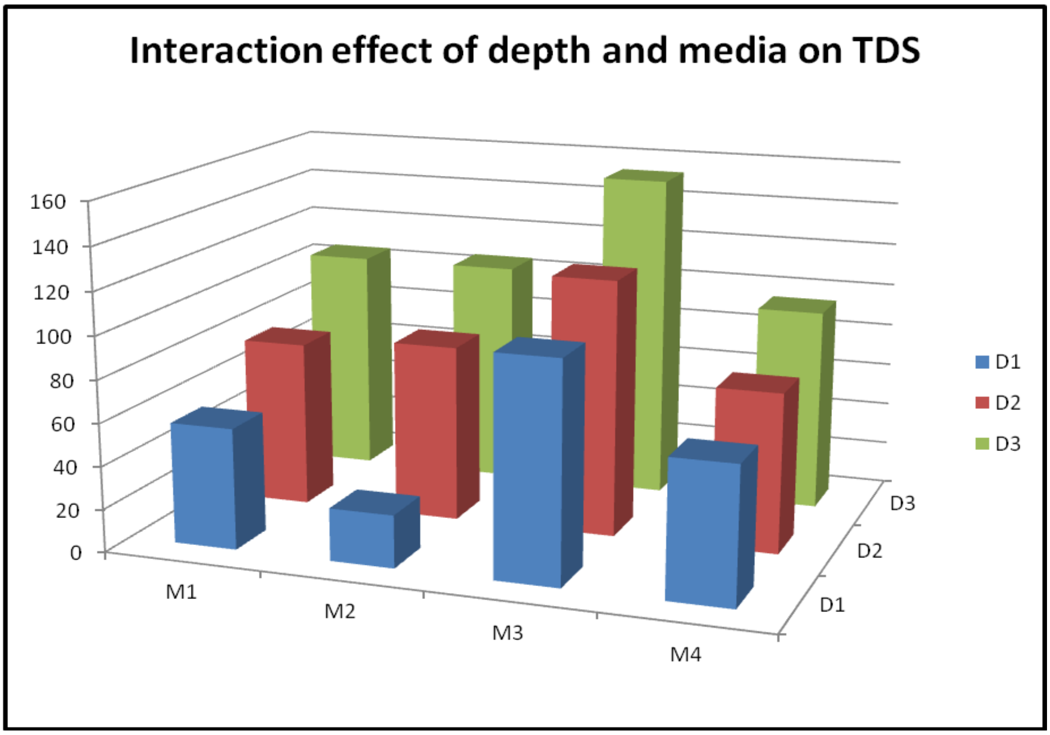


**Fig. 4.4 Interaction effect of depth and media on TDS**

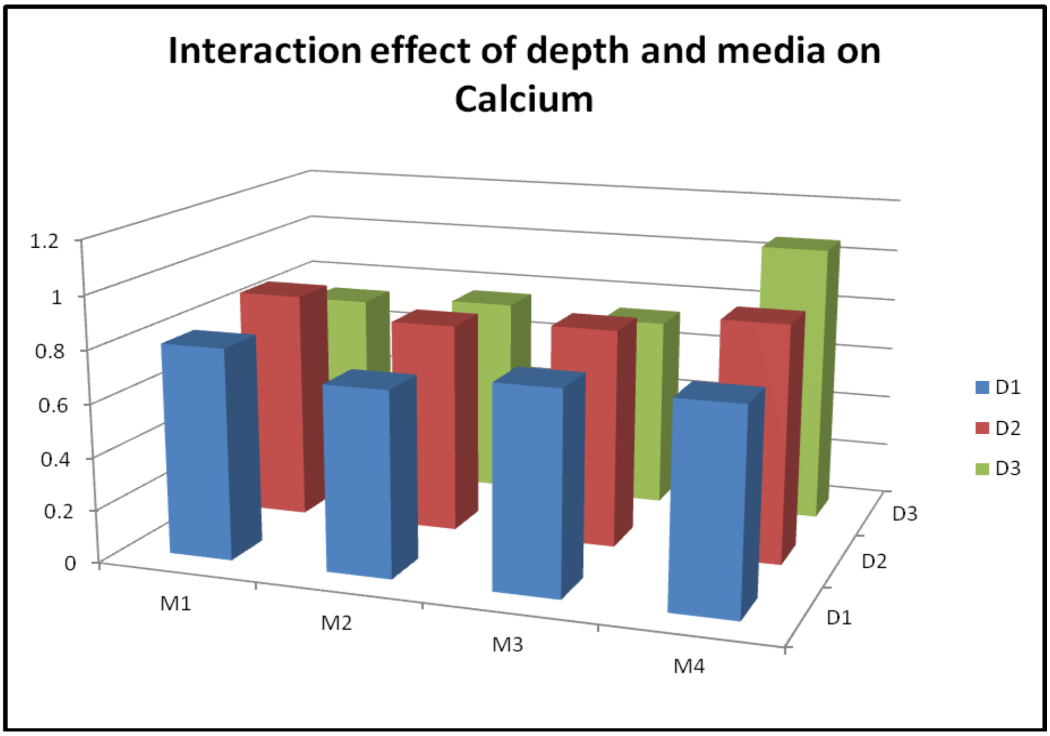


**Fig. 4.5 Interaction effect of depth and media on Calcium**

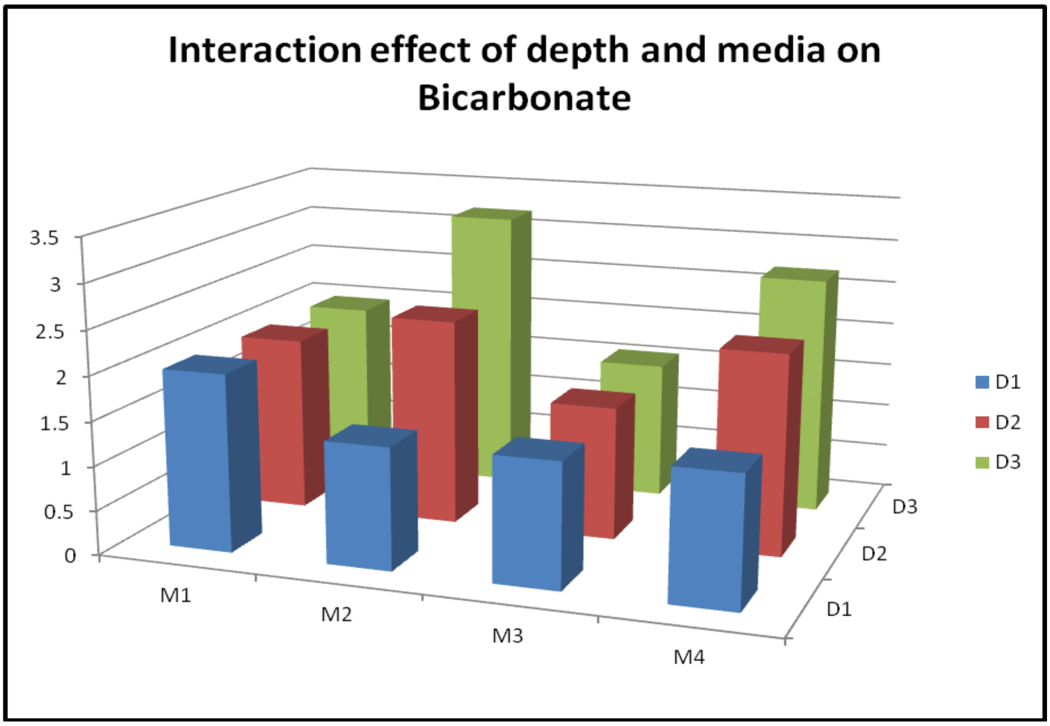


Fig. 4.6 Interaction effect of depth and media on Bicarbonate

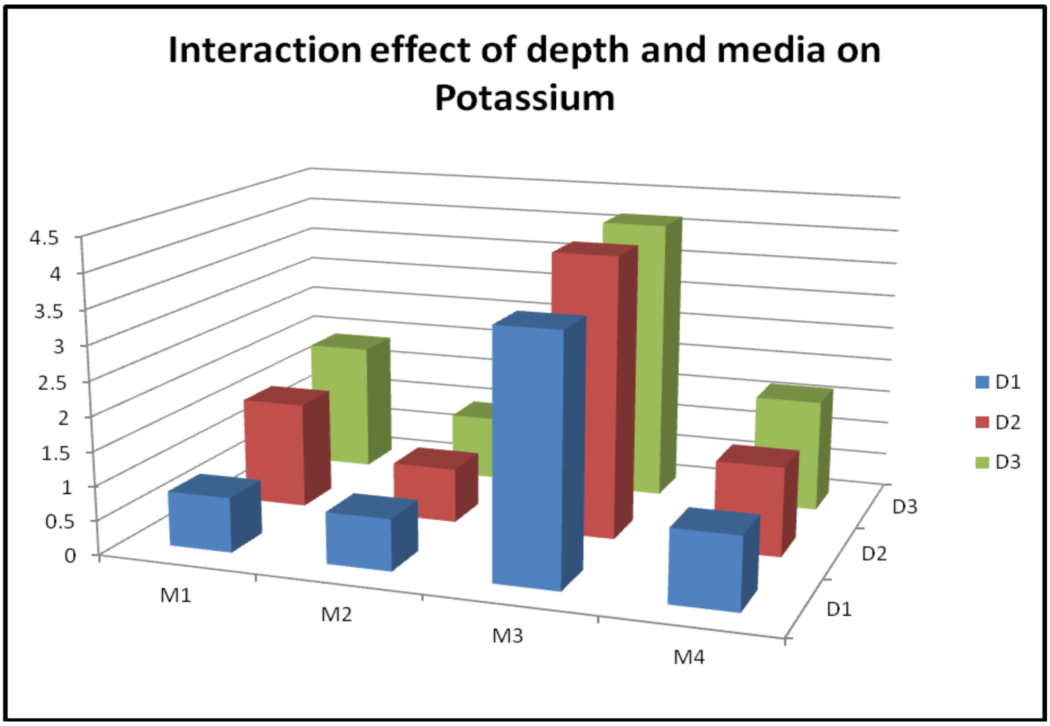


Fig. 4.7 Interaction effect of depth and media on Potassium

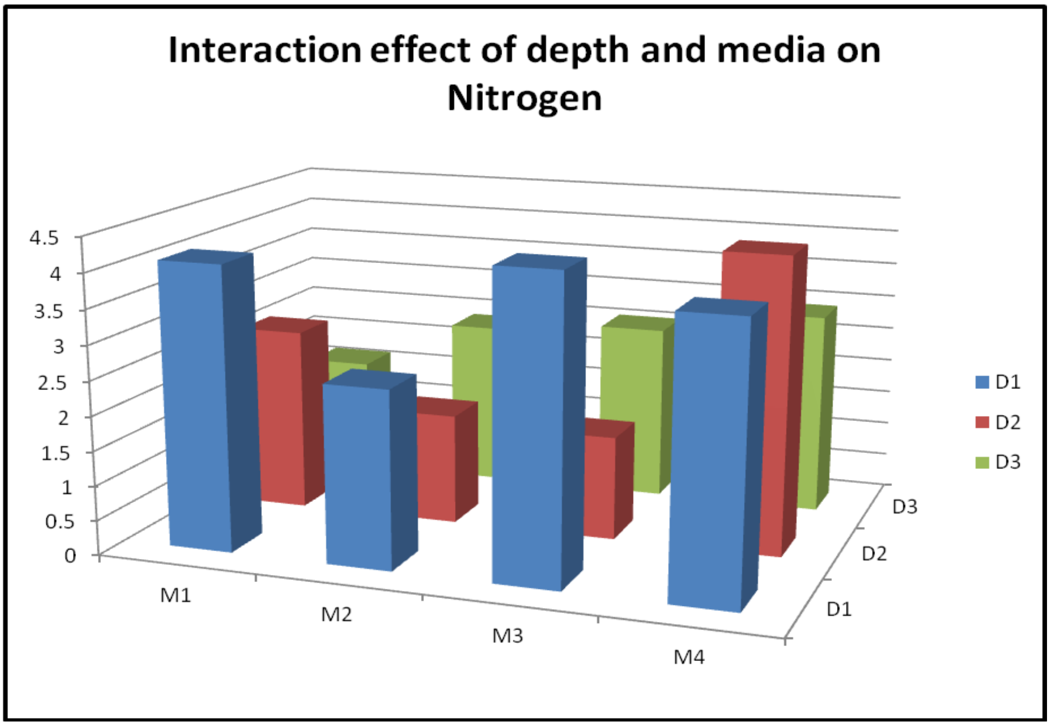


Fig. 4.8 Interaction effect of depth and media on Nitrogen

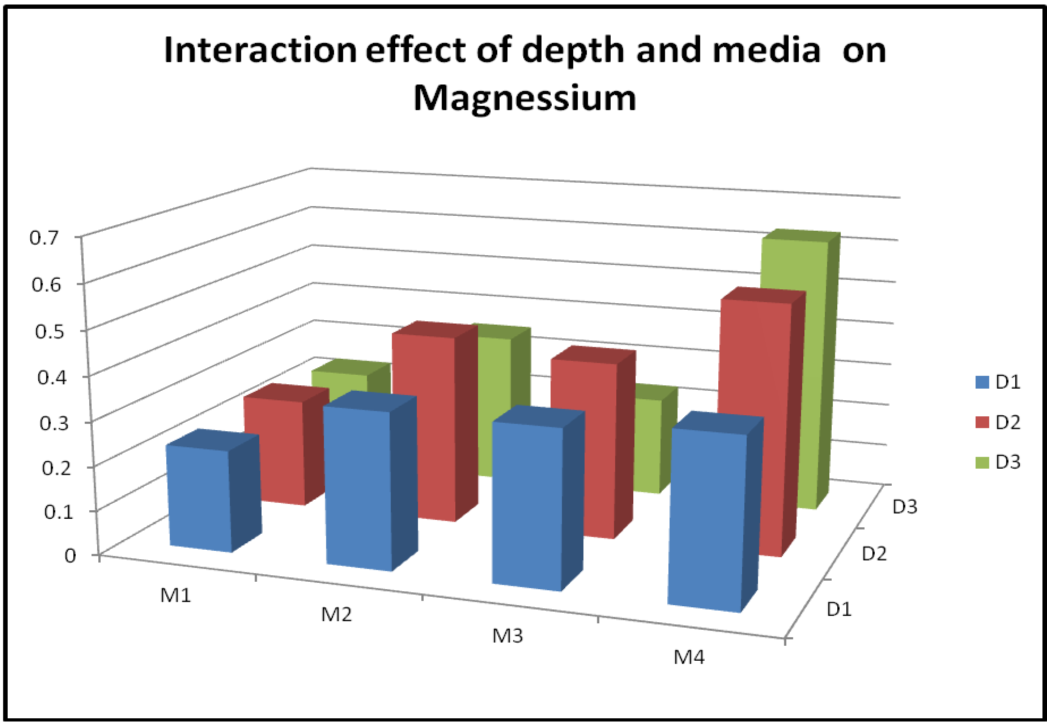


Fig. 4.9 Interaction effect of depth and media on Magnesium

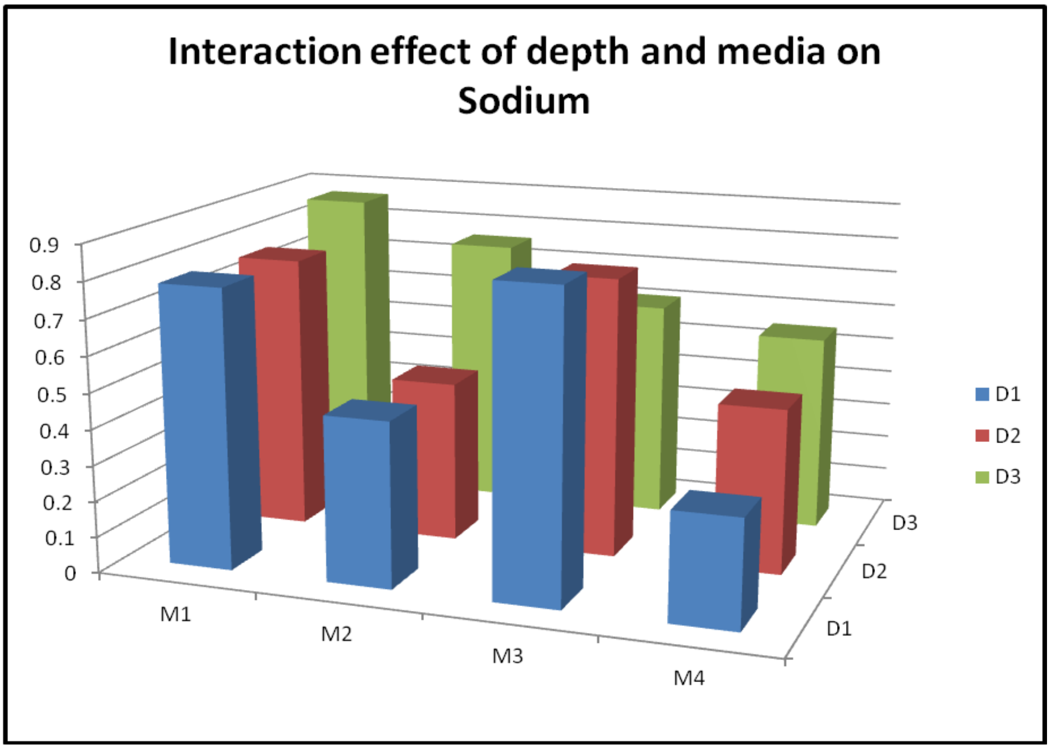


**Fig. 4.10 Interaction effect of depth and media on Sodium**

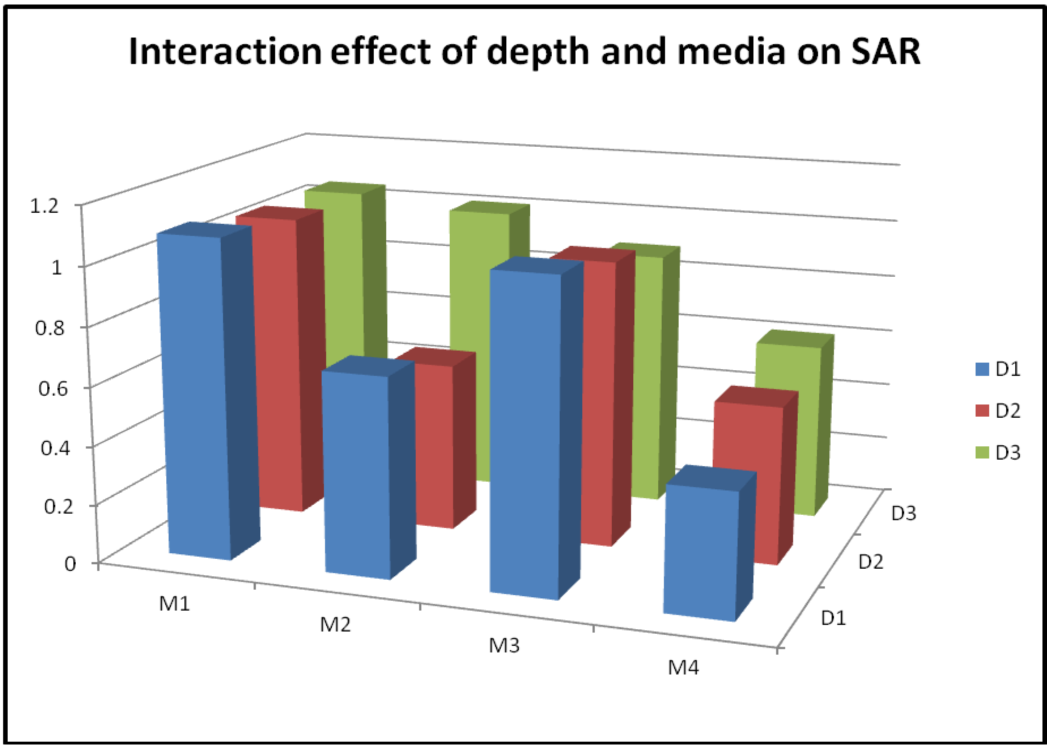


**Fig. 4.11 Interaction effect of depth and media on SAR**

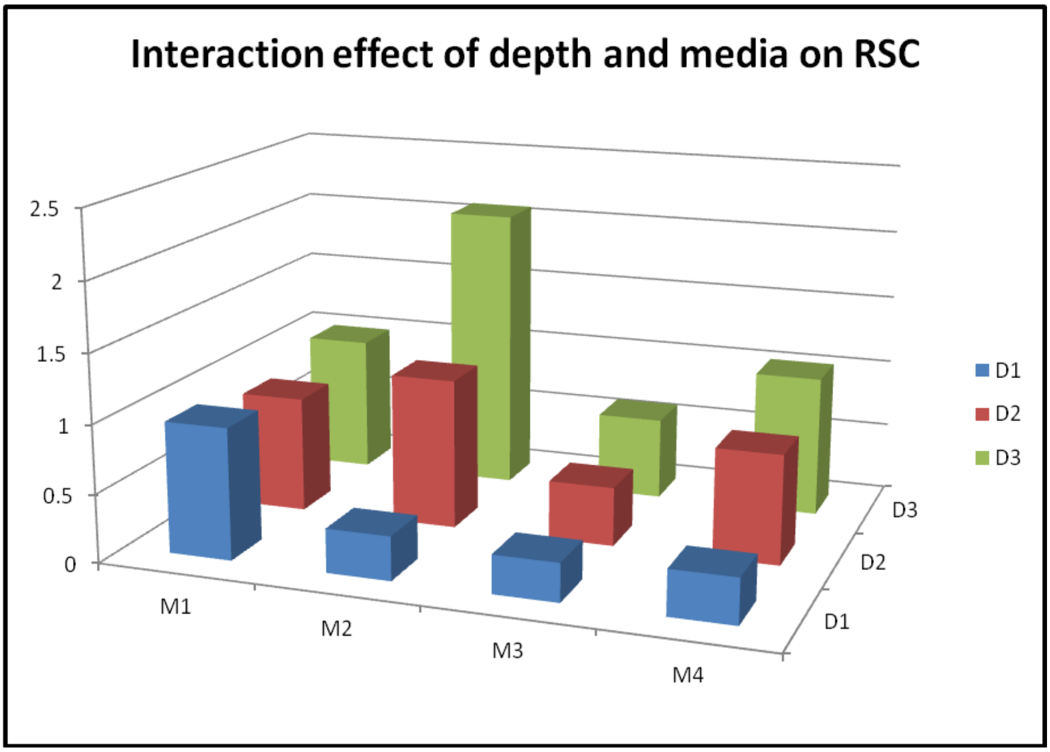


**Fig. 4.12 Interaction effect of depth and media on RSC**

**Table 4.15Effect of depth on the basis of pH, EC, SAR and RSC**

| | **Parameters** | | | |
|---|---|---|---|---|
| **Depth** | **pH** | **EC (micromhos/cm)** | **SAR** | **RSC (me/l)** |
| $D_1$ | **6.66** | **94.40** | 0.84 | **0.47** |
| $D_2$ | 6.54 | 133.79 | **0.76** | 0.79 |
| $D_3$ | 6.43 | 179.78 | 0.96 | 1.17 |

**Table 4.16 Effect of media on the basis of pH, EC, SAR and RSC**

| | **Parameters** | | | |
|---|---|---|---|---|
| **Media** | **pH** | **EC (micromhos/cm)** | **SAR (me/l)** | **RSC (me/l)** |
| $M_1$ | 6.24 | 125.07 | 1.19 | 0.93 |
| $M_2$ | 6.42 | **111.62** | 0.75 | 1.16 |
| $M_3$ | **7.16** | 185.7 | 0.97 | **0.43** |
| $M_4$ | 6.34 | 121.57 | **0.5** | 0.72 |

**Selection of depth wise filtration media on the basis of above results as follows:**

1. Gravel – 15cm
