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Impact Analysis of Cement on Rain Water

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ABSTRACT
Worldwide rainwater is harvested from many surfaces including roof tops and ground surface and it is harvested from many surfaces including roof tops and ground surfaces. It interacts with different materials in the process of domestic rainwater harvesting. In Kerala, for the storage of rainwater, in addition to traditional methods, ferrocement tanks are widely used, for the construction of which Ordinary Portland cement (OPC) and Portland Pozzolano Cement (PPC) are used. There is a chance of leaching of cement constituents and heavy metals during the storage of rainwater in cement tank for a long period of time,. This paper outlines the effect of cement on rain water.

KEY WORDS: *Rain water, Ordinary Portland cement, Portland Pozzolano Cement Leaching, Electrical conductivity, Storage, Harvested rainwater*

I. INTRODUCTION

The cement paste can be leached by water, when water conduits are made of concrete or are line with cement mortar This occurs to a significant degree if the water remains prolonged contact with the cement paste .The consequences of leaching are an increase in pH and in the content of $CaCO_{3.}$ (Adam.et.al.2001) A critical review of the available literature points to the need for study of the quality of rainwater stored in ferrocement tank in order to ascertain the health risks, if any involved.

II. MATERIAL AND METHODS

In this study sampling of rainwater was conducted in Kalamassery-a typical suburban location in Cochin, Kerala using a wet-only rainwater sampler. The rainwater samples were stored in plypropylene bottles. To conduct the leaching studies cement mortar cubes were prepared using cement and sand in the proportion 1:3. Ordinary Portland cement (OPC) 53 Grade of Zuari Cements make and Portland Pozzolano cement (PPC) of Coromondel Cements make used for the study were procured from the local market. River sand used for making cement mortar cubes were obtained from the banks of Periyar River, Kerala. Plastic tanks of capacity 500 litres, procured from the local market were used to store rainwater samples. Twenty one numbers of cement mortar cubes made up of PPC and OPC as explained above were kept in two plastic tanks of capacity 500 litres. The cubes were arranged in such a way that there is constant contact with water on all the sides of the cubes when the tank is filled with rainwater. Water collected from the tanks were analysed for conductivity, pH, alkalinity, hardness, sulphates and heavy metals by standard methods.

III. RESULTS AND DISCUSSIONS

Effect of Leaching on Electrical Conductivity

The variation of electrical conductivity with time for the control as well as the duplicate samples is shown in figure 1. The control did not show any significant variation in conductivity. It can be seen from the figure that water in which PPC samples were immersed showed higher electrical conductivity compared to that of OPC samples. This is probably due to the higher proportion of refractory materials in PPC derived from fly ash. Cement upon hydration becomes gelled silica, alumina, calcium hydroxide and various complex components derived from them. Of these calcium hydroxide readily dissolves and raises the electrical conductivity of the medium. Rate of leaching depends on temperature, surface area exposed to water and turbulence. The variables have been the same in all the experiments. Conductivity is a good estimator of TDS because TDS in mg/l is proportional to the conductivity in micromhos. Based upon that, it can be estimated that TDS of water containing PPC samples was higher than OPC samples, indicating that leachability of PPC is more than that of OPC.

