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Estimation Of Fluoride Ion Concentration Levels In Drinking Water Samples Of Chickballapur Taluke By Using Ion Selective Electrode By Potentiometry (Activity Coefficient- Approach)

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***Abstract:** A systamatic approach and method for potentiometric estimation of dissociation constant (K_a) of hydrofluoric acid are described. This method is based on using commercial fluoride ISE (FISE) as very inexpensive, simple and reasonably fast method for determination of fluoride species. We are sugesting a usage of direct potentiometric method for determination of fluoride species and K_a of hydrofluoric acid in water solutions for $1.05 \leq pH \leq 7.05$ and $1.0\times10^{-1} \leq c_T(F^-) \leq 1.0\times10^{-6}$ mol L^{-1}. Found acid dissociation constant of hydrofluoric acid ($pK_a = 3.00\pm0.02$, $K_a = 3.95\times10^{-4}$ L mol^{-1}) and formation constant of HF_2^- ($\log\beta = 0.400$, $\beta = 4.98$ L mol^{-1}) are agreeing values.*

***Keywords:** Fluoride, potentiometry, determination, Ion-selective electrode*

I. INTRODUCTION

In this paper potentiometric method is being used for estimation of fluoride species and how potentiometric method is more convient for teaching in early stage of Water Chemistry for understanding problem of dissociation of weak acid in function of pH and analytical (total) concentration of a weak acid and species what dissociation yields too. In the most cases we give an example for dissociation of weak acid Ethylene diamine tetra acetic acid (EDTA). EDTA is very complex organic compound with hexaprotic dissociation system. In other meaning, hydrofluoric acid is inorganic compound well known to analysts through course of Inorganic Chemistry. Fluoride solutions are very interested for analysts because many fluoride species can occur depending upon of analytical fluoride concentration and pH values in drinking water at various regions.

Dissociation constant of hydrofluoric acid was determined by potentiometrically with reported values for pK_a from 2.82 to 3.33 at 26.5°C, but IUPAC suggests $pK_a = 3.004$ while books of Water Chemistry was established values of $pK_a = 3.00\pm0.02$ [6-8]. Wide range of pK_a values can be explained by creating different fluoride species like H_mF_m, m = 1 to 2 and H_nF_{n+1}, where n = 1 to 4 and F^-. Searching the literature we were not able to find a recently made potentiometrically determination values for pK_ausing fluoride ion-selective electrode (FISE), but there are numerous papers potentiometrically made determination values for pK_a of different weak organic acids. This fact is interesting because FISE was described in paper of Frant et al. back in 1966. FISE is one of the earliest designed ion-selective electrode beside glass or pH electrode.

For our needing we calculated $pK_a = 3.00\pm0.02$ at 26.5 °C. Calculated value is in very good agreement literature with error of 1.49 %. Values of stability constant (β) of HF_2^- are in wide range, but one value, $\log\beta = 0.400$ is in very good agreement with the mentioned values.

II. EXPERIMENTAL

REAGENTS AND CHEMICALS

Required solutions were prepared by dissolving certain amount of chemicals in floridated water samples

Following chemicals were used: Sodium nitrate, $NaNO_3$, AR., Sodium fluoride, NaF, AR., Sodium acetate, CH_3COONa, AR, Sodium hydroxide, NaOH, AR., Acetic acid, CH_3COOH, AR., Nitric acid, HNO_3, . NaF was dried at 110 °C for two hours and after cooling was used for solutions preparation.

APPARATUS

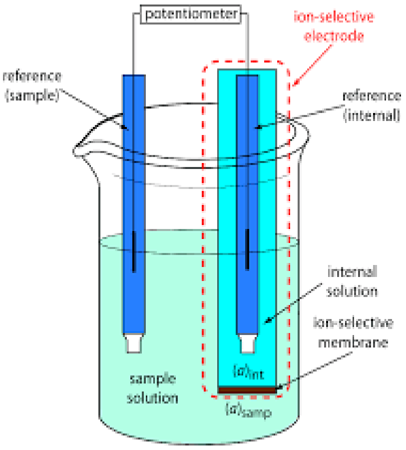

Figure 1: Potenciometric system in thermostated vessel

The indicator electrode was a combined fluoride ion-selective electrode. Potentiometric data were recorded at26.5±0.01 °C in thermostated polyethylene vessel with a millivoltmeter

III. RESULTS AND DISCUSSION

Potentiometric measurements have been done by using previously described FISE. FISE has been tested for response to fluoride concentration for pH values between 1.01 and 7.01. Change of concentration of F^{-} was performed by standard dilution method. During measurement, solution was stirred and kept at constant temperature of 25±0.01 °C. Results are shown at Figure 2.