2. Grit – 45cm
3. Sand – 45cm
4. Broken brick – 30 cm

5. Charcoal – 30cm

## 4.3 Designed Parameters of filtration media for waste water treatment plant

### Table 4.17 Porosity of filtration media

| Sr. No. | Media | Porosity (Per cent) | Method adopted |
|---|---|---|---|
| 1. | Sand | 39 | Laboratory method |
| 2. | Grit | 37 | |
| 3. | Gravel | 32 | |
| 4. | Broken Brick | 31 | |
| 5. | Charcoal | 38 | |

Laboratory test was conducted to determine porosity of various media and results are reported in Table 4.17. Due to fine grain size, sand had highest porosity of 39 per cent followed by charcoal 38 per cent, grit 37 per cent, gravel 32 per cent and brick 31 per cent. The highest porosity in sand and grit will work on filtration quality. Broken brick had less porosity but good adsorbent property. The gravel will act as supporting media for fine grained media.

### Table 4.18 Voids ratio of filtration media

| Sr. No. | Media | Voids Ratio | Method adopted |
|---|---|---|---|
| 1. | Sand | 0.63 | Laboratory method |
| 2. | Grit | 0.59 | |
| 3. | Gravel | 0.44 | |
| 4. | Broken Brick | 0.46 | |
| 5. | Charcoal | 0.63 | |

Voids ratio play vital role in volume change tendency control. If voids ratio is high voids in medium tend to minimize under loading. The opposite situation, i.e. when voids ratio is relatively small (dense medium) indicate that the volume of the soil is vulnerable to increase under loading. Loose medium shows high conductivity while dense medium are not so permeable. Particles movement in a loose particles medium can move quite easily, whereas in dense medium, finer particles cannot pass through the void which leads to clogging. (Lambe, 1991)