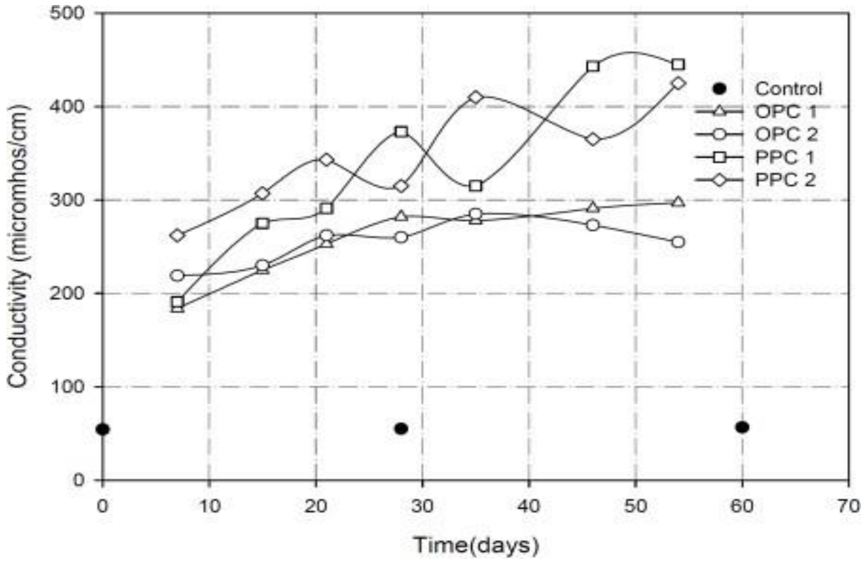

Figure 1 Variation of Conductivity of rainwater with storage

Effect of Leaching on pH

The main effect of leaching is a rise in the value of pH. The variation in pH of water in which OPC and PPC cement mortar cubes were immersed, with time is shown in Fig.2.All the samples showed pH above 10, which slightly increased and fluctuated with time. Cement upon hydration becomes gelled silica, alumina, calcium hydroxide and various components derived from them. Calcium hydroxide, being the major component that could be leached, the pH of the medium increases with increasing leaching from the samples. It can also be seen that the variation of pH among PPC and OPC immersed in water samples is not appreciable. However, the pH of PPC samples is slightly higher than that of OPC samples.

The pH of both samples were in between 10 and 11 as shown in figure 1, and that of raw water is around 6.5. In a solution saturated with calcium hydroxide, the pH would be above

11. This means that the medium not saturated with respect to hydrated lime solubility is probably limited by the dissolution of surface bound lime.

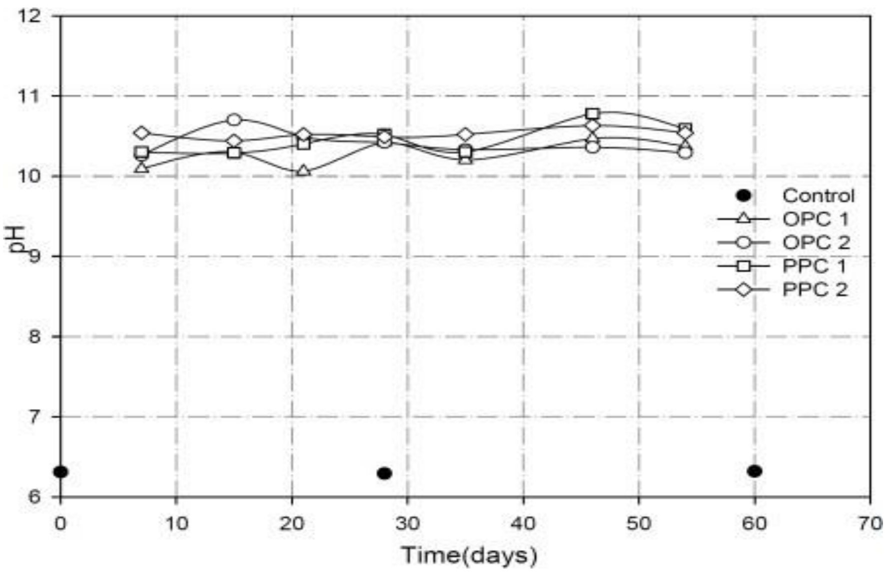

Figure 2 Variation of PH of rainwater on storage

For health reasons, the value of pH at the point of delivery should not exceed 9.5, but values well in excess of 10, or sometimes even more, have been found. Occasionally, there have been complaints about skin irritation developed by contact with such water.

Effect of Storage on Alkalinity

In figure 3, variation in alkalinity of stored rain water is given. The calcium carbonate alkalinity of the water in which PPC and OPC samples were immersed increased from 17.04 mg/l as $CaCO_3$ (control) to 55.38 and 57.51 respectively, after a week. Rainwater with alkalinity of 17 can be considered as very low alkaline water. It can also be seen that after a period of 54 days, the alkalinity of water in which PPC and OPC mortar cubes were immersed were 85.2 and 108.6 mg/l as $CaCO_3$ respectively, a five fold and six fold increase when compared to the control. Even though the alkalinity of water containing PPC is 108.6 mg/l as $CaCO_3$, it is well within the limiting value of 200 mg/l.

Another interesting observation is that with increase in time, the rate of leaching decreases. It is evident that the increase in alkalinity of water due to leaching of cement mortar cubes is more pronounced in the initial stage (ie., the filling of water for the first time after construction of tank).

