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Estimation of First-Flush Diverter Phenomena through Volume Based Grab sampling of Rainwater

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Abstract: The first-flush diversion is deliberately branded as a constructive intervention to cut both suspended and dissolved contaminants load in rainwater systems. Setting-up a first flush diverter (FFD) is an economical practice for enhancing the quality of harvested rainwater. This study depicts the estimation of the volume of first flush and quality of rainwater harvesting in Nathiagali, Abbottabad through volume based grab sampling of rainwater straight from the catchments area (roof) and contains analysis of few physicochemical water quality parameters including turbidity, pH, electrical conductivity (EC) and total dissolved solids (TDS). First flush phenomena distinct sediments, bird droppings, spiders, insects, mosquito eggs and debris from penetrating into the storage tanks. It depends on the preliminary rain to wash the roof beforehand water is stored in the main tank. Though there is almost widespread acceptance that this practice is valuable hence there is no stringent standards or agreements on how much water is to be diverted in the first flush as literature demonstrated fluctuated values. It depends on subsequent factors that affect the first flush including rainfall intensity or average rainfall, roof size, roof material, slope, exposure, antecedent dry time. This study recommended that, firstly, 25 to 30 gallons of rainwater should be diverted to the first flush.

Keywords: Rain Water Quantity, Rain Water Quality, Rainwater Harvesting, First Flush Diverter (FFD)

1. INTRODUCTION

First flush diversion (FFD) is one of the most operative parts of rainwater harvesting system. FFD mounted above the main storage tanks with collector pipe to drain out the early minutes of stormwater. It has been considered that this early first water could be more contaminated because of particulates, birds dropping, dust and other materials that have been placed on the rooftop. To reduce the contamination in rainwater harvesting systems, FFD is considered as one of the valuable interventions in rainwater harvesting systems. FFD flushes off the early minutes of stormwater before it get penetrated into the storage tank that is considered as highly contaminated (Abbott *et al.*, 2007; Ntale and Moses, 2003).

The accumulation of dust, leaves, animal excrement, dead insects and other particulate matter due to the dry weather is washed off during the rain, resulting in cleaning the rooftop. It is evident that the intense rain cleans most of the area of the rooftop. The working concept behind FFD is to prevent the initial dirty/contaminated water from penetrating into the storage tank and to allow cleaner water to fill the tank to improve water quality and that has been the focus of this research paper.

Though the FFD idea initiated in the urban stormwater and sewer literature (Doyle 2008), it has also been widely accepted and applied to rooftop rainwater harvesting. The agreement on the amount of water that must be diverted is slightly lesser, but the most obvious reason is that FFD is site-specific. The volume of water that must be diverted for a system is dependent on the acceptable risk, site-specific characteristics and on the value of water is based on the end users of that water. A variety of site-specific aspects arise when calculating a suitable size for an FFD chamber, most apparently including proximity to roadways, distance from trees, quality of the roofing material, and abundance of birds, small animals (i.e. lizards), and insects. The other factors include roof material, roof size, slope, exposure, and meteorological factors including rainfall intensity and antecedent dry time (Meera and Ahammed, 2006)

The recommendations on how much water runoff is required for diversion from domestic rooftop harvesting is cited from the available literature in **(Table 1).** In some cases, the values supplied in the literature were converted to millimeters of rain for easy comparison, while some scientists recommended that the first ten minutes of the rain water should be diverted in first flush. Some researchers suggested that from the first flush volume we should remove about 10 gallons (37.8 liters) of water per 1000 square feet (92.9 square meters) of roof/catchment area. A long first flush is required in an area which is densely polluted (e.g. urban area with poor air quality), an area with a lot of dust or other pollution sources.