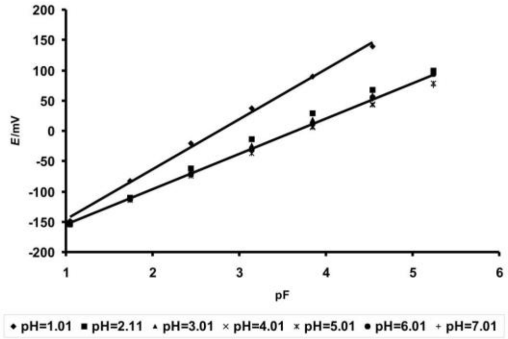

Figure 2: Variation of emf with pH (from 1.05 to 7.05)

Points on the graph represent experimental data and straight line was calculated by using method of linear regression. As it can be seen, FISE linearly follows changing of F^{-} concentration in wide concentration range. Stable potential was reached in 1 minute. Potential change of 58.10 mV per decade of fluoride concentration change was recorded in solutions pH ranged between 2.11 and 7.01, with correlation coefficient of 0.9986, which is in good agreement with theoretical Nerstian slope for monovalent cations. For solutions with pH = 1.05, we obtained supernestian slope of 82.49 mV per decade with correlation coefficient of 0.9971 what was expected [10]. In solutions with pH = 1.1, FISE gives shorter linear response range (2.9×10^{-5} – 9.0×10^{-2} mol L^{-1}) than for other pH values (1.2×10^{-6} –9.0×10^{-2} mol L^{-1}). This effect was expected because in solutions with high H^{+} concentration, dominated specie would be HF and by dilution it would be less and less F^{-} for reaction with active places at FISE membrane. In the other hand, it is very interesting that there is no significant difference in slope of calibration curves for pH > 2.11 in wide concentration range and we can suggest using a same calibration curve for $2.11 \le pH \le 7.01$ (Fig. 2).

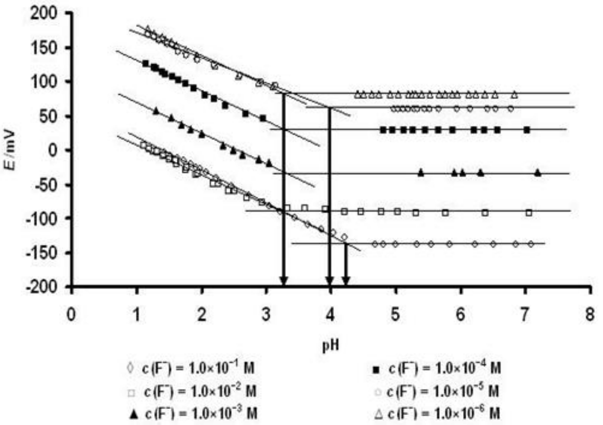

Figure 3: Response of FISE in function of pH changing

Collected experimental data were drawn and by using method of linear regression we added trend lines with calculated equations for each fluoride concentration. When we extrapolate every trend line to intersect with the line on the right side of Fig. 3 for suitable concentration, pK_a values can be calculated as point what suits equations of both lines, a decreasing (on the left side Fig. 3) one and constant (on the right side Fig. 3) one. We gave an example of calculating pK_a value for $C_T(F^{-})=1.0\times10^{-2}$ mol L^{-1}.

$$E_1 = -43{,}6647pH + 51{,}4851$$

$$E_2 = -90$$

Hence pK_a is intersection of 2 lines, that point suits both lines' equations:

$$E_1 = E_2$$

$$-43{,}6647pH + 51{,}4851 = -90$$

$$P^H = -90 - 51{,}4851$$

$$-43{,}6647$$

$$pH = 3{,}24$$

$pH \equiv pK_a$

Calculated pK_a values are given in Table 1.

