*Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 26 No. 1-2021*
*ISSN:1813-1786 (Print) 2313-7770 (Online)*

# Performance Evaluation of Filter Used in Groundwater Recharging Through Wells

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***Abstract-*** Water has significant importance in life. Groundwater is one of the main source which is used for different purposes. It should be free from all kind of impurities in order to make it drinkable. The rainwater runoff plays a vital role to sustain the water table beneath the surface of the earth. The quality of groundwater is affected by different impurities as runoff makes its way to groundwater table. In many areas of Pakistan, ground water recharging wells are installed to recharge the groundwater table. Soil are natural filter which purifies water from the sediments. Many factors are involved that affects the efficiency of natural filter. In this study, an attempt has been made to find the best combination of filter for water purification. A series of experiments were conducted on custom made equipment. The thickness of filter layer, material type, gradation is also varied in order to find the optimum result. Contaminated water is poured from the top and filtered water is collected at the bottom. The efficiency of proposed filter varies for different filter combination. The results have indicated that the high discharge filter can be install in those areas where slight purification of water is required..

***Keywords-*** Groundwater, Recharging well, Filter, Contaminaton, Stormwater, Soil.

## I. INTRODUCTION

Groundwater is major source of drinking water. Around the world, 35% of drinking water used for drinking purpose whereas, 20% of fresh water is used for agriculture. Pakistan used a large portion of fresh water daily. Around 80% of ground water in Pakistan used for agriculture and drinking purposes. In Pakistan, underground water due to its fast usage reaches to an alarming level. To overcome this situation, the ground water recharging by wells is an effective solution but the runoff rainwater contains many types of impurities, municipal solids and contaminations that can cause considerable trouble. When such contaminated water comes in contact with the water table beneath the earth it can cause severe problem. This polluted water will be provided for the agriculture and drinking purpose, that ultimately results in affecting the health and can be cause of deadly diseases.

According to Meteorological Department, many areas of Pakistan receive precipitation not less than 250 mm in a year, which is a large quantity of water having in any area. The recharging by well is an affective solution in those areas having high rainfall.

It is essential that we must accumulate the stormwater runoff and used it for groundwater recharging. In order to protect the groundwater, the stormwater must be purified from all harmful impurities and suspended solids. The water contains many types of impurities that can affects the filter function. Therefore its care and preservation are required on regular basis [1]. Gravel filter is efficient for its use against all type of pollutants and most of the toxic waste stuck in between 0.5m depth. Its use has proven effective against liquefying nutrient pollutant [2]. Clogging can create an obscure in the transmission of oxygen to the water. It is essential to find the proper solution of impurities that affects the quality of water to be used in recharging well [3]. It is observed that if the water table is kept constant, the clogging of filter will be at much slower rate [4]. The discharge rate can be increased by inclusion of medium sand in the filter layers. Researchers have also investigated the impact of moisture content and flow percentage on the filter by using different combinations of layers [5].

Researchers have performed series of experiments with variable ratios of coarse sand, gravels and pebbles [6]. Stormwater filtration system are mostly used nowadays due to its efficiency and also an economical method. But the main problem of this filter is the clogging, resulted from contaminations and sediments present in the municipal wastewater [7]. The mixing of municipal solid waste water into the groundwater without purification can cause health issues which should be carefully considered and evaluated [8].

If the rainwater mixes with solid or industrial waste, it will be very difficult to purify the water due to the high level of minerals and chemicals that may change the chemistry of water. Modern technology have also brought some problems like presence of concrete pavements obstacle the movement of water. It is observed that recharging rate increases with the increase in size of medium sand [9]. Boulder, gravel and coarse sand is used in various combination by researchers for filter design [10]. The efficiency of gravel and sand filter alongwith combination of compost, mesoporous etc have been evaluated by the researchers against water borne diseases [11]. Considering the requirement and needs, an optimum filter can be selected with limitations [12].Slow sand and rapid sand filter was found effective in reducing the turbity, solids, etc. in Pakistan [13].

Recharging by well can be an effective way to counterbalance this situation and restores the water table.

Generally recharging wells are of two types i.e. horizontal and vertical. The vertical recharging wells are relatively economical as compared with horizontal wells. The efficiency of the filter used in recharging wells are assessed by its discharge rate and quality of water.