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Reference	Specifications	How much is flushed?
Yaziz, et al. 1989	Protection against microbial contamination	0.33mm
Ntale, et al. 2003	Empirical value Should be reduced in rainy season	0.83 mmor first 10 minutes
Martinson and Thomas 2005	Based on sample quantities	For each mm flushed away, the contaminant load will halve
Cunliffe 1998	For an "average-sized roof"	20-25 Liters
Rain Harvestingr undated	Minimum Less pollution More pollution	− 0.20mm − 0.50mm − 2.0mm
Pacey and Cullis 1986		First 10 minutes of rain event
Texas Water Development Board 2005	Contingent on dry days debris, trees, and season	0.41 – 0.82 mm
Michaelides 1987	Grounded on experimental work in Thailand	0.28 mm

Table1 Different literature review on first flush diversion

If the rooftop water is being used for potable purposes or if rooftop contaminants spoil the rainwater due to heavy bird droppings, then FFD systems will be needed for sure. This system keeps away the first wash of water out from your storage container. The general rule of thumb for the discarded quantity of water is 5-10 gallons per 1000 square feet of the roof or smaller. For larger roofs, discard 10 gallons per 1000 square feet. The most literature cites 5-10 gallons of water per 1000 square feet of roof area should be diverted.

The main objective of this study is to assess the quantity and quality of first flush rainwater through volume based grab sampling of rainwater directly from catchments area (roofs). Nathiagali, Abbottabad is a tourist place, during summer water is consumed with double and triple rate just because of tourism so, the water shortage is a major issue in the study area. The average annual rainfall in the Nathiagali is 1500 mm to 1600 mm from this amount of rain we can harvest a lot of water and use it for both non-potable and potable purpose. Nathiagali is less polluted area than others polluted areas of the country. The focus of this study is to estimate the how much rainwater divert in the first flush because Installation of a first flush diverter (FFD) is an economical practice for enhancing the quality of harvested rainwater.

2. MATERIALS AND METHODS

2.1 Study areas

Nathiagali, Abbottabad is hill station in Hazara, KPK, Pakistan. It is very famous for its attractive exquisiteness, hiking tracks and pleasing weather, which is considerably cooler than the rest of the Galiat area due to its existence at a greater altitude (PMD).

2.2 Materials used

Multi-parameter probe (PH/EC/TDS/TEMP (HI-98129) digital meter was used for analyses of rainwater samples. The turbidity of samples was analyzed by using portable turbidity meter. Global positioning system device (GPS 60 Garmin) was used for location identification of sampling points. 15 liters and 10 Gallons buckets and sterilized water bottles were used for the collection of rainwater directly from catchments area (roof). Microsoft Excelwas used for data analysis.

2.3 Methodology

200 households' questionnaire survey was conducted tofind the average size of roofs top (catchment area)and used meteorological Information of Nathiagali. The data were achieved from Pakistan Meteorological Department (PMD) and Earth quake reconstruction and Rehabilitation Authority (ERRA). GPS Coordinates of each sampling site were taken. Both quantitative and qualitative methods were used for data analysis. For data analysis Microsoft Excel was also used.

2.4 Volume Base Grab sampling

Rainwater samples were collected from 3 various locations namely, Passala, Kassian Bagan and Main Nathiagali during rain fall. Samples were collected from these three places for three times. The rainwater samples were directly collected from catchments area of Corrugated Galvanized Iron (CGI) roof. First of all the samples were collected, from Passala village during rain fall with the help of 10 Gallons bucket, one sample was taken when the bucketwas filled then again second sample was taken when the bucket was filled and same procedure was followed for the thirdtime sampling. Secondly three samples were taken from Bagan village and the same procedure was followed for all sampling. From the thirdlocation (Main Nathiagali) 12 rainwater samples were also collected. 15 liters bucket and water bottles were used for the collection of rainwater directly from the catchments area (roof). Rainwater samples were collected directly from the roof for the estimation of first flush volume. Rainwater samples were collected from three different' sites and from different catchments areas at different time for the estimation of first flush volume through physical parameters. Values of the rainwater samples like turbidity, pH, total dissolved solids and electrical conductivity. These parameters were analyzed by using a multi-parameter probe (PH/EC/TDS/TEMP (HI-98129) digital meter and portable turbidity meter. All measurements were performed in triplicates to avoid the errors. Finally, the conclusions were drawn in comparison with the WHO drinking water quality guidelines.