$C_T(F^-)$ mol/L	pKa value Calculated values	Graphically found values
1.0×10^{-1}	4.39	4.26
1.0×10^{-2}	3.14	3.12
1.0×10^{-3}	3.11	3.09
1.0×10^{-4}	3.22	3.25
1.0×10^{-5}	3.24	3.25
1.0×10^{-6}	3.94	3.94
	3.24	3.25
Standard deviation	0.02	0.02

Table 1: Found pKa values

pKa values are obtained graphically by drawing a perpendicular line form intersection of two lines added to experimental data by method of linear regression to the abscissa axis.

From results given in Table 1 can be seen very good agreement between calculated and graphically found results and they are practically same. There are only significant difference for $CT(F-) = 1.0\times10^{-1}$ mol /L and $CT(F-) = 1.0\times10^{-6}$ mol /L what can be easily explained. For all weak acids dissociation is turned to reactant's side by increasing analytical concentration what happened in our case. In the other hand, for $CT(F-) = 1.0\times10^{-6}$ mol /L that concentration is on the very end or even below of linear response range and can not be taken without suspicion.We decided to ignore pKa for $CT(F-) = 1.0\times10^{-1}$ mol /L and $CT(F-) = 1.0\times10^{-6}$ mol /L on fact that trend lines on left sides at Fig. 3 are overlapped with ones for $CT(F-) = 1.0x\ 10^{-2}$mol /L and $CT(F-) = 1.0\times10^{-5}$ mol/ L, respectively. All other found PKa values are also in very good agreement with values, PKa = 3.19, the literature ones.

Determined pKa of hydrofluoric acid, calculated a stability constant of hydrogen difluoride ion, HF2−. HF2− is a ion created on strong hydrogen bond between H and F. HF2- is dominated specie in solutions with $C_T(F-)$.

$$\begin{array}{l} HF + F^- \rightleftarrows HF2^- \\ H3O^+ + F^- \rightleftarrows HF + H2O \\ \hline H3O^+ + 2F^- \rightleftarrows HF2^- + H2O \end{array}$$

With belonging stability constant, β:

$$\beta = \frac{a_{HF_2^-}}{a_{HF}\,.\,a_{F^-}}$$

While we know accurate C_T(F-), we can write equation :

$$c_T(F^-) = [H_2F_2]+[HF]+[HF_2^-]+[H_2F_3^-]+[H_3F_4^-]+[H_4F_5^-]+[F^-]$$

In dilute solutions, what is in our case, we can expect reasonably concentrations of only three species, HF, F^- and HF_2^- hence we are able rewrite in next form using mass balance:

$$c_T(F^-) = [HF] + 2[HF_2^-] + [F^-]$$

Results calculated by using above are given in Table 2.

Analyzed data are shown in Table 2., we can observe that results are very divaricated and pretty much different of results found in literature, logβ= 0.598. Only result what is close to literature value is logβ= 0.600, with very good agreement. This awkward situation can be explained that our solutions not contain enough F− concentration; in fact they are dilute and to acidic. By decreasing pH value and especially decreasing CT(F−), it is obliviously that dominate specie becomes HF and statistically is very hard expect that would be enough available F− to form HF2−. On the other hand for4≤ pH ≤ 6 and cT(F−) ≤ 1.0×10−4 mol L−1, we have got high logβ, so it can be assumed that chemical equilibrium is moved to the products and HF2− would be dominated specie, but that can not be possible.

$p\{c_T(F^-)\}$	pH						
	1	2	3	4	5	6	logβ
1	0.	3.72	3.19	2.71	3.10	3.77	
2	*	*	1.42	2.35	3.59	5.13	
3	*	*	2.37	3.49	4.93	5.39	
4	*	*	2.82	5.23	6.33	6.83	
5	*	*	*	4.85	7.13	8.12	

Table 2: Calculated logβ values

We should explain this phenomena very easy if we look up to Eq.(6). High logβ values are resulted by decreasing values of a_{H3O} + and a_F -, and especially that a_F - is put on second power. Most results shown in Table 2 are within range found under similar conditions. We are stressing deviation of logβ values is common in cited literature and authors often selected one value.