Laboratory test was conducted to determine voids ratio of various media and results are reported in Table 4.18. Values of voids ratio varied due to consistence and packing of medium. Sand had highest voids ratio of 0.64 followed by charcoal 0.63, grit 0.59, gravel 0.44 and brick 0.46.

### Table 4.19 Dry bulk density ($\varrho_b$) and Wet bulk density ($\varrho_w$)

| Sr. No. | Media | Dry bulk Density (gm/cc) | Wet bulk Density (gm/cc) | Method Adopted |
|---|---|---|---|---|
| 1. | Sand | 0.86 | 1.16 | Laboratory method |
| 2. | Grit | 0.95 | 1.33 | |
| 3. | Gravel | 1.12 | 1.27 | |
| 4. | Broken brick | 0.54 | 0.89 | |
| 5. | Charcoal | 0.25 | 0.65 | |

The bulk density of porous medium depends greatly on degree of compaction. It plays a vital role in determination of volume of filtration media. The results of dry and wet bulk density of all filtration media are reported in Table 4.19.

**Table 4.20 Hydraulic conductivity by constant head method**

| Sr.No. | Media | Hydraulic conductivity (m/day) | Method adopted |
|---|---|---|---|
| 1. | Sand | 4.5 | Laboratory method |
| 2. | Grit | 53.50 | |
| 3. | Gravel | 85.11 | |
| 4. | Broken brick | 123 | |
| 5. | Charcoal | 19 | |

The hydraulic conductivity was affected by porosity of media and particle size. For larger particle size, porosity value is smaller but voids ratio was relatively smaller giving higher hydraulic conductivity and vice versa. In case of broken brick the particle size was 25-30 mm. Therefore, hydraulic conductivity was greater i.e. 123 $m.day^{-1}$ however in case of sand having size 0.42 mm; hydraulic conductivity was less i.e. 4.5 $m.day^{-1}$. Similarly, all results were determined and are reported in Table 4.20.