3. RESULTS AND DISCUSSION

3.1 Rain Water Quality Analysis and First Flush Estimation

For checking quality of rainwater and estimation of first flush volume for rainwater harvesting system (RWHS) volume-based grab samples were taken from Baghan village (5567ft N34 02.049 E73 21.229) and the catchment area of sampling site was 1200 sq. ft, Three samples were taken from each collection point. 10 gallons bucket and water bottles were used to collect after filling 10 gallons bucket then second samples is also taken when the bucket is filled & third sample was also taken from the discard bucket so three samples were taken by discarding 33 gallons volume of rainwater. For analyzing rainwater quality, the following water quality parameter was analyzed (turbidity, pH, TDS and EC. The value of these parameters, turbidity, TDS, and EC were higher for the first sampling then decreased in next sampling while the value of pH was less in the first sample and increased in next samples results shown in Fig. 1.

Graphic result shown in Fig- 1 that first sample of rain is more turbid (71.NTU) because in first sample of rain, contain more concentration of suspended matter like dust clay and other particles these particles come from roof usually these particles are found (stick) with roof due to this in first sample of rain turbidity value is more and clearly shown in graph, turbidity value is decreasing in next samples in correspondence to initial samples. The pH value is less (acidic) 5.9 in the first sample of rainwater and in next samples value of pH was increased 6.4, 6.12. after discarding 33 gallons of rainwater value of pH did not match WHO value 6.5-8.5. TDS value was 155PPM in the first sample then decreased in other samples same as the value of EC was 378 µS and decreased in second and third samples shown in **(Fig.1).**

As shown by the results, it is concluded that, firstly, 31 gallons of rainwater should be diverting to first flush water; this water can't use as portable purpose due to its turbid and acidic characteristics. This first flash volume is specified for this specific 1200 sq. Feet catchment area, as under observation. Second time three samples were taken from Passala village and the same procedure was followed, and the catchment area of sampling site was 600 sq. ft. Generally, pH readings in first sample was slightly acidic than second and third samples. Turbidity value was higher in first sample 17 NTU while decreased in second and third sample 4.9, 3.8 NTU. TDS and EC also shows good improvement after discarding water . Graphic Representation of Turbidity, pH, TDS & EC Variation in rainfall of Pasala village shown in **(Fig- 2).**

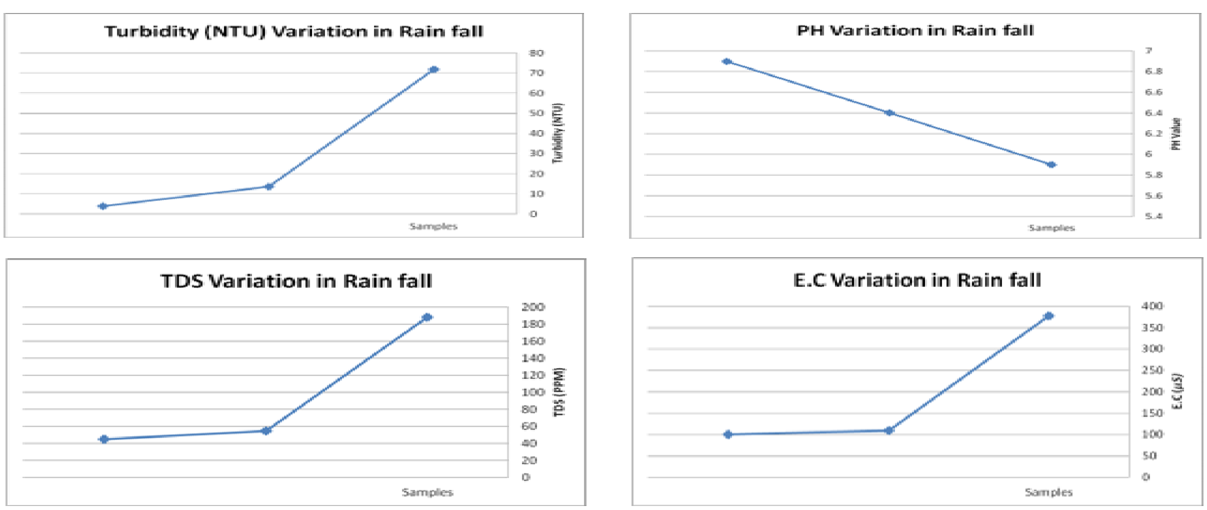

Fig. 1: Graphic Representation of Turbidity, pH, TDS & EC Variation in rainfall of Bagan village