Groundwater is depleting at an alarming rate in Pakistan. World resources institute has included Pakistan among highly water stressed countries. The water demand in Pakistan is high as compared with its supply. Groundwater need to be recharge to maintain its level. In Pakistan, rain and flood water is mostly wasted due to not having proper storage facilties like ponding areas and insufficient dams. Groundwater recharging by well can be an efficient solution to this problem. However, care must be taken to avoid mixing of contaminated surface water with groundwater. Surface water must be treated for impurities before mixing it with groundwater.

In this study, possible filter combinations for vertical recharging wells are investigated. The quality and performance of storm filtered water is also assessed.

## II. Material and Methods

The custom made equipment is used to asses the filtration process. The apparatus consists of a cylinder having a 30.48cm diameter and 122cm height. The cylinder was supported on iron stand (Fig. 1). The height of the stand and width was 45.72cm and 76.2cm respectively. The details are mentioned in Table I.

The contaminents are introduced artificially in water to asses the filtration process during experiments. Following contaminents are used:

- Cans
- Paper

TABLE I
SPECIFICATIONS OF APPARATUS

| Sr. No. | Different Parts | Size | |
|---|---|---|---|
| | | SI units | British |
| 1 | Height | 122cm | 4ft |
| 2 | Diameter of apparatus | 30.48cm | 1ft |
| 3 | No. of Valves | 5 | 5 |
| 4 | Diameter of side valves | 1.27cm | 0.5in |
| 5 | Diameter of the outlet | 1.905cm | 0.75in |
| 6 | The vertical distance between side valves | 15.24cm | 6in |
| 7 | Thickness of plastic | 0.6cm | 0.24in |

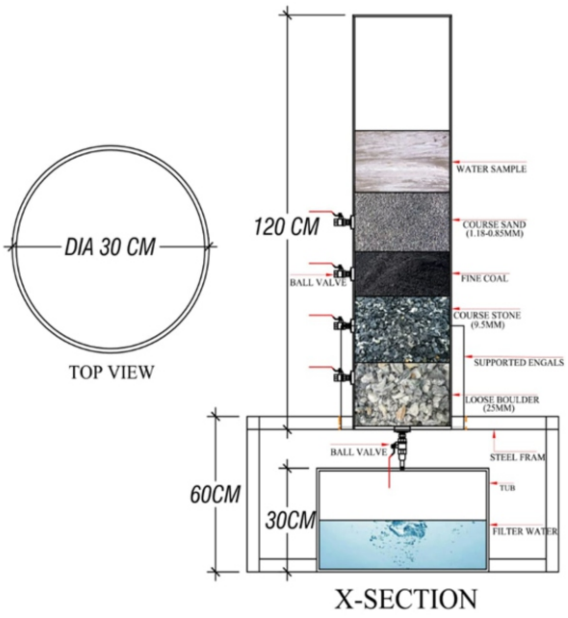


Fig. 1. Schematic diagram of filtration equipment

- Sediments
- Plastic Bags
- Food Wrappers
- Cigarette Butts

Lawrencpur sand and margala aggregates are used in filter. The gradation are also varied in order to get optimum results. The aggregates are first washed and then air dryed before its used as a filter materail. The loose, compacted bulk density of aggregates and void ratios are calculated. The discharge rate depends on void ratio as with the increase of void ratio, discharge rate as increases.

First filter layer is installed and afterwards stormwater with impurities is poured on it. The discharge is calculated at the bottom of the cylinder. Different combination of filter are used like, coarse and fine aggregrate, boulders, marble chips and coal. In total eleven (11) different combinations of filter are tested. The flow chart of methodology is presented in Fig. 2.

ISSN:1813-1786 (Print) 2313-7770 (Online)