## 4.4 Designed parameters of filtration media

**Table 4.21 Designed parameters of filtration media of small scale domestic waste water treatment plant**

| Sr. No. | Design Parameter | Results obtained |
|---|---|---|
| 1. | Discharge (Q) | 24 lit/day |
| 2. | Flow velocity (v) | 3.8 m/day |
| 3. | Surface area of filter bed (A) | $6.35\times10^{-3}$ $m^2$ |
| 4. | Hydraulic Loading Rate (HLR) | 3.77 m/day |
| 5. | Volume of filter unit (v) | $0.011m^3$ |
| 6. | Hydraulic Retention Time (HRT) | 1.3 hrs |
| 7. | Average interstitial velocity ($V_a$) | 9.7m/day |
| 8. | Equivalent vertical hydraulic conductivity ($K_z$) | 8.18 m/day |
| 9. | Types of flow through filtration media on the basis of Reynolds number ($N_R$)<br>1. Gravel<br>2. Grit<br>3. Sand<br>4. Broken brick<br>5. Charcoal | All are Laminar flow |
| 10. | Frictional head loss through media, ($h_L$) | $1\times10^{-3}$m |

### 4.5 Designed parameters of filtration media for waste water treatment plant for Jayaprabha hostel

**Table 4.22 Designed parameters for domestic waste water treatment plant for Jayaprabha Hostel**

| Sr. No. | Design Parameter | Results obtained |
|---|---|---|
| 1. | Discharge (Q) | 22000 lit/day |
| 2. | Flow velocity (v) | 3.8m/day |
| 3. | Surface area of filter bed (A) | 6 $m^2$ (3m×2m) |
| 4. | Hydraulic Loading Rate (HLR) | 3.73 m/day |
| 5. | Volume of filter unit (v) | 11$m^3$ |
| 6. | Hydraulic Retention Time (HRT) | 1.3 hrs |
| 7. | Average interstitial velocity ($V_a$) | 9.57 m/day |
| 8. | Equivalent vertical hydraulic conductivity ($k_z$) | 8.18 m/day |
| 9. | Types of flow through filtration media on the basis of Reynolds number ($N_R$)<br>1. Gravel<br>2. Grit<br>3. Sand<br>4. Broken brick<br>5. Charcoal | All are Laminar flow |
| 10. | Frictional head loss through media, ($h_L$) | $2\times10^{-8}$m |

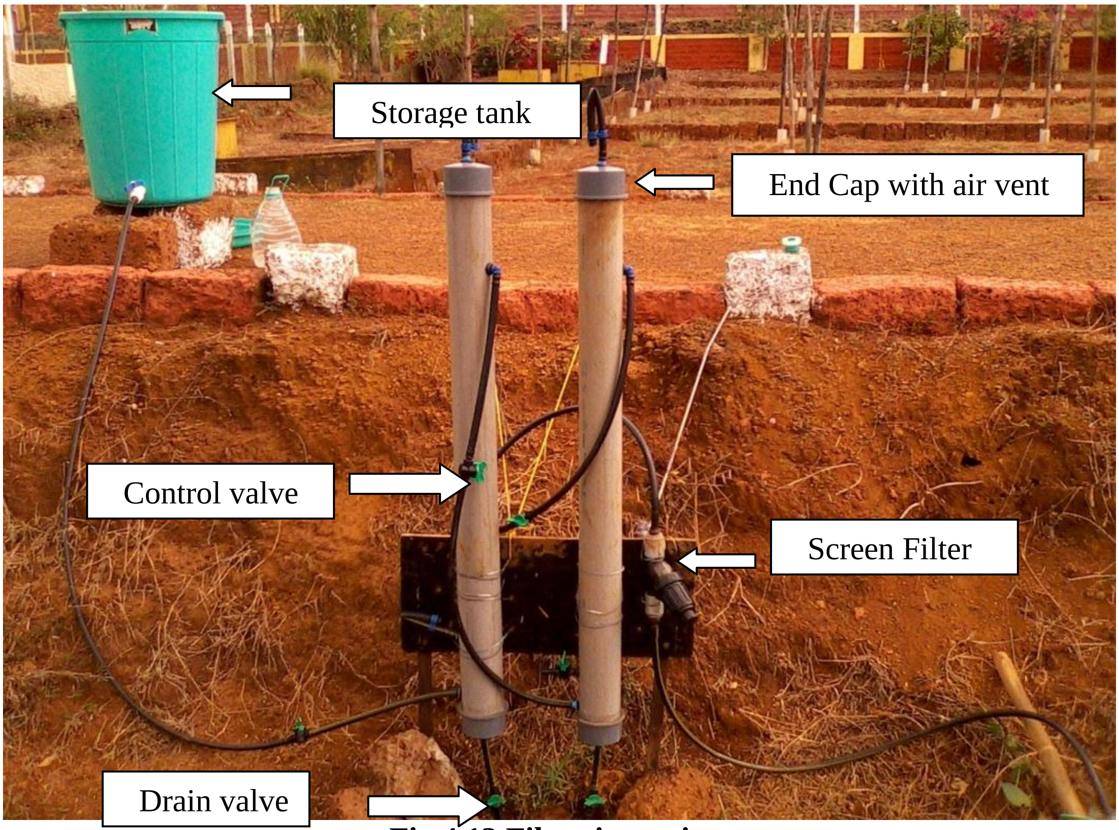


**Fig.4.13 Filtration unit**


**Fig. 4.14 Fitting of control valve**

**Fig. 4.15 Fitting of air vent to end cap**

**Fig. 4.16 Starting manual control valve**

**Fig. 4.5 Collection of treated grey water**


**Fig. 4.6 Grey water sample before and after treatment**

## 4.6 Chemical properties of untreated and treated grey water after filtration

**Table 4.23 Chemical properties of untreated and treated grey water after filtration through designed small scale waste water treatment plant**

| Sr. No. | Properties | Untreated | Treated |
|---|---|---|---|
| 1. | pH | 7.32 | 7.27 |
| 2. | Electrical conductivity (EC), micromhos/cm | 210 | 155 |
| 3. | Total Dissolve Solids, mg/lit | 134 | 92.2 |
| 4. | Calcium, me/l | 1 | 0.8 |
| 5. | Carbonate, me/l | Nil | |
| 6. | Bicarbonate, me/lit | 2.9 | 1.6 |
| 7. | Potassium, me/l | 8.1 | 4.15 |
| 8. | Nitrogen, mg/l | 5.04 | 4.76 |
| 9. | Magnesium, me/l | 0.6 | 0.4 |
| 10. | Sodium, me/lit | 1.05 | 0.72 |
| 11. | Sodium Adsorption Ratio, me/l | 1.17 | 0.92 |
| 12. | Residual Sodium Carbonate, me/lit | 1.3 | 0.4 |
| 13. | Oil and grease | 13.2 | 2.8 |
| 14. | Chemical Oxygen Demand (COD), mg/lit | 376 | 56 |
| 15. | Biological Oxygen Demand (BOD), mg/lit | 185 | 32 |

## 4.7 Analysis for determination of Chemical properties of grey water before and after treatment for combination or multilayer filtration unit

### 4.7.1 pH

The range of pH values in bathroom grey water were found as 7.32 and 7.27 for untreated and treated water, respectively which can be maintained within permissible range of standard irrigation water quality by using designed small scale waste water treatment plant. Trends are matching with previous results. (Chidozie *et al*., 2013)

### 4.7.2 Electrical Conductivity (EC)

The obtained results of EC were 210 μs/cm and 155 μs/cm for untreated and treated grey water. Trends are matching with previous results (Mohamed *et al*. 2014).This range is within permissible range of standard of irrigation water quality. Therefore the treated water is suitable for irrigation purpose.

### 4.7.3 Total Dissolved Salts (TDS)

The obtained results of TDS were 134 and 99.2 mg/lit for untreated and treated grey water respectively and it is within permissible range of standard of irrigation water quality. Therefore it is suitable for the irrigation purpose. Trends are matching with previous results (Mohamed *et al*., 2014)

**Table 4.24 Salt hazard limits for waste water (Richards, 1954)**

| Hazard | TDS, mg/lit | EC, dS/m |
|---|---|---|
| None | <500 | <0.25 |
| Slight | 500-1000 | 0.25-0.75 |
| Moderate | 1000-2000 | 0.75-2.25 |
| Severe | >2000 | >2.25 |
| | Source:FAO 1979 | Source: Richards, 1954 |

### 4.7.4 Calcium

Results found that values for Ca were 1 and 0.8 me/l for untreated and treated grey water which was within permissible range of standard irrigation water quality. Therefore it is suitable for irrigation.

### 4.7.5 Carbonates and Bicarbonates

The carbonates were found nil. The obtained results of bicarbonate were 2.9 and 1.6 me/l for untreated and treated grey water, respectively which is within permissible range of standard of irrigation water quality of literature values. Results are matching with previous research (Ladwani *et al*. 2012). Therefore, it is suitable for irrigation purpose.

### 4.7.6 Potassium

The obtained results were found that the potassium for untreated water was 8.1me/lit. The level of K was reduced up to 4.15 me/lit by using combination of all filtration media at the depth of 1.8 m. It is suitable for irrigation.

### 4.7.7 Nitrogen

The ammonium nitrogen concentration of untreated grey water was 5.04 mg/l and it was reduced up to 4.76 mg/lit. Therefore it is suitable for irrigation purpose. Trends are matching with previous results (Mohamed *et al*. 2014).

### 4.7.8 Magnesium

The Mg concentration obtained for untreated grey water was 0.6 me/l and it was reduced upto 0.4 me/l by using designed of small scale filtration unit. Trends are matching with previous results (Alpha, 1996).