Final part of our investigation was calculating specie's fraction values. This part is very important because from these results can be clearly seen what specie dominated as function of pH and concentration. Calculation was done using Eq.(1) for HF and Eq.(2) for F^-. Fraction of $HF2^-$ was calculated using Eq.(3). In Table 3. are given calculated fraction values of HF, $HF2^-$ and F^-.

$$\alpha = \frac{[H^+]}{[H^+]+K_a} \tag{1}$$

$$\alpha = \frac{K_a}{[H^+]+K_a} \tag{2}$$

$$\alpha = \frac{a_{HF^-}}{C_T F^- .\gamma} \tag{3}$$

Results are shown in Table 3& 4. confirm our assumptions earlier said about $HF2^-$ concentration in dilute fluoride solution are very low and for most cases it can be taken as zero. Same situation is for other H_nF_{n+1} complex, where n = 1 to 4 for dilute solutions because they are formed in very acidic and very concentrate fluoride solution.

pH1			
pH	α(HF)	$\alpha(HF_2^-)$	$\alpha(F^-)$
1	0.986	5×10^{-4}	0.014
2	0.911	1×10^{-5}	0.089
3	0.524	6×10^{-6}	0.476
4	0.101	1×10^{-7}	0.899
5	0.012	6×10^{-9}	0.988

Table 3: Calculated species' fraction values

pH	pH 2			pH 3			pH 4			pH 5		
	α(HF)	$\alpha(HF_2^-)$	$\alpha(F^-)$	α(HF)	$\alpha(HF_2)$	$\alpha(F^-)$	α(HF)	$\alpha(HF_2)$	$\alpha(F^-)$	α(HF)	$\alpha(HF_2)$	$\alpha(F^-)$
2	0.990		0.010	0.990		0.010	0.991		0.009	0.929		0.071
3	0.936		0.064	0.929		0.071	0.921		0.079	0.573		0.427
4	0.576	8×10^{-5}	0.424	0.538	9×10^{-7}	0.462	0.533	4×10^{-9}	0.467	0.105		0.895
5	0.140	2×10^{-6}	0.860	0.102	1×10^{-8}	0.898	0.096	9×10^{-13}	0.904	0.012	9×10^{-14}	0.988

Table 4: Calculated species' fraction values

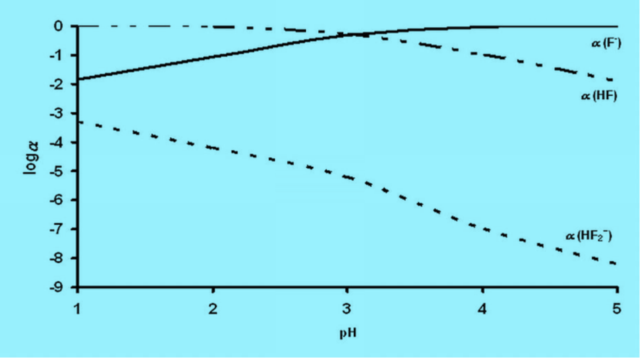

Figure 4: Fraction of fluoride specie in function of pH changing for C_T(F-) = 1.0×10^{-1} mol /L

IV. RESULTS AND DISCUSSION

All the experiments were helpful for researcher and students, to understand the problem of dissociation of weak acid and forming different species in solutions. During this work we took a few assumptions, choosing a temperature of 26.5 °C for experiments, using dilute and very dilute solutions (C_T(F-) $\leq 1.\times10^{-1}$ mol /L) and approximation of concentration of H_nF_{n+1} complex, where n = 1 to 4 are zero for dilute solutions (this was direct consequence of using dilute solutions). Choosing to do all experiments at 26.5 °C made doing experiments simpler but we cannot be sure what situation about species' fraction would be at lower or higher temperature of 26.5 °C. On the other hand, choosing 25 °C was logically because of most analytical methods are done at 25 °C. Dilute solutions are also interest for students attend elementary grade of Analytical Chemistry because of all experimental teaching is done with dilute concentration. The last, but not less important thing was use of glass electrode for pH measurements. We cannot neglect this fact had some influence to final results. If we remember experiment had a qualitative purpose for teaching students in their very beginning, we neglected this fact, but deeply aware of.