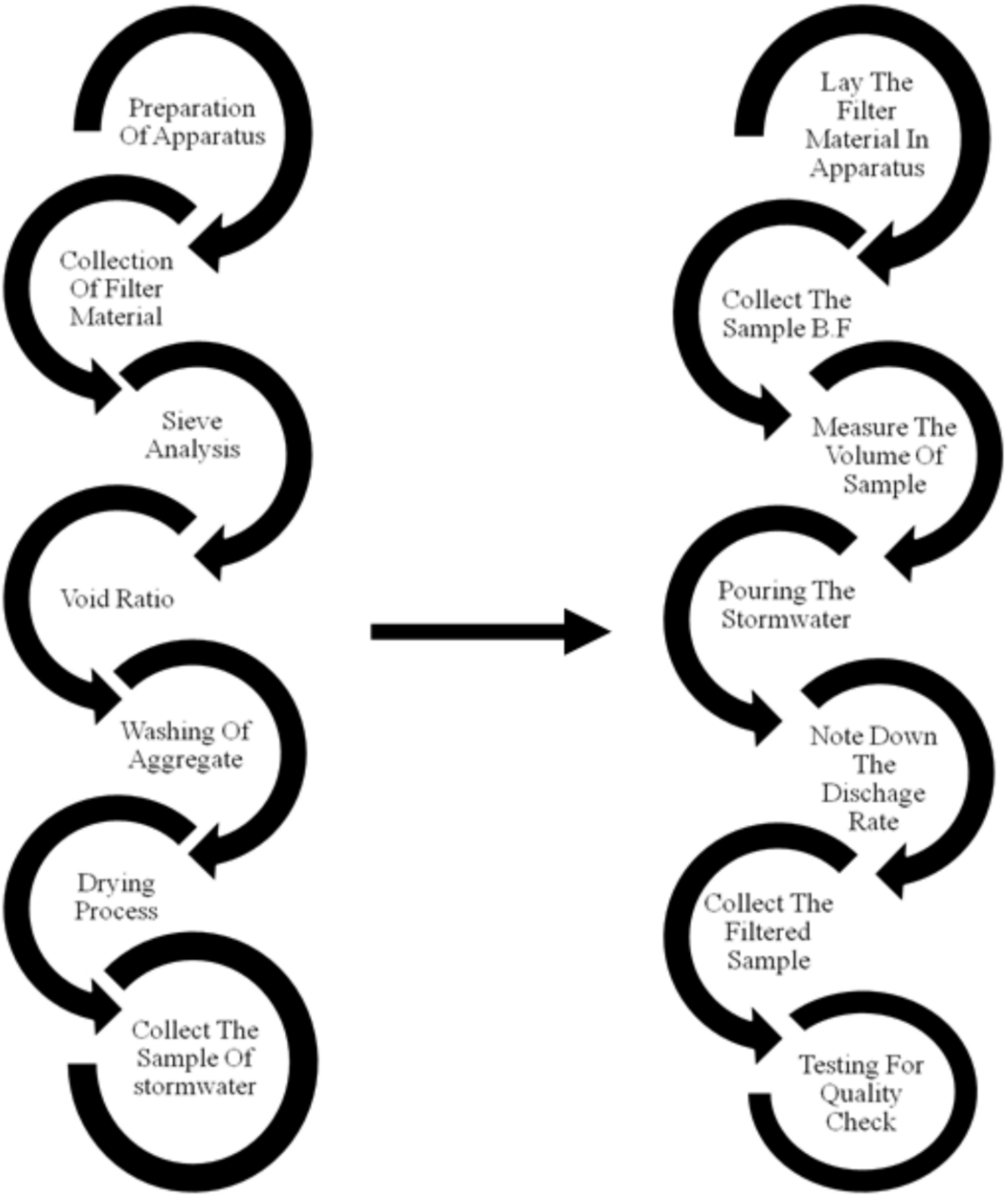


Fig. 2. Methodology Flow Chart

## III. Test Results and Discussion

Performance of the recharging well depends on many factors such as particle size of filter material, combination of layers, layer thickness, catchment area and size of contaminants. For tests, rain water was collected from ponding area at Jinnah road, Sialkot bypass road and Chand da qila of Gujranwala City. The collected sample was then brought to the laboratory for testing. During collection, it was ensured that impurities are not added to it. Sample water was poured from the top of the cylinder. Upon completion of filtration process, the filtered water is collected at the bottom of the cylinder which was later tested for

TABLE II
DENSITY OF AGGREGATES

| Density | Mass (kg) | Volume ($m^3$) | Density ($kg/m^3$) |
|---|---|---|---|
| Loose Bulk Density of Coarse Aggregate | 13.05 | 0.009879 | 1320.93 |
| Compacted Bulk Density of Coarse Aggregate | 14.60 | 0.009879 | 1477.80 |
| Loose Bulk Density of Fine Aggregate | 10.85 | 0.009879 | 1098.24 |
| Compacted Bulk Density of Fine Aggregate | 12.3 | 0.009879 | 1245.00 |