### 4.7.9 Sodium

A soil permeability problem occurs with high sodium content in the irrigation water. The increase in concentration of exchangeable sodium may cause an increase in the soil pH. The results were found that the sodium concentration in untreated grey water was 1.05 me/lit and it was reduced up to 0.72 me/lit. Table 4.25 shows the nature of hazardness of irrigation water related to sodium concentration.

**Table 4.25 Irrigation water use on the basis of sodium concentration (Richard, 1968)**

| Parameter | Irrigation use | | |
|---|---|---|---|
| | No problem | Increasing problem | Severe problem |
| Sodium, me/lit | <3 | 3-9 | >9 |

### 4.7.10 Sodium Adsorption Ratio

The obtained results of SAR were 1.17 and 0.92 for untreated and treated grey water, respectively. Results matching with previous research values (Alpha, 1996). The SAR results were within permissible range compared with the recommendation limit for irrigation water quality. Therefore treated water is suitable for irrigation purpose.

### 4.7.11 RSC

When RSC value is lower than 1.25 me/lit, the water is considered good quality, while if the RSC value exceeds 2.5 me/lit, the water is considered harmful (Ayers and West cot, 1985). The obtained results for RSC were 1.3 and 0.4 for untreated and treated grey water. Therefore it is suitable for irrigation purpose.

### 4.7.12 Oil and Grease

Oil and grease contained of grey water calculated by the process of saponification. Saponification values were determined for untreated as well as treated water. From results it is observed that, the saponification value for unfiltered grey water was 13.2 and it was reduced up to 2.8. It means that 2.8 mℓ of KOH is required for neutralizing the fatty acids resulting from the complete hydrolysis of 5 mℓ of oil or fat.

### 4.7.13 Chemical Oxygen Demand (COD)

The obtained values of COD for untreated water was 376 mg/l and it was reduced up to 56 mg/l by the process of filtration at the depth of 1.8 m. Limits are matching with previous results (Mohamed et al., 2014). The permissible range of COD for untreated and treated water is 600 and 110 mg/l. The obtained results are within permissible range. Hence treated water can be used for irrigation purpose.

### 4.7.14 Biological Oxygen Demand

The obtained values of BOD for untreated and treated grey water were 185 and 32 mg/l. The permissible range of BOD for untreated and treated water is 400 and 30 mg/l. Hence treated water can be used for irrigation purpose. Trends are matching with previous results (Kushwah *et al*. 2011).

# II. REVIEW OF LITERATURE

Many researchers have been carried out work on use of domestic grey water for irrigation purpose. The literature available on physical and chemical properties of grey water before and after treatment and design of waste water treatment plant has been reviewed. The research work done has been reviewed mainly under following topics as described below,

1. To study physical & chemical properties of domestic grey water before and after treatment.
2. Design of small scale waste water treatment plant.
3. Waste water use in agriculture.

## 2.1 To study physical and chemical properties of domestic grey water before and after treatment:

Jefferson *et al*. (2004) studied grey water characterisation and its impact on the selection and operation of technologies for urban reuse. In this study it revealed that characterisation of grey water is a source of water that is similar in organic strength to a low medium strength municipal sewage in effluent but with physical and biodegradability characteristics similar to a tertiary treated effluent. Grey water was collected from 102 individuals made up of a distribution of ages, gender and washing applications (bath, shower and hand basin). Sample were collected on the day of production (preferably within two hours) and either immediately analysed or stored at 5˚C for maximum of 24 hours. Sample stored for longer periods or at higher temperatures was discarded from study. Grey water generated from the shower, bath and hand basin sources all displayed similar biodegradable contents as demonstrated by $BOD_5$ concentrations of $146\pm55$, $129\pm57$, $155\pm49$ $mg.lit^{-1}$ respectively at 76 per cent confidence level. Also observed that total COD concentrations of the same sources of $420\pm245$, $367\pm246$ and $587\pm379$ $mg.lit^{-1}$

Mahmood and Maqbool (2006) studied the impacts of grey water irrigation on water quality and on the health of local community in Faisalabad, Pakistan. Field study was conducted in Chakera village, Faisalabad (Pakistan) and quality parameters like pH, EC, SAR, TDS. Results of the study revealed that untreated grey water application raises the values of EC, TDS, and SAR compared with the National

Environmental Quality Standards (NEQS). This not only degrades the soil structure but also contaminated the groundwater, causing severe health hazards to the local community.

Kushwah *et al.* (2011) conducted waste water quality studies of influent and effluent water at municipal waste water treatment plant, Bhopal (India). The study was to determined pH, DO, BOD and turbidity reduction from municipal waste water. In the present study, samples of influent and effluent waste water from Badwai sewage treatment plant (STP) situated at Bhopal, Madhya Pradesh were collected during the year 2010. Physical and chemical parameters were analysed using standard methods. The result with treated water indicate that the waste water treatment plant was efficient in treating waste water. From the experiment it revealed that, the pH values varied from 6.62 to 6.77 in the influent of STP. In investigation period for DO was nil in the influent and 2.4 mg/l to 5.2 mg/l in effluent water. During the period of investigation BOD varied from 198.6 mg/l to 382.4 mg/l in the influent and 30.2 to 102.6 mg/l for effluent water. Turbidity was observed from 116.5 NTU to 248.6 NTU in the influent water and 18.5 NTU to 35.2 NTU in effluent water. This treated water recommended for use of irrigation and gardening.

Berger (2012) examined bio char and activated carbon filters for grey water treatment-comparison of organic matter and nutrients removal. In this study it revealed that Activated carbon filter has long been used for the treatment of water. Bio char, which is organic material pyrolyzed or charred, often by means of simple and low cost techniques, an interesting alternative to replace the industrial activated carbon for grey water cleaning. Also they evaluated and compared bio char and activated carbon by assessing reductions of COD, Tot-N and Tot-P as well as transformation of nitrogen in the grey water-infiltrated filters. The activated carbon and bio char were packed to depth of 50 cm into columns with a diameter of 4.3 cm. The columns were feds with artificial grey water at a hydraulic loading rate of $0.043m^3/m^2$/day under vertical flow. The bulk density, particle density, total porosity and residence time of the filters were initially measured. Then their water cleaning capacity was assessed over a period of ten weeks based on nine chemical parameters (pH, EC, $NH_4$-N, $NO_3$-N, Tot-N, $PO_4$-P, Tot-P, MBAS and COD). The resistance time in the activated carbon filters was 119 hours and in the bio char filters 108 hours. Both materials cleaned the grey water well from organic matter, with 99 per cent efficiency for COD and MBAS. Also it is remarked that bio char removed Tot-P and $PO_4$-P more effectively than activated carbon, on average to 89 per cent in case of Tot-P and $PO_4$-P.

Ukpong and Agunwamba (2012) studied grey water reuse for irrigation. The objective of this study was to design and construct a filter for grey water reuse for irrigation of not less than one hundred household. To achieve this objective, samples were collected from one hundred households within the University of Nigeria, Nsukka campus and its environs. Laboratory tests were conducted on these samples and they revealed the presence of BOD, TSS, nitrate, pH, Coli form etc, whose values varies when compared with that of the parameters for standard irrigation water. From the results obtained a slow sand filter bed for not more than one hundred households was designed and constructed. A filter which was used for filtration consists of a layer of sand or crushed coal supported on a bed of gravel. The sand used in the filter was hard and resistant to chemical attack and free from dirt such as clay or dust. It also examined that the sand should be coarse (0.4-2.0mm), medium (0.3-1.8) or fine (0.25-1.50mm). Also 30 per cent of natural colour in waste water effectively removed by slow sand filter. The filter media was made of two medium which are fine and coarse gravel and with both filling the entire 50cm. The bed started with the coarse gravel occupying 15 cm of the depth in the ranges from coarse particles (0.4mm-2.0mm) to fine sand (0.25mm-1.50mm) occupying 35 cm of the depth of the filter as specified for slow sand filter.

Chan (2013) predicted post-filtration compressibility characteristics of peat used as grey water filter media. In this study it revealed that in typical Malaysian household, used water from the laundry, bathroom and kitchen contribute to the total grey water discharge. Also it examined that the laboratory test or examination of peat as a potentially cheap and effective filter media for household grey water. The grey water was prepared with controlled measures of common contaminants to represent the types of household grey water commonly produced. The filtered water quality was monitored over a month to gauge the effectiveness of the peat filter media. The peat upon filtration of different grey water after 28 days was subjected to the odometer test to examine its one dimensional compressibility characteristics in relation with the filtration process. The findings indicated that the pit media could be beneficial in the removal of suspended solids and lowering of BOD and COD of the grey water, through laundry grey water showed behaviour commonly observed in soft materials like peat, with an apparent reduction of settlement post-filtration of the grey water. The reduction of void ratio (e) and water content (w), pre-and post-tests was found to be linear pattern, while bulk density showed less compatibility, especially of the mixed grey water sample. Overall, the compressibility of peat improved post-filtration with lower void ratio and water content.