On the other hand, using potentiometric methods as an example of simple analytical technique was an excellent choice. Results were collected by using potetiometric methods gave very accurate values of constant dissociation of hydrofluoric acid (pKa = 3.24±0.03) compared with results were found (pKa = 3.19±0.02) or suggested in literature (2.82 ≤ pKa ≤ 3.33). Situation with stability constant of HF^{2-} complex was complicated, but one value (logβ= 0.400) is in very good agreement with literature ones.

From the above experimental methods we analyzed Fluoride ion concentration levels of the various regions of Rural areas of chickballpur taluk the results are correlates with the earlier results and they are below the WHO standard, these water sources are useful for drinking except few other aspects.

SL No	Village	Type of Source	Location	Potentiometry values F^- (mg/lit)	
				Monsoon	pH
1.	JADALATIMMANAHALLI	PWS S1	Narayanappa land side	1.60	7.2
2.	JADALATIMMANAHALLI	PWS S2	Chikkanarasimhappa land side	1.00	7.2
3.	CHEDACHIKKANAHALLI	MWS S2	Road side	0.00	7.3
4.	CHOKKAHALLI	PWS S1	Beside oniyamma temple	0.00	7.3
	SRIRAMPUR	PWS S2	Beside temple	0.00	7.3
5.	SRIRAMPUR	HP S4	Main road side	0.00	7.5
6.	AGALAGURKI	PWS S2	Beside forest	0.00	7.4
7.	AGALAGURKI	PWS S3	Main road side	0.00	7.1
	AGALAGURKI	HP S7	Beside aganavadi school	0.00	7.4
8.	CHIKKAKADIGANAHALLI	PWS	Beside kalamma temple	0.50	7.2
9.	KATTARIGUPPE	PWS S1	Inside tank bund	0.00	7.4
10.	KATTARIGUPPE	PWS S2	Kesha achari land side	0.50	7.3
11.	MARALUKUNTE	MWS	Near ashwatha katte	0.00	7.4
12.	HIRINNAHALLI	PWS1	Beside maramma temple	0.00	7.2
13.	HIRINNAHALLI	PWS2	Inside tank bund	0.00	7.4
14.	PATURU	MWS	Main road side	0.00	7.2
15.	KANDAKANAHALLI	MWS	Inside tank bund	0.00	7.3
16.	AVALAHALLI	MWS	main road side	0.00	7.1
17.	BADINIGANAHALLI	MWS	Beside dayvappa house	0.00	7.4
18.	ANGAREKANAHALLI	PWS 2	Inside tank bund	0.00	7.1
19.	AJJAVARA	PWS S1	beside tank bund	0.00	7.2
20.	AJJAVARA	PWS S2	beside seethappa house	0.00	7.3
21.	SONNAPUR	MWS S1	beside eshwarappa temple	0.00	7.2
22.	SONNAPUR	MWS S2	inside tank bund	0.00	7.4
23.	NUGETHAHALLI	MWS S1	beside cannal	0.00	7.3
24.	NUGETHAHALLI	MWS S2	main road side	0.00	7.2