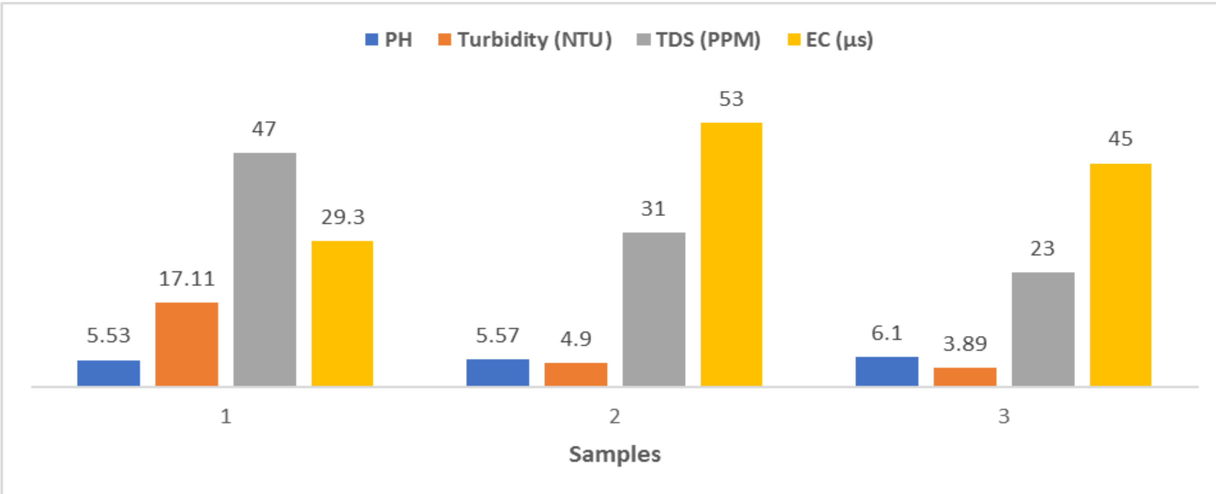

Fig. 2: Graphic Representation of Turbidity, pH, TDS & EC Variation in rainfall of Passala Village

From the third location (Main Nathiagali) 12 rainwater samples were collected. And the catchment area of the sampling site was 2500 sq. ft. During the third time, 15 liters bucket and water bottles were used and 180 litters rainwater discarded. Main Nathiagali rainwater samples parameters readings showing in **(Table 2)**

Table 2: Main Nathiagali Rain Water Samples (Volume Based) Quality Parameters Readings

	Samples	PH	Turbidity *NTU*	TDS PPM	E.C *uS/cm*
WHO Guideline		***6.5-8.5***	***‹ 5 NTU***	***‹ 1000***	***2100***
Rain water Samples (Volume Based)	0-15L	5.9	70	110	102
	16-30 L	6.1	61.3	100	89
	31-45L	6.4	43	100	88
	46-60L	**6.83**	28.9	73	58.2
	61-75L	6.9	25	72	58
	76-90L	7.3	13.3	53	38
	91-105L	7.41	4.9	30	36
	106-120L	7.45	**1.9**	29.9	33.9
	121-135L	7.45	0.9	28	33.7
	136-150L	7.09	0.5	27	33.3
	151-165L	7	0.5	24	**25**
	166-180L	7.03	0.4	**19**	23