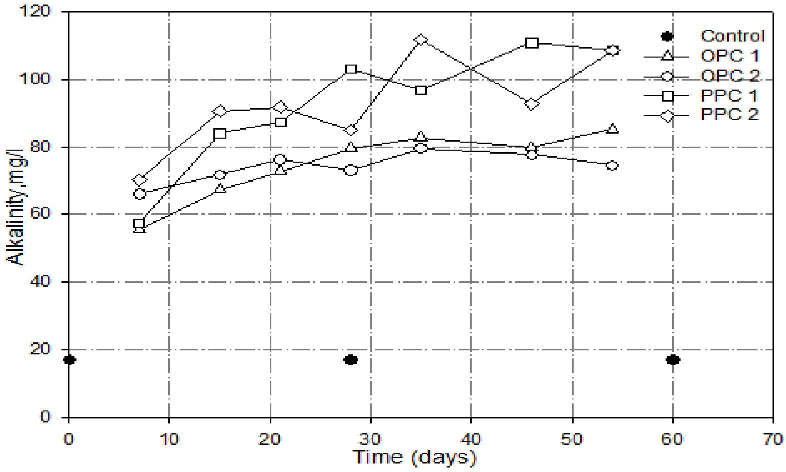

Figure 3 Variation of Alkalinity of stored rainwater with time

Effect of Storage on Hardness of Water

Though there is an increase in the hardness of the samples, the total hardness is within the limit. The effect of storage on Ca hardness and total hardness of water are given in figure.4. According to the hardness alkalinity relationships, if the alkalinity is less than the total hardness, then the alkalinity equals the temporary hardness. If the alkalinity is greater than the total hardness, then all hardness is temporary. It is quite evident from the discussion that, the alkalinity of the water containing submerged PPC and OPC blocks is higher than the total hardness and hence all hardness is temporary, which is due to bicarbonates.