25.	VARADAHALLI	MWS	main road side	0.00	7.3
26.	NUGETHAHALLI	MWS	beside chikkavenkatappa house	0.00	7.1
27.	DODDAKIRUGAMBI	MWS	beside chenakeshwa temple	0.00	7.2
28.	MANNARAPURA	MWS	beside cannal	0.50	7.3
29.	MANNARAPURA	MWS	inside tank bund	1.00	7.2
30.	NAYANAHALLI	PWS S1	beside manjunatha house	0.00	7.2
31.	NAYANAHALLI	PWS S2	beside maheshwari temple	0.00	7.3
32.	NAYANAHALLI	PWS S3	beside gudiyappa house side	0.00	7.5
33.	NAYANAHALLI	PWS S4	beside m.p.c.s.	0.00	7.1
34.	BANNIKUPPE	PWS S4	main road side	0.00	7.3
35.	ARURU	MWS	check dam side	1.56	7.4
36.	SETTYGERE	PWS	beside forest	1.00	7.2
37.	BHOGAPARTHI	MWS	inside tank bund	1.60	7.4
38.	KAKALACHINTA	MWS	inside tank bund	1.00	7.2
39.	PERESENDRA CROSS	MWS	inside tank bund	1.00	7.4
40.	ARURU	PWS S1	inside tank bund	1.00	7.1
41.	ARURU	PWS S2	main road side	1.60	7.4
42.	KAKALACHINTA	PWS	inside tank bund	1.80	7.2
43.	KAKALACHINTA	PWS	beside vasantareddy land	1.00	7.1
44.	ARURU	MWS	beside school	0.50	7.4
45.	BOOSHETTYHALLI	MWS S1	inside tank bund	1.00	7.2
46.	BOOSHETTYHALLI	MWS S2	near berial ground	0.50	7.4
47.	KAKALACHINTHA	PWS	inside tank bund	0.50	7.2
48.	ARURU	MWS	road side	1.60	7.3
49.	HANUMATHAPURA	MWS	road side	0.50	7.4
50.	BANDAHALLI	HP	beside shivanna land	1.00	7.2
51.	KAKALACHINTHA	MWS	inside tank bund	0.50	7.1
52.	AAVALAGURKI	PWS S1	beside forest	0.50	7.3
53.	AAVALAGURKI	PWS S2	beside bachappa land	0.00	7.4
54.	AAVALAGURKI	PWS S3	main road side	0.00	7.1
55.	SULAKUNTE	MWS	main road side	1.60	7.1
56.	NADUVANAHALLI	MWS	beside appaji land	1.00	7.4
57.	GERAHALLI	MWS	road side	1.51	7.2
58.	KOWRANAHALLI	MWS	beside rajanna land	1.60	7.1
59.	GONDAHALLI	MWS	beside thimmaiya land	1.00	7.4
60.	SUSEPALYA	MWS	inside tank bund	1.00	7.2
61.	AAVALAGURKI	MWS	inside tank bund	0.00	7.3
62.	HONNENAHALLI	PWS S3	beside tank bund	0.00	7.5
63.	LINGASHETTYPURA	MWS S1	near berial ground	0.50	7.2
64.	AAVALAGURKI	MWS S1	beside muniyappa land	0.50	7.1
65.	AAVALAGURKI	MWS	beside forest	0.00	7.2
66.	ARIKERE	MWS	inside tank bund	1.00	7.1
67.	ARIKERE	MWS	main road side	1.60	7.2
68.	NALLIMARADAHALLI	PWS S1	beside srinivasareddy land	0.00	7.3
69.	NALLIMARADAHALLI	PWS S2	beside gangamma temple	1.00	7.3
70.	RENUMAKALAHALLI	PWS	beside forest	1.30	7.2
71.	RENUMAKALAHALLI	PWS	beside forest	1.00	7.4
72.	GOLLU	MWS S1	beside ravi land	0.00	7.3
73.	LAKKINAKANAHALLI	MWS	near berial ground	1.60	7.3
74.	DIBBURU	PWS S1	near factory	0.00	7.2
	GANGAREKALUVE	H,P	beside venkatarayappa land	0.00	7.5
75.	RAYAPANAHALLI	MWS	near berial ground	0.00	7.2
76.	DODATAMMANAHALLI	PWS	road side	0.00	7.4
77.	GOLLUCHINAPANAHALLI	MWS	main road side	0.00	7.1
78.	DODDAMARALI	HP S2	village center	1.00	7.2
79.	DODDAMARALI	PWS S3	road side	1.60	7.3
80.	GAVIGANAHALLI	MWS S2	near berial ground	0.00	7.3
81.	VARAMALLENAHALLI	MWS	beside venkateshappa land	0.00	7.2
82.	BEEDAGANAHALLI	PWS S3	beside railway track	0.50	7.1
83.	CHADALAPURA	PWS	near berial ground	1.60	7.1
84.	DODDAMARALI	PWS	near gate	1.80	7.4
	KOLAVANAHALLI	PWS S4	road side	0.00	7.4
85.	DEVISHETTYHALLI	MWS	main road side	1.00	7.1
86.	YALAVAHALLI	PWS S1	beside suggalamma temple	2.00	7.3
87.	YALAVAHALLI	PWS S2	near k.e.b.	1.80	7.1
88.	SAMASENAHALLI	MWS	main road side	1.60	7.2
89.	DODDAPALYAGURKI	MWS	road side	1.53	7.3
90.	MARAGANAHALLI	MWS	beside tank bund	1.00	7.1
91.	ENAMINCHANAHALLI	MWS	road side	0.00	7.2
92.	REDDYHALI	MWS-1	inside tank bund	1.60	7.3
93.	REDDYHALI	MWS2	road side	1.00	7.2
94.	REDDYGOLLAVARAHAL	PWS	inside tank bund	1.60	7.3