TABLE III
VOID RATIO OF AGGREGATES

| Aggregates | Void Ratio |
|---|---|
| Coarse Aggregate | 0.237 |
| Fine Aggregate | 0.231 |

TABLE IV
FILTRATION DISCHARGE

| Test No. | Size* | Filter Material* | | | | | | | | Discharge l/min |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Chips | L.B | Sand | Sand | C.S | Coal | C.A | L.B | |
| 1 | T.L(cm) | --- | 8 | 10 | 5 | 2 | 4 | 10 | 8 | 0.96 |
| | P.S(mm) | --- | 19 | 0.425 | 0.3 | 0.85 | 12.25 | 9.5 | 19 | |
| 2 | T.L(cm) | --- | 7 | 10 | --- | --- | 5 | 18 | 18 | 0.72 |
| | P.S(mm) | --- | 19.5 | 0.425 | --- | --- | 12.25 | 9.5 | 25 | |
| 3 | T.L(cm) | 20 | --- | --- | --- | --- | --- | 20 | 30 | 1.2 |
| | P.S(mm) | 0.85 | --- | --- | --- | --- | --- | 9.5 | 25 | |
| 4 | T.L(cm) | --- | --- | --- | --- | 18 | --- | 48 | 24 | 0.5 |
| | P.S(mm) | --- | --- | --- | --- | 0.85 | --- | 9.5 | 25 | |
| 5 | T.L(cm) | --- | --- | --- | --- | 30 | --- | 20 | 30 | 0.35 |
| | P.S(mm) | --- | --- | --- | --- | 0.85 | --- | 9.5 | 25 | |
| 6 | T.L(cm) | --- | --- | --- | --- | 10 | --- | 20 | 30 | 0.65 |
| | P.S(mm) | --- | --- | --- | --- | 0.85 | --- | 9.5 | 25 | |
| 7 | T.L(cm) | --- | --- | --- | --- | 15 | --- | 20 | 30 | 0.75 |
| | P.S(mm) | --- | --- | --- | --- | 0.85 | --- | 9.5 | 25 | |
| 8 | T.L(cm) | --- | 30 | --- | --- | --- | --- | 30 | 30 | 10.25 |
| | P.S(mm) | --- | 25 | --- | --- | --- | --- | 9.5 | 25 | |
| 9 | T.L(cm) | --- | 45 | --- | --- | --- | --- | 30 | 45 | 9.8 |
| | P.S(mm) | --- | 25 | --- | --- | --- | --- | 9.5 | 30 | |
| 10 | T.L(cm) | --- | 45 | --- | --- | --- | --- | 30 | 45 | 9.8 |
| | P.S(mm) | --- | 25 | --- | --- | --- | --- | 9.5 | 25 | |
| 11 | T.L(cm) | --- | 22 | --- | --- | 22 | --- | 22 | --- | 0.05 |
| | P.S(mm) | --- | 25 | --- | --- | 0.85 | --- | 9.5 | --- | |

*T.L is Layer thickness, P.S is Particle size, L.B is Loose boulder, C.S is Coarse stone, C.A is Coarse aggregate

impurities to check the efficiency of the filter. The density of the aggregates, void ratio, filter discharge and chemical analysis are given in Table II, III, IV and V respectively. The filter having coarse aggregate and loose boulder material results in maximum discharge afer filtration.The chemical analysis of water before and after filtration have highlighted the effectivneness of the filter combinations for reducing the Hardness, Calcium and Chloride content in stormwater etc.