Nnaji *et al*. (2013) studied feasibility of a filtration adsorption grey water treatment system for developing countries. In this study the performance and economic viability of simple inexpensive grey water treatment system consisting of a filtration unit and an adsorption unit was evaluated. At steady state, the overall performance of the combined system was 85.68 per cent BOD removal, 57.09 per cent COD removal and 70.74 per cent TSS removal. Most of the BOD removal 83.6 per cent was achieved in the filtration unit, while most of the faecal coliform removal was achieved in the adsorption chamber. The pH of the entire system remained stable ($7.6\pm 0.29$) throughout the experiment. The dissolved oxygen concentration of the final effluent was ($1.3\pm0.28$), indicating the need for aeration. Problems with carbon particle washout were observed in the adsorption chamber. Generally, the final effluent was found to be suitable for the range of uses such as toilet flushing, irrigation and fire protection. An economic sand filter media used with effective size of $d_{10}$=0.19, $d_{60}$=0.55 and Cu=2.89 was laid on the top of the gravel layer. Analysis shown that 77.5 per cent saving in water expenditure can be achieved, if a simple grey water treatment is installed for toilet flushing.

Uveges *et al*. (2013) studied chemical treatments for bathroom grey water reuse. This research was performed in respect of households located in the capital of eastern region in Debrecen. Ten different households were chosen for the research, including flats, terraced houses, and detached houses. Grey water samples were collected from baths and showers for research purposes. Mixed sample were prepared by mixing equal volumes of grey water samples from each individual sample. The samples were filtered through 0.45 μm membrane filter and examined within 24 hours after sampling. Grey water samples were analysed for pH, electrical conductivity, turbidity, dissolved organic carbon (DOC), microbial load. For measurement of pH and conductivity, multiline P4 meter portable instrument was used. For turbidity a turbid meter Turb 555 IR was used, DOC was measured using a total organic carbon analyser. The pH value of the bath waters appeared to be around neutral (6-8), the individual samples did not show significantly different extremes. The electrical conductivity of the grey water samples were between 519 μm and 610 μm, which values are considered low in terms of waste water classification. The turbidity values of bath water samples appear too vary considerably, with result ranging between 6-81 NTU, which indicate the variety in the floating content of the individual samples. For measuring DOC used grey water samples filtered through membrane filters (0.45mm pore size). The average DOC concentration appeared to be 49±21 mg/l. The relatively low values indicate that this kind of grey water is much less loaded with dissolved salts.

Bhelose and Salunkhe (2014) studied effect of various filtration media on grey water. They determined some chemical parameters before and after treatment on grey water such as pH, EC, TDS, potassium, calcium, carbonate and bicarbonate. The results were found as pH varied from 6.14 to 7.23 for treated sample sample and 6.27 for untreated sample, EC varied from 88.58 micromhos/cm to 209.7 micromhos/cm for treated sample and 298 micromhos/cm for untreated sample. TDS varied from 40.96 mg/l to 134.2 mg/l for treated sample and 190.80 mg/l for untreated sample. Values of calcium for treated water varied from 0.8 to 1.2 me/l and 1.3 me/l for untreated sample. Carbonates found were nil. Values of bicarbonate varied from 0.9 to 1.55 me/l for treated sample and for untreated sample it was 1.1 me/l. Also potassium varied from 0.8 to 4.15 mg/l for untreated sample and it was found 6.2 for treated grey water sample.

Lakhiwal and Chauhan (2014) studied Physico- chemical analysis of treated waste water: A case study of Delawas Area, Jaipur (Rajasthan). In this study it revealed that due to scarcity of water and increasing population at an alarming rate reuse of treated waste water has become our present need. The samples were collected from Delawas Sewage Treatment plant, Pratap Nagar, Jaipur. The study was carried out for a period of one year (2011-2012). Results revealed that pH varied between 7.80 to 8.35 and electrical conductivity between 0.64 to 1.16 mmhos/cm. Total solids 687mg/l to 910 mg/l. Calcium and magnesium hardness ranged between 220 to 330 mg/l and 340 to 440 mg/l, respectively. The total hardness was found between 560 to 770mg/l. Chloride and DO values were between 155.60 to 262.70mg/l and 4.3 to 6.0mg/l. Alkalinity found between 740to 830 mg/l respectively. Heavy metals were also analyzed, from the results it was found that Cd, Cr, Ni and Pb were absent and Fe (0.118) and Cu (0.010) were present in very minute quantity. The treated water was found suitable for irrigation purpose.

Miguntanna *et al*. (2014) studied use of bricks as an alternative filter media for pebble matrix filters. In this, the pebble matrix filters technology has been used to treat high turbidity of water. To investigate possibilities of utilizing alternative filter media, laboratory tests were conducted using different configurations with chips and burnt bricks due to its availability. Result showed that bricks as an effective and feasible alternative filter media to natural pebbles. Also turbidity removal efficiency has increased with the increment of influent turbidity when the bricks were used as a filter media compared to chips. In the tested filtration velocity of 0.16 m/hr and inlet turbidity range of 60-600 NTU, produced above 80 per cent removal efficiency.

Radin and Saphira *et.al.* (2014) studied the use of natural filter media added with peat soil for household grey water treatment. In this study it examined that, the effects of household grey water treated with locally available peat soil. This study was performed by using a two stage filter media including pre-treatment (gravel+sand), peat based (peat+ charcoal+gravel). Effects of filtration on peat soil were examined via the one dimensional consolidation test and x ray fluorescence test. Removal efficiency of the grey water effluent was found to be TSS-81 per cent, BOD 54 per cent, COD 52 per cent and ammonium nitrogen 87 per cent. The pH of the grey water was improved from acidic (4.6) to neutral (6.9). Quality of the treated grey water complied with the limits of the Malaysian standard (standard B) for waste water effluent discharge. The consolidation test was affected and became slower. The XRF test indicates that peat soil has an increased amount of the content of silicon dioxide and aluminium oxide associated with the absorption of certain elements in grey water. The peat based filter resulted in a substantial removal of pollutants.

## 2.2 Design of small scale waste water treatment plant:

The research work on design of small scale waste water treatment plant was reviewed mainly under following topics.

### 2.2.1 Design, Construction and operation of waste water treatment plant

### Gravel- pack design

Johnson and Ahrens (1963) concluded that design of filter (gravel) pack is very important in producing a good quality of water from grey water. The common usage is to refer the zone as a “gravel pack”, but also noted that the terminology is misleading because such packs may range in particle size from fine sand to coarse gravel-depending upon gradation of the aquifer materials. To make the filter pack approximately ten times as permeable as the aquifer material, Terzaghi concluded that the 15 per cent size of the filter pack should be at least four times as large as the 15 per cent size of the aquifer material. They concluded that, to prevent the fine particles of the aquifer material from continuously washing through the filter pack, the 15 per cent size of the filter pack should not be more than four times as large as the 85 per cent size of the aquifer material.

Darby *et al*. (1996) studied shallow intermittent sand filtration, performance and evaluation. In this study, twelve shallow sand filters (0.38 m deep, nominal diameter of 1.2m) were loaded intermittently with primary effluent to evaluate the effect of hydraulic loading rate (HLR), dosing efficiency (DF) and filter media characteristics on removal of BOD, COD , suspended solids, turbidity and organic and ammonium nitrogen. Hydraulic loading rate varies between 0.041 and 0.652 $m.day^{-1}$ were applied during an 85 day period. Media effective sizes ($d_{10}$) ranged from 0.29 to 0.93 mm with uniformity coefficients between 1.4 and 4.52. Hydraulic loading rate of 0.163 $m.day^{-1}$, effluent quality was excellent and comparable to effluent from advanced waste water treatment facilities. Especially average removal rate of BOD between 90 to 99 per cent and it was 81 per cent for SS, organic and ammonia nitrogen and turbidity.

Amini and Troung (1998) studied effect of filter media particle size distribution on filtration efficiency. In this study, three types of sands namely fine, medium and coarse were used to study the effect of filter media of particle size distribution on sediment removal efficiency. The results indicated that the sediment removal efficiency for all sand types decreased with time. The use of medium sand provided scale model filter with the highest sediment removal efficiency. The finding of the study indicated that the media grown size has a measurable effect on the efficiency of sand filter water quality structure.

Bower and Scholzed (1999) studied small scale waste water treatment plant. In this study it revealed that processes performed at different levels, of treatment. The basic form of treatment was the breaking down of organic waste by bacteria either aerobically or anaerobically or a combination of both which occurred in secondary treatment. Primary treatment offered the settlements of solids. Tertiary treatment involved the removal of phosphorus, nitrogen and toxic substances. Pathogen removal occurred throughout treatment but became more effective mostly at tertiary levels through the use of UV rays and chlorination. They revealed that it required low land space, low cost, no electrical requirements, low operational and maintenance requirements. Also construction material was locally available with head 22 cm.