	LI				
	HARISTHALA	PWS	inside tank bund	0.50	7.2
95.	HARISTHALA	PWS	inside tank bund	1.00	7.4
96.	RAMAGANAPARTHI	MWS	near berial ground	0.00	7.3
97.	ENAMINCHANAHALLI	PWS S2	beside tank bund	0.50	7.4
98.	KADURU	MWS	inside tank bund	1.00	7.2
99.	PAPINAYAKANAHALLI	MWS	near govt primary school	1.51	7.4
100.	CHIKKAPAYALAGURKI	PWS	near h. kurubarahalli	1.00	7.1
101.	KADURU	MWS	main road side	1.60	7.2
102.	BHOMMAHALLI	MWS	road side	1.52	7.4
103.	BHOMMAHALLI	MWS	beside thimmanna house	1.60	7.5
104.	KAMATHAHALLI	MWS	inside tank bund	1.00	7.1
105.	A.KOTHUR	MWS	inside tank bund	1.00	7.1
106.	NASTHIMANAHALLI	MWS	road side	0.00	7.4
107.	GOLLAHALLI	MWS	road side	1.00	7.2
108.	NALLAGUTTAPALYA	MWS	road side	1.60	7.3
109.	KETHENAHALLI	PWS S1	beside sc colony	0.60	7.1
110.	KETHENAHALLI	MWS S2	main road side	0.50	7.4
111.	GOLLADODDI	MWS	main road side	0.00	7.2
	NASTIMANAHALLI	MWS	near shanimahathma temple	1.00	7.3
112.	SADENAHALLI	MWS	near gate	0.00	7.4
113.	ETTAPPANAHALLI	MWS	beside krishanareddy land	0.00	7.1
114.	YALAGERE	MWS S1	road side	0.50	7.1
115.	KOTHURU	MWS	inside tank bund	0.00	7.4
116.	NASTIMANAHALLI	MWS	road side	0.50	7.3
117.	YARANAGENAHALLI	MWS	road side	0.50	7.3
118.	KARIGANAPALYA	MWS S2	road side	0.00	7.1
119.	BEERAGANAHALLI	MWS	near berial ground	0.50	7.4
120.	GAMGADIPURA	MWS	main road side	0.00	7.2
121.	GOLLADODDI	MWS	road side	0.50	7.1
122.	NELAMAKANAHALLI	MWS	neside hanumapa house	0.00	7.2
123.	THAMMANAYAKANAHALLI	MWS	main road side	0.00	7.2
	JATHAVARA	PWS	near dinne dasappa tank	0.00	7.5
124.	ELEHALLI	MWS	beside cannal	0.00	7.3
125.	HOSAHUDYA	MWS S1	beside high school	1.56	7.3
126.	HOSAHUDYA	MWS S2	beside tank bund	0.50	7.4
127.	HENURUKADIRENHALLI	MWS	inside tank bund	0.50	7.4
128.	HOSAHUDYA	PWS S3	beside patalamma temple	1.60	7.2
129.	JATHAVARAHOSAHALLI	MWS S1	h.v.venkateshaih land side	1.60	7.4
130.	JATHAVARAHOSAHALLI	MWS S2	beside cannal	0.50	7.2
131.	KESHAWARA	PWS S3	inside tank bund	0.00	7.4
132.	ELEHALLI	MWS S3	beside tank bund	0.00	7.3
133.	SOPPAHALLI	MWS1	inside tank bund	0.50	7.2
134.	SOPPAHALLI	MWS S2	beside tank bund	1.00	7.4
135.	GUVALAKAYANAHALLI	MWS	beside tank bund	0.50	7.2
136.	GUVALAKAYANAHALLI	MWS	road side	0.00	7.4
137.	AKALATHIMMANAHALLI	MWS	beside tank bund	0.00	7.2
138.	DEVASTANAHOSAHALLI	PWS	beside venkateshappa house	0.00	7.1
139.	MARASANAHALLI	PWS	inside tank bund	0.00	7.4
140.	HARABANDE	MWS S1	road side	0.00	7.1
141.	HARABANDE	MWS S2	beside venkatanarasimhaiya land	0.00	7.4
142.	HARABANDE	HP S3	road side	0.00	7.2
143.	HUNEGAL	PWS	beside manjunatha house	0.00	7.4
144.	HUNEGAL	PWS	main road side	0.50	7.1
145.	HARABANDE	PWS S1	beside tank bund	0.00	7.1
146.	DEVASTANAHOSAHALLI	MWS	main road side	0.00	7.5
147.	GUVALAKAYANAHALLI	MWS	inside tank bund	0.00	7.4
148.	KADESEGENAHALLI	PWS	main road side	0.00	7.4
149.	KANITHAHALLI	PWS S1	inside tank bund	0.00	7.2
150.	NAKKALABACHAHALLI	MWS	main road side	0.00	7.1
151.	NAKKALABACHAHALLI	PWS 1	road side	0.00	7.4
152.	KONDENAHALLI	PWS 1	near anjaneyaswamy temple	0.00	7.1
153.	NAKKALABACHAHALLI	MWS	main road side	0.00	7.1
154.	BHOMMANAHALLI	PWS	beside chikkanarasimhappa	0.00	7.4
155.	CHIKKASAGARAHALLI	MWS S1	road side	1.00	7.3
156.	THIRNAHALLI	PWS	main road side	2.00	7.4
157.	KADUVATHI	MWS	main road side	0.50	7.2
158.	KUPPAHALLI	PWS S3	road side	0.00	7.3
159.	ANGATTA	PWS S1	beside doctor	1.60	7.2
160.	ARASANAHALLI	PWS 1	main road side	0.00	7.1
161.	ARASANAHALLI	PWS 3	beside cannal	0.00	7.4