TABLE V
CHEMICAL ANALYSIS RESULTS

| Test No. | C* | Filter Material* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pH | Odor | Colour | T (NTU) | TDS (mg/l) | Ca (mg/l) | M (mg/l) | TH mg/l as $CaCo_3$ | B (mg/l) | TA mg/l $CaCo_3$ | Cl (mg/l) | CD µs/cm |
| 1 | B.F | 7.9 | Fowl | Br | 10.06 | 461 | 64 | 20 | 200 | 160 | 160 | 186 | 659 |
| | A.F | 7.6 | Clayish | Co | 3.15 | 417 | 72 | 15 | 170 | 120 | 120 | 174 | 595 |
| 2 | B.F | 7.6 | Fowl | Br | 9.95 | 426 | 64 | 29 | 260 | 210 | 210 | 189 | 609 |
| | A.F | 7.4 | Clayish | Co | 4 | 357 | 52 | 22 | 200 | 160 | 160 | 110 | 510 |
| 3 | B.F | 7.8 | Fowl | Br | 4.02 | 532 | 84 | 38 | 340 | 220 | 220 | 173 | 760 |
| | A.F | 7.8 | Clayish | Co | 3.29 | 237 | 44 | 11 | 120 | 80 | 80 | 55 | 339 |
| 4 | B.F | 7.5 | Fowl | Br | 9.04 | 379 | 60 | 27 | 240 | 160 | 160 | 107 | 541 |
| | A.F | 7.3 | Clayish | Co | 5.79 | 285 | 48 | 18 | 170 | 110 | 110 | 72 | 407 |
| 5 | B.F | 7.9 | Fowl | Br | 3.29 | 237 | 44 | 11 | 150 | 100 | 100 | 67 | 379 |
| | A.F | 7.8 | Clayish | Co | 2.7 | 265 | 44 | 16 | 120 | 80 | 80 | 55 | 339 |
| 6 | B.F | 7.8 | Fowl | Br | 8.14 | 269 | 48 | 18 | 170 | 100 | 100 | 73 | 384 |
| | A.F | 7.4 | Clayish | Co | 7.02 | 266 | 44 | 14 | 140 | 100 | 100 | 70 | 380 |
| 7 | B.F | 7.5 | Fowl | Br | 3.41 | 301 | 48 | 20 | 180 | 120 | 120 | 90 | 430 |
| | A.F | 7.2 | Clayish | Co | 1.3 | 226 | 40 | 11 | 110 | 80 | 80 | 55 | 323 |
| 8 | B.F | 7.8 | Fowl | Br | 3.34 | 352 | 56 | 28 | 240 | 150 | 150 | 98 | 497 |
| | A.F | 7.6 | Clayish | Co | 2.89 | 348 | 52 | 25 | 220 | 140 | 140 | 90 | 430 |
| 9 | B.F | 7.9 | Fowl | Br | 3.03 | 368 | 60 | 26 | 230 | 160 | 160 | 119 | 525 |
| | A.F | 7.3 | Clayish | Co | 1.9 | 362 | 56 | 23 | 210 | 150 | 150 | 113 | 517 |
| 10 | B.F | 7.9 | Fowl | Br | 7.6 | 339 | 52 | 25 | 220 | 140 | 140 | 105 | 484 |
| | A.F | 7.5 | Clayish | Co | 4.12 | 333 | 52 | 21 | 190 | 120 | 120 | 102 | 475 |
| 11 | B.F | 7.7 | Fowl | Br | 3.98 | 400 | 64 | 31 | 270 | 180 | 180 | 145 | 571 |
| | A.F | 7.3 | Clayish | Co | 5.49 | 358 | 56 | 58 | 240 | 160 | 160 | 128 | 511 |

*C is condition, B.F is Before filtration, A.F is After filtration, Br is Brownish, Co is Colurless, T is Turbidity, TDS is Total dissolved solids, C is Calcium, M is Magnesium, B is Bicarbonate, TH is Total hardness, TA is Total alkalinity, Cl is Chloride, CD is Conductivity