Prathapar *et al*. (2005) have done a study on the design, construction and evaluation of an ablution water treatment unit in Oman. This experiment indicated that grey water can be a cost effective alternative source of water. The treatment unit improved used ablution water quality to acceptable limits for irrigation. It was also investigated that demonstration of this treatment unit to local community will lead to the transformation of tacit knowledge to safe and explicit knowledge on ablution water reuse in Oman. Treated water was used for irrigating public parks and road pavement gardens. Ablution water and treated water samples were collected and analysed for a period of eight weeks. The following parameters were determined: pH, TSS, TDS, $BOD_5$, COD, califorms and E.coli. Results from ablution water quality analysis and comparison with waste water reuse guidelines in Oman showed that the pH, EC, TDS, TSS and COD of ablution water produced were within limits of water suitable for irrigation but BOD5, califorms and E. coli levels exceed permissible concentration, requiring treatment before use. Filtering included slow sand filters and carbon filters to remove odour and toxins. A sand filter was included, to filter accidental increase in TSS in ablution water within the treatment system. It is also anticipated that, the sand filter would help to improve other water quality parameters such as DO, BOD and COD. Also caliform levels were above acceptable levels, a chlorination chute was considered. The ablution waster was sent through a sand trap to allow settlement of soil particles. The dimensions of the ablution water storage tank are 1.5m×1.5m × 1.7 m hence it could store up 3.825$m^3$ water. Also maximum ablution water produced in a day was 1.94 $m^3$ only. Depth of water in storage tank was 0.5m and pump operation stopped when the depth of water in the storage tank dropped to 0.2m depth. Water entered in a filter unit which consisted of an activated carbon tray (10cm deep), 0.2mm washed beach sand (70 cm depth), gravel 1/8

(0.32cm diameter gravel to a depth of 10cm), gravel ¼ (0.62 cm diameter gravel to a depth of 10cm deep), and stones (10 cm deep). Then the water passed through a chlorination chute, packed with chlorine tablets. Results showed that treatments did not change pH significantly. The EC and TDS have increased significantly. Use of beach sand as a filter material although the beach sand was washed prior to use, salts have not been completely removed. Turbidity and COD was significant. The carbonates, Na, Mg, chlorides and sulphates have increased significantly during treatment.

Almoayied (2011) studied drawer compacted sand filter: A new and innovative design for onsite waste water treatment. In this study, it revealed that drawer compacted sand filter DCSF is a modified design for sand filter, in which sand layer is broken down into several layers (10 cm each) and placed in a movable drawers separated by 5 cm space each. Lab scale DCSF was designed and operated for 49 days and fed by synthetic grey water. The 30 cm of sand media was placed in three drawers, 10 cm each, 8 cm gravel, was placed in the first drawer at the top of the chest. The effective size of the sand media and gravel were 0.2 mm, 3mm, respectively. The organic load was 42780 $mg/m^2$ day and hydraulic load was 50 $L/m^2$ day. Significant reduction in BOD5 and TSS was noticed between drawers 1 and 2, whereas no significant reduction was observed by passing water through all drawers also concluded that, accommodating sand media in movable drawers and distribute hydraulic load between drawers would minimize the maintenance and space requirement for sand filter.

Parjane and Sane (2011) studied performance of grey water treatment plant by economical way for Indian rural development. In this study it revealed that conventional groundwater and surface water sources are becoming increasingly vulnerable to anthropogenic, industrial and natural pollution. Also this study represent the finest design of laboratory scale grey water treatment plant, which is combination of natural and physical operations such as primary settling with cascaded water flow, aeration, agitation and filtration that known as hybrid treatment process. This grey water reuse system is developed for the small college campus in rural areas. The economical performance of the plant were investigated for treatment of bathrooms, basins and laundries grey water and recycled in residential hostel at college campus in Sinner rural area in Nasik city, India. Total eight samples of grey water were taken at first day of morning and evening of every week and the performances of the system were investigated for these eight samples of grey water at steady state conditions and the average organic load in grey water found 327 mg COD/lit. The solids in grey water found to have about 76 per cent dissolved and 24 per cent suspended particles. Also determined percentage removal of parameters for winter, spring and summer season. It revealed that better results of percentage removal of parameters or the performance of the plant is better in winter season and less in the spring season, because in the spring season, the pollutant are more dissolved in the surface water and ground water.

Zaidun (2011) studied the effect of sand filter characteristics on removal efficiency of organic matter from grey water. The specific goals of the study were to determine the optimum inflow to the filters (Hydraulic Loading Rates) and media characteristics such as the effective size, particle size distributions within the bed media. Three sets of experiment were carried out during nine months from April to December in Mustansiryiah University, College of Engineering, and Environmental Hydraulic Laboratory. The first set of experiments were achieved by using (1m height) sand of effective diameter 0.35mm, uniformity coefficient, Uc of 2.2 and porosity 39 per cent, the second set of experiments were carried out by using sand of 0.75 mm diameter, Uc= 2.9 and porosity 43 per cent to study the effect of grain size of sand on water head over sand surface and removal efficiency. Measurements of chemical, physical and bacterial parameters were achieved. These parameters include pH, turbidity, phosphates, biological oxygen demand, and chemical oxygen demand, TDS, TSS and caliform removal for treated grey water. Also results shown that filter loading rate has been [determined to be not more than 680 $l/hr/m^2$ which removed efficiency of $BOD_5$ was 51% and minimum filter loading rate has been tested to be 212 $l/hr/m^2$ which removal efficiency of $BOD_5$ was 83 per cent.

Berbeka *et al.* (2012) studied municipal waste water treatment in Poland-efficiency, costs and returns to scale. The study revealed that the costs of municipal waste water collection and treatment in Poland based on an empirical sample of 1400 operators. Treatment cost functions were investigated economically using the Box-Cox regression model, indicating high non-linearity and significant scale effects. Wastewater increasing with technology efficiency and decreasing with higher waste water treatment plant capacity. Also survey distributed among municipal waste water operators in Poland. The survey was carried out by Regional Water Boards in Poland and aggregated by the national Water Board. The rational of the survey was to obtain some insight into economic analysis of water management, especially in the area of water provision and waste water collection in the municipal sector. Such an investigation was a part of the general economic analysis required by the water framework directive. Total 1420 survey were collected, which resulted from a response of 87 per cent of these, 1237 were eligible for further processing. The total volume of wastewater treated by the facilities included dataset in 2008 was 1282 $hm^3$. To give some perspective, the amount of water sold by municipal operators in the same year in Poland totalled 1580 $hm^3$.

Karlsson (2012) reported modelling of bark, sand and activated carbon filters for treatment of grey water. In this study, the part of the waste water produced in a household, originating from showers, dish and wash water, called grey water using three column filters with different materials such as activated carbon, pine bark and sand were examined. A set of physical filters were available where flow measurements were performed. Complete model was used for evaluation of the treatment of the filters. Two of the six columns were filled with sand and lebbled them, another two with charcoal and lebbled them, and last two with bark. At the bottom, the effluent passed through a plastic pipe into bucket. The pH of grey water determined 5.1,10.4 and 7.9 for bark, charcoal and sand, respectively. Hydraulic conductivity determined 330, 500 and 360 cm per hour for bark, charcoal and sand, respectively.

Dalahmeh (2013) studied bark and charcoal filters for grey water treatment. In this study it revealed that grey water is a sustainable water source for recycling. Laboratory-scale pine bark, activated charcoal and sand filters were evaluated as regards their pollutant removal and interactions between medium properties, grey water, microbial activity and bacteria community structure. The effects of hydraulic and organic loading rates (HLR and OLR) were described by general regression models (GRM). A series of experiments examined treatment of artificial grey water in terms of lowering the biochemical oxygen demand ($BOD_5$), chemical oxygen demand (COD), phosphorous (Tot-P), nitrogen (Tot-N) and pathogen indicators (total thermotolerent califorms) and tracer microorganisms. The driving force shaping bacterial communities in bark material was its organic composition and low pH while the communities in the charcoal and sand filters were more influenced by the grey water. The organic matter content and surface and hydraulic properties of the bark filters resulted in high $BOD_5$ removal rates (94-99%), even at increased HLR and OLR. High nitrification occurred in the bark filters in all loading regimes tested but with low Tot-N removal. The charcoal had large specific surface area, which provided the capacity for intermediate high removal of $BOD_5$ (83-97%), Tot-N (50-98%), Tot-P ((64-98%), but removal of microorganisms was poor. Also sand filters demonstrate low BOD removal 67-91 per cent and high nitrification, but low nitrogen removal.

Godfred and Adjei (2014) studied the potential utilization of grey water for irrigation. In this study it examined the suitability of locally available materials (beach sand, oyster shells, and charcoal) to treat grey water samples collected weekly from three halls of residence on Kwame Nkrumah university of Science and Technology campus for irrigation. Beach sand, oyster shells and charcoal were employed in the construction of three vertical flow through filter system, each consisting of PVC pipes of height 100 cm and internal diameter is 5.08 cm. The grey water samples were filtered and the levels of physicochemical parameters (pH, conductivity, TDS, and salinity), nutrients and microbial counts determined over a three-week period. Results indicated that the measured physicochemical parameters treated grey water were within the permissible limits for irrigation water. Also filtration process was effective in reducing phosphate, the total and faecal caliform levels in grey water from the halls of the residence.

Nwajuaka *et al*. (2015) studied analytical study and performance evaluation of a lab scale grey water treatment plant. In this study a laboratory scale grey water treatment was designed and fabricated to treat grey water with a combination of physical and natural treatment system. A total of five samples of raw grey water were collected every morning from two female hostels in Nnamdi Azikiwe University, (NAU), and Awka, Nigeria. These samples were analyzed for turbidity, Biochemical Oxygen Demand, Chemical Oxygen Demand, TSS, TDS, and total hardness, analysis of variance (ANOVA), coefficient of variance and correlation matrix were used to analyse data obtained. Differences in parameter concentration between in effluent and effluent parameters were considered significant at 5 per cent level of significance. The concentration of these parameters decreased significantly as a result of the treatment.

Coefficient of variations indicated that are less than 10 per cent meaning that the raw grey water sample were collected and consistent in quality.