162.	KOTHANUR	PWS S3	beside college	0.00	7.4
163.	TUMAKALA HALLI	MWS	near s.j.c.	0.00	7.3
164.	RAMAPATNA	PWS S2	besde sheep house	1.51	7.2
165.	UDAYA GIRINALLA ANAHALLI	MWS	road side	1.60	7.2
166.	NAGASANA HALLI	MWS	beside ashwathappa house	1.60	7.3
167.	KAMMAGUTTAHALLI	MWS	near forest	0.00	7.3
168.	NAGASANA HALLI	MWS	near ashwatha katte	0.00	7.5
169.	BHOMMANA HALLI	MWS	main road side	1.00	7.3
170.	MUDDALAHALLI	MWS	road side	0.50	7.3
171.	BHODINARE NAHALLI	MWS	beside tank bund	0.50	7.2
172.	HIRENAGAVALLI	PWS	road side	0.50	7.4
173.	R.CHOKKANAHALLI	MWS	main road side	1.00	7.5
174.	RENUMAKALAHALLI	MWS	beside afrs school	1.00	7.2
175.	CHIKKASAGARAHALLI	MWS	road side	0.50	7.3
176.	MANCHANABALLE	MWS	near forest	1.60	7.1
177.	KAMASHETTIHALLI	MWS	near ganesha temple	0.00	7.4
178.	SABBENAHALLI	MWS	road side	0.00	7.1

Figure 5

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