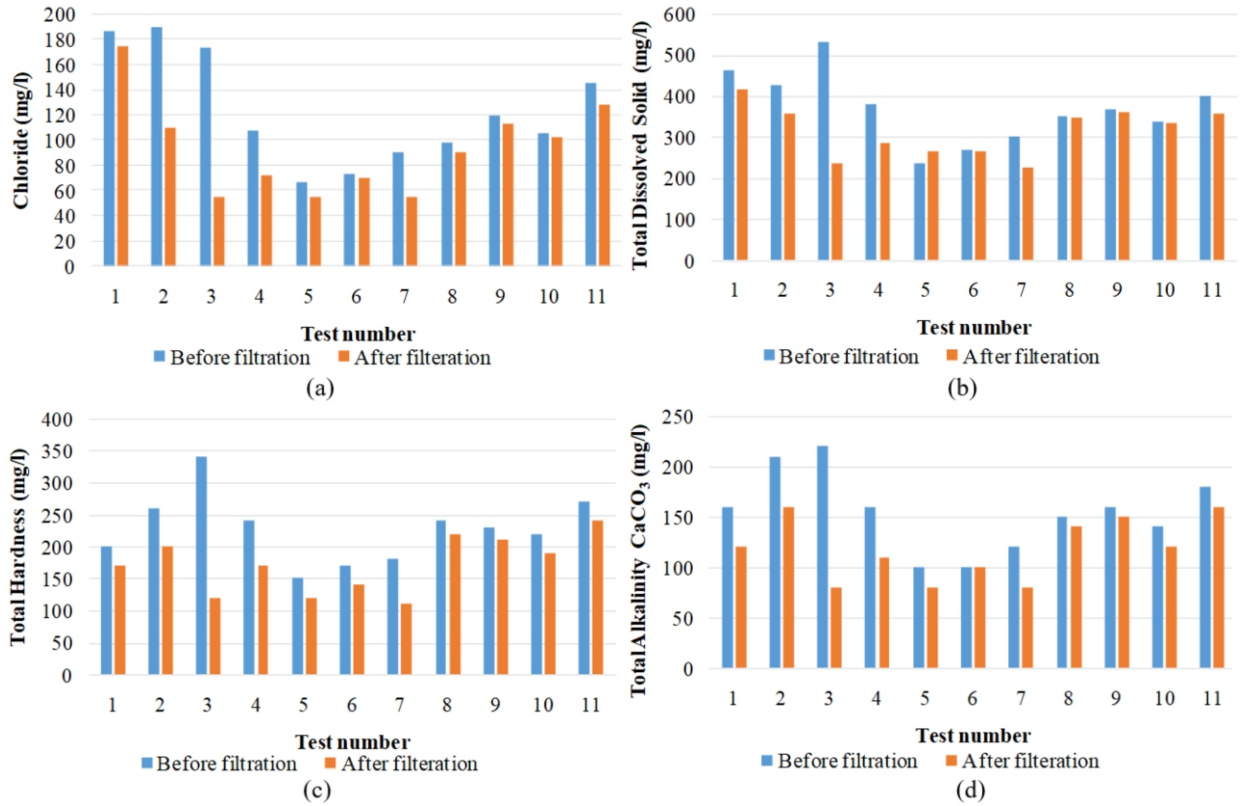


Fig. 3. Chemical Analysis of filtered and un-filtered water for (a) Chloride, (b) TDS, (c) Hardness, and (d) Alkalinity

## IV. CONCLUSIONS

Pakistan is considered as water-scarce country with groundwater depleting at an alarming rate. Recharging of groundwater using recharging well is very essential for maintaining groundwater level. Filter needs to be properly designed to avoid mixing of contaminated surface water with groundwater. The effectiveness of filters for vertical recharging well is investigated in this research. Following results are deduced from the experiments:

- Their is a considerable improvement in quality of water tested after filtration. Improvement in quality of water is confirmed from chemical analysis of filtered and un-filtered water (Table 5).
- Filter with combination of loose boulder and coarse aggregate results in maximum discharge output i.e. 10.25 l/min.
- Filter with high discharge rate can be install in garden, roof or in such areas where chances of contamination are minimum. The optimum filter combination for such use of water comprises of loose boulder and coarse aggregate (Test # 9).
- Areas with stormwater having high concentration of contaminants, the optimum filter comprises of coarse sand, coarse aggregate and loose boulder (Test # 4). Though it has a low discharge rate but the quality of water is good.
- Areas with stormwater having higher concentration of total dissolved particles, the optimum filter combination comprises of marble chips, coarse aggregate and loose boulder (Test # 3).
- Filter design are always specific to particular situation. Parameters needs to be considered carefully while deciding optimum filter design.

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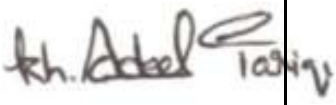
| 1 | Khawaja Adeel Tariq | Basic study design, methodology, analysis and manuscript writing |  |
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| 3 | Muhammad Mudassar | Literature review, Data Collection, statistical analysis and interpretation of results etc. | |
| 4 | . . Muhammad Awais . . | Data Collection, statistical analysis and interpretation of results etc. | |