## 2.3 Waste water use in agriculture:

Hussain *et al*. (2002) revealed wastewater use in agriculture. The study revealed that, Faisalabad area in Pakistan illustrated this problem. Both treated and untreated municipal waste water in vicinity of large cities used for vegetable production. A selective review of recent empirical studies identified major impacts, both positive and negative of wastewater irrigation. Also it provides the environmental valuation techniques for analysing impacts of wastewater uses in agriculture. This framework applied to a developing country of Faisalabad area in Pakistan in IWMI research program. In Faisalabad, a large proportion of municipal wastewater from some section of the city consists of industrial wastewater discharges. The municipal sewage network also serves as the storm water severe. Due to defects in the sewerage system, there is groundwater seepage as well adding to the volume of sewage to be disposed. Also revealed that, reclaimed wastewater reuse for irrigation do not address human health and safety issues related to the introduction of toxic pollutants into the ecosystem through wastewater irrigation.

Raschid-Sally and Jayakody (2008) conducted drivers and characteristics of waste water in developing countries. In this study it revealed that the main drivers of waste water use in irrigated agriculture were a combination of increasing urban water demand and related return flow of used but seldom treated waste water into the environment and its water bodies, causing pollution of traditional irrigation water sources. Also Urban food demand and market incentives favouring food production in city proximity, where water sources were usually polluted and lack alternative (cheaper, similarly reliable or safer) water sources. In four out of five cities surveyed, waste water was used (treated, raw or diluted) in urban and peri-urban agriculture, even if areas cultivated in each of the cities may sometimes be small. From the data gathered across 53 cities alone, approximately 0.4 Mha were cultivated with waste water by a farmer population of 1.1 million with at least 4.5 million family dependants.

Ladwani *et al*. (2012) concluded impact of domestic waste water irrigation on soil properties and crop yield. In this study it revealed that crops were irrigated with groundwater and domestic waste water. Each crop was applied at recommended NPK dose of fertilisers for treatment. The use of domestic waste water has shown improvement in physic chemical properties of the soil, yield along with the nutrient status as compared to the application of groundwater. Research work was carried out using domestic waste water generated from Nagpur city, which was discharged into nallah. Crops like wheat, gram, and palak were grown by dibbling method for irrigation with the application of domestic waste water and ground water. Domestic waste water collected from nallah, Nagpur (India). Ground water was collected from nearby field. Samples from domestic waste water were collected two times during the study period in pre-sowing and after harvesting field crops and analyzed in laboratory for their physic chemical parameters pH, EC, Na, K, carbonates and bicarbonates, calcium, magnesium were determined. The Ca and Mg were measured using EDTA titration method. The pH of waste water was 7.6 which was greater than ground water pH as 7.1. Also EC of domestic waste water was 780 µS/cm and ground water it was 400 µS/cm. Values of carbonates were 0.85 and 0.30 me/l, respectively and for bicarbonate values determined 5.10 and 2.38 me/l, respectively. Ca from domestic waste water was greater i.e. 4.76 me/l than ground water (2.65 me/l) and values of Mg and K of domestic waste water also greater than ground water, which were beneficial because they considered as a plant nutrients.

Yeole *et al.* (2012) reported evaluating pollution potential of irrigation by domestic waste water on fertile soil quality of Mamurabad watershed area near Jalgaon urban centre, Maharashtra, India. In this study, water and soil quality investigations were carried out. Total six sample of soil and four sample of waste water of Lendi Nala were analysed from study area. Application of untreated sewage water for the irrigation purpose is the common practice in the study area. The main aim of this study was to investigate and correlate the adverse impacts on soil quality around the Mamurabad watershed area. The results showed that EC, COD, BOD, $SO_4$, $Cl^-$, $NO_3^-$ and some heavy metals such as $Fe^{++}$, $Ca^{++}$ were observed above the limit. The calculated values of SAR and RSC suggesteed the long term use of untreated sewage will lead to some serious pollution aspects and ultimately to the health of peoples in study area.

Amerasinghe *et al.* (2013) conducted urban wastewater and agricultural reuse challenges in India. In this study it revealed that, the major users of wastewater in the study sites include growers of cereal (like rice), horticultural and fodder crops and aquaculture (mostly in Eastern Calcutta wetlands and also in Delhi), and to a lesser extent floriculturists. In Delhi and Kanpur, treated water was issued for agricultural production. However, with time the quality of waste water had deteriorated, especially in Kanpur and however it was no longer suitable for crop production and also data from selected sites shown that, the financial benefits associated with waste water farming were higher than those associated with freshwater agriculture for cities were domestic waste water does not mix with industrial sewage. Also adverse health and environmental impacts were lower in such cities. The highest gains were reported from the eastern Calcutta wetlands, where sewage farming has been practiced for management needs.

# V. SUMMARY AND CONCLUSION

## 5.1 Summary

Water and soil pollution due to waste water is a major problem, creating acute insanitation as well as affecting the soil and crops when waste water is used for irrigation. In our countries many cities discharge their waste water on open land or in rivers without treatments. The results presented in this study established the potential applicability of the developed methodology.

The present investigation was undertaken with view to study physical and chemical properties of domestic waste water and design of small scale waste water treatment plant for Jayaprabha girl's hostel of university, Dr. BSKKV, Dapoli. The grey water generated from bathrooms, basins, and kitchen of Jayaprabha hostel were analysed by using different filtration media during December to February, 2015.

The grey water sample was filtered through individual filtration media which were easily available included gravel, grit, sand and broken brick at the depth of 45cm, 30cm, and 15cm respectively for selection of medium and its efficient depth for installation of small scale filtration unit. The physical and chemical properties of untreated and treated grey water were determined. Under the physical properties, temperature, colour, turbidity and odour were studied. Also, turbidity removal efficiency was also higher and it is desirable from irrigation point of view. The odour of untreated water was high and it was reduced after filtration and found out non offensive.

Also grey water was analysed for chemical parameters viz., pH, EC, TDS, calcium, carbonate and bicarbonate, potassium, sodium, nitrogen, SAR, RSC, oil and grease, BOD and COD. Similarly, analysed of physical and chemical properties of treated grey water for multilayer small scale filtration unit, along with charcoal, water quality was decided. The removal efficiency of COD and BOD were also higher and obtained results were also within the permissible limit of standard of irrigation water quality.

The analysis of water sample showed that the pH of untreated grey water was reduced upto certain level and the desirable range is at the depth D1 (45cm). As per classification of irrigation water on the basis of EC and SAR the estimated values of treated and untreated samples for EC and SAR were classified in class C1S1, which can be used for irrigation on almost all the types of soil. And results of EC and SAR were within permissible range compared with recommendation limit for irrigation water quality.

## 5.2 Conclusions

1. The grey water samples collected from Jayaprabha girl's hostel which contained some the chemical constituents which were above the permissible limit of standard irrigation water quality. Hence this water cannot be used directly for irrigation purpose and treatment of such water is necessary.
2. The pH and bicarbonate of treated grey water found most desirable in sand medium at the depth 45 cm and potassium generally considered as beneficial nutrient for plant growth and potassium of treated grey water was most desirable in sand medium at the depth 15 cm than any other combinations.
3. The EC and TDS of treated grey water obtained most desirable in grit medium at the depth 45 cm and magnesium found most desirable in grit medium at the depth 30 cm than any other combinations.
4. The nitrogen promotes succulence in forage crops and leafy vegetables. However it considered essential nutrient for plant growth. Also excess amount of sodium present in irrigation water can adversely affect soil structure and plant growth. The nitrogen, sodium and RSC of treated grey water found desirable in brick medium at the depth 45 cm and SAR and calcium found desirable in brick medium at the depth 30 cm than any other combinations.
5. The selected combinations of media and depth for multilayer domestic grey water model includes gravel 15 cm, grit 45 cm, sand 45cm, broken brick 30cm and charcoal 30cm.
6. Porosity concluded for sand 39 percent, grit it was 37 percent, gravel 32 percent, broken brick 31 percent and for charcoal it was 38 percent. Voids ratio concluded for sand 0.63, grit it was 0.59, gravel 0.44, broken brick 0.46 and for charcoal it was 0.63.
7. Dry and wet bulk density for sand 0.86 $gm.cc^{-1}$ and 1.16 $gm.cc^{-1}$, for grit it was 0.95 and 1.33 $gm.cc^{-1}$, for gravel 1.12 $gm.cc^{-1}$and 1.27 $gm.cc^{-1}$, for broken brick 0.54 $gm.cc^{-1}$ and 0.89 $gm.cc^{-1}$ respectively.

8. Hydraulic conductivity concluded by using constant head method and for sand medium it was 4.5 $m.day^{-1}$, for grit 53.5 4.5 $m.day^{-1}$, for gravel 85.11 $m.day^{-1}$, for Brocken brick 123 $m.day^{-1}$ and for charcoal it was 19 $m.day^{-1}$
9. Hydraulic retention time for combinations of media was 1.3 hrs for 1.8 m head. Interstitial velocity (Va) considering sand medium having effective size 0.42 mm was concluded 9.7 m/day.
10. Domestic waste water treatment plant having capacity of 1.8 $m^3$/day requires 1 $m^2$ area along with other designed parameters. The total depth of media for designed filter was 1.8 m. Volume of small scale filtration unit was concluded 0.011$m^3$ and the surface area of all filter bed was $6.35\times10^{-3}$.
11. The benefits found are low energy demand, less operating and maintenance cost, lower load on fresh water, highly effective purification and ground water recharge. Hence this is an environmental friendly, cost effective and resourceful plant.