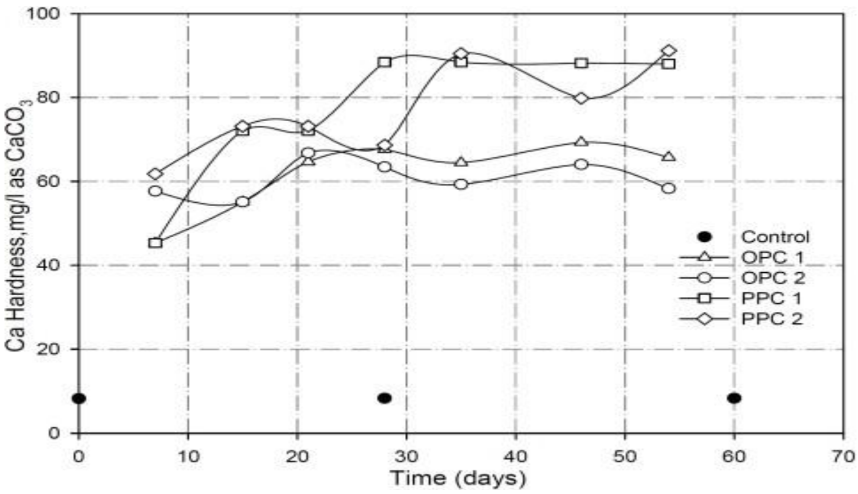

Figure 4 Variation of Ca Hardness of rainwater on storage

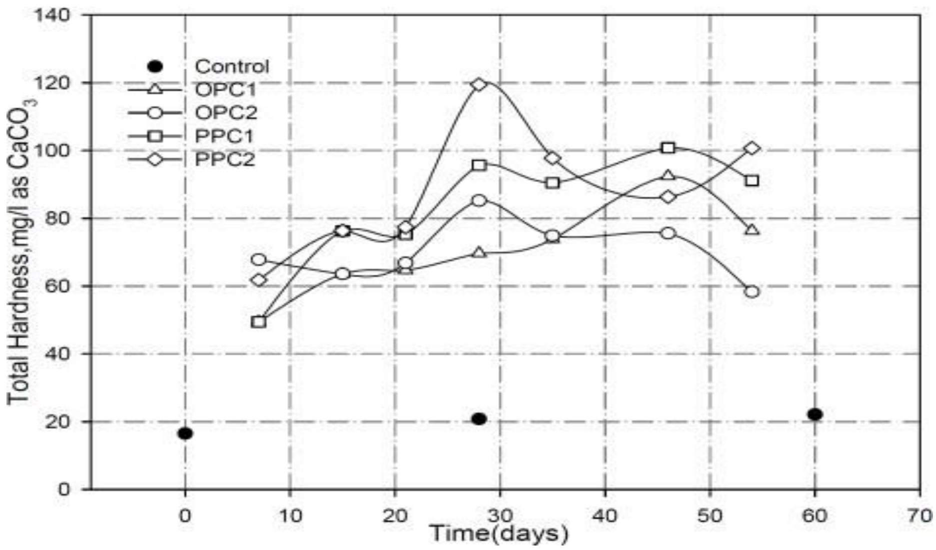

Figure 5 Variation of Total Hardness with Time

Leaching of Heavy Metals

Tables 1 and 2 gives the concentration of heavy metals in the sample. ICP-AES was used to measure three typical heavy metals, namely copper, mercury and lead. Detection limits for the three elements are also shown in the table. Twice the detection limit is considered as the quantification limit. It is clear from table1 that the concentration of heavy metals is much higher in OPC than in PPC. This higher concentration in OPC may be attributed in their origin from the minerals used in the manufacture of cement. Interestingly, PPC shows lower concentration of copper and lead.

Table 1 Concentration of heavy metals in the cement used

Elements	Sample detection limit (ppm)	Ordinary Portland cement (ppm)	Portland pozzolano cement (ppm)
Cd	0.01	0.907	0.145
Hg	0.1	0.05	0.05
Pb	0.05	0.113	0.039

The cements were leached with dilute hydrochloric acid to extract the metals. Normal cementatious materials dissolve in warm dilute hydrochloric acid. During the manufacture of cement, the temperature in the furnace exceeds 950^0C,when metals are converted to their oxides, which combine with more silica, which is acidic in nature. The metal oxide dissolve in silica forming microbeeds of silica, which is glassy and refractory and cannot be decomposed with warm dilute hydrochloric acid. This is a possible explanation for the low amount of heavy metals present in PPC.

Table 2 gives the concentration of heavy metals present in the water in which the cement samples were submerged as well as in raw water. It is seen that the concentration of the three metals is low in raw water (control). The concentrations in PPC were comparable to that of OPC. Even though a slight leaching is evident compared to control water, they are well within the safe limit for drinking water.

Table 2 Concentration of heavy metals (in ppm) in the leachate

Elements	Sample detection limit	Control	OPC-1	OPC-2	PPC-1	PPC-2
Copper	0.01	0.002	0.002	0.002	0.003	0.001
Mercury	0.1	0.01	0.05	0.04	0.06	0.03
Lead	0.05	0.023	0.025	0.025	0.029	0.023

Quality of Rainwater at Various Stages of Harvesting

Table 3 Quality of rainwater at various stages of domestic rainwater harvesting at a suburban location

			Soon after curing*		**six months after construction**	
Parameter	**Freefall**	**Roof harvested rainwater**	**1 month of storage**	**2 months of storage**	**1 month of storage**	**2 months of storage**
pH	5.94	7.11	10.52	10.54	7.40	6.8
Conductivity µs/cm	14.82	36.61	373	475	104.65	80.52
Total hardness mg/l as $CaCo_3$	3.68	7.24	95.25	91.16	13.00	2.00
Alkalinity mg/l as $CaCO_3$	10.00	10.00	79.55	85.20	46.00	8.00
Total coliform MPN/100ml	460	1000	-	-	460	300

It is clear from the physico-chemical, microbiological and statistical analysis of rainwater samples that there is significant variation in the quality of rainwater from free fall as it interacts with the various components of harvesting system. The quality of rainwater at various stages of domestic rainwater harvesting at the suburban sampling site is tabulated in Table 3. The pH of the free fall is 5.94 while at the point of exit from the harvesting storage tank it is 6.8. At various stages of harvesting and storage in between these, the pH of rainwater is 7.11, 10.52 and 7.4.The increase of pH from 7.11 to 10.52 is due to the leaching of cement constituents in water. It can be seen that the pH of stored water in the tank is greater if the tank is put to use, soon after curing. It is evident that in order to have a pH with in6.5-8.5, the rainwater storage tank may be put to use, preferably four months after construction. The same trend is seen with all the other parameters also.

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IV. CONCLUSIONS

It is concluded that cement constituents in the cement water tank leaches only in a very low concentrations at the initial period of installing the tank and the quality of rainwater satisfied all the physico-chemical parameters for potable water at various stages of harvesting except when cement tank is put for storage soon after the curing period. The tanks made with PPC and/or OPC are safe for storage of rainwater.

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