The pH values, ranged from 5.9 to 7.45, indicating that in the studied area the rain is not more acidic. The first sample shows that of rainwater is acidic because rainwater is usually acidic. Normal rainwater has a pH of 5.6 (slightly acidic). This is because it is exposed to the carbon dioxide in the atmosphere. The carbon dioxide gets dissolved in the rainwater and forms carbonic acid (H {-2} CO {-3}). pH of rainwater differs from place to place. The variations of pH values also occur because rainwater that fall through the catchment area roof system was mix in with leaves, dust and bird drops. These depositions of particulates were contributing to the differences in pH (Kathy et al. 2014). In Nathiagali less atmospheric pollution due to this pH of rainwater was not more acidic in the present scenario urbanization has increased its acidity. But in case of rains whose pH generally falls around 5.6, it is potable, but it will be slightly acidic and corrosive (Casiday and Frey, 1998).

Chemical equation CO2 + H2O ---> H2CO3 (carbonic acid)

Table result shown that first sample of rain is more turbid (70 NTU) because in first sample of rain, contain more concentration of suspended matter like dust clay and other particles these particles come from roof usually these particles are found (stick) with roof due to this in first sample of rain turbidity value is more and clearly shown in Table 2 turbidity value is decreasing in next samples in correspondence to initial samples. As shown by the results, it is concluded that, firstly, 39.6 gallons of rainwater shouldn't be used as potable water, as due to its turbid characteristics. This flash volume is specified for this specific 2550 sq. feet catchment area, as under observation. The result of both TDS & E.C shown above in table 2 in the first sample of rain its value is high then decreases in furthers samples it Indicates that the first sample of rain is more turbid and as shown by the results. EC of rainwater reflect the impact of atmospheric particulate matter if the EC of rainwater is low is an indicator of good atmospheric environmental quality. The value of EC was higher in first sample 102 uS/cm and gradually decreased in other samples. TDS in rainwater, creating from particulate matter suspended in the atmosphere (Cobbina *et al.* 2013). TDS value was also higher in first sample 110 PPM and decreased in other samples shown in table 2

3.2 Average Rainfall and size of roofs in Nathiagali

After 200 houses household's questionnaire survey find out the average size of roofs top (Catchment area) the average size of roofs in Nathiagali was 60ft (L) 20 ft. (W) which is 1200sq ft. And used meteorological Information of Nathiagali this data were achieved from Pakistan Meteorological Department (PMD) and Earth quick reconstruction and Rehabilitation Authority (ERRA). The average annual rainfall in Nathiagali is approximately 1500 to 1600 mm shown in **(Fig. 3).**

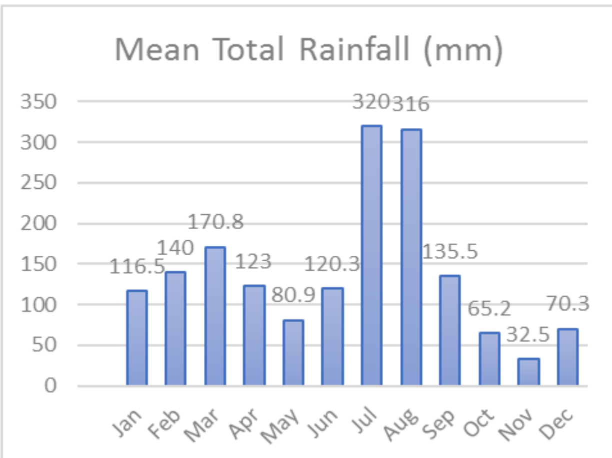

Fig- 3 Information of Meteorological normal for Nathiagali (PMD).

4. CONCLUSION

The focus of this study was to estimate the how much rainwater divert to the first flush because installation of a FFD is an economical practice for enhancing the quality of harvested rainwater. As shown by the results, it is concluded that, firstly, 25 to 30 gallons of rainwater should be diverted in the first flush in the study area and shouldn't be used as potable water, as due to its turbid and acidic characteristics but this water can be utilized for non-potable purposes at domestic and commercial levels. This first flash volume is specified for the 1200 to 1500 sq. feet catchment areas and the average rain fall is 1500 mm approximately. More research is needed about this topic, integrated approaches (both volumes based sampling and engineered based technique is a need for further studying of this topic.

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