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A Study Focused on Alkalinity Dependent pH Alteration of Drinking Water and Comparing Impact Based Suitability of Alkali Solutions for pH Improvement

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***Abstract*: All drinking water available in Kerala from different sources are not always having the prescribed potable range of pH. Major quality parameters of drinking water are analysed. This study is conducted to see the existence of any relation between pH alteration and alkalinity of water and to find suitable alkaline reagents for improving pH of drinking water.**

***Keywords*: pH, TDS, Alkalinity, Hardness, FRC, Drinking water, IS method**

1. Introduction

The potenz hydrogen(pH), that is., power of hydrogen, is a measure of concentration of hydrogen ions in a solution. When the concentration of hydrogen ions goes up, the pH goes down and vice-versa. Hence, pH is calculated by the expression,

$$pH = -\log[H^+]$$

Relative to pure water, which has a perfectly neutral pH of 7, pH of solutions may be

Acidic, if pH<7

Basic, if pH>7

Neutral, if pH =7

Thus, pH refers to how acidic or basic(alkaline) the substances are.

Total Alkalinity is a measure of the amount or concentration (in ppm) of all alkaline substances dissolved in water-primarily carbonates, bicarbonates and hydroxides along with borates, silicates and phosphates. Thus alkalinity includes causes of temporary hardness also (carbonates and bicarbonate). These dissolved substances resist change in pH of water by neutralizing acids, that is it buffers water. Thus alkalinity is a measure of the buffering capacity of water. Low pH samples usually don't have alkalinity; they have acidity.

Total dissolved solids (TDS) refers to a measure of all solids dissolved in water. This means that it will measures ions that contribute to water hardness like calcium, magnesium, carbonate, bicarbonate, chloride, sulphate etc., but also other ions like sodium, potassium, nitrate etc. The TDS measurement is a better reflection of the total mineral content of the water. TDS includes alkalinity.

Total hardness (TH) includes dissolved compounds of calcium and magnesium. It is formed when water percolates through the deposits of lime stone, chalk, gypsum, dolomite which are largely made up of carbonates, bicarbonates and sulphates of calcium and magnesium.

Chloride, sulphate, nitrate, ammonia and free residual chlorine (in case of chlorinated water) are also contribute to quality of drinking water.

2. Materials and Methods

A. Materials

Study Setting: This study was carried out at Government Analysts Laboratory, Trivandrum, Kerala under the Commissionerate of Food Safety.

Sample collection: The available sources of drinking water for this study included well water, bore well water, pipe water etc. Samples were collected from different areas of Trivandrum and Kollam districts of Kerala and were analysed between 03.12.2019 and 21.12.2019.

Apparatus and Reagents:

Electronic balance	Sodium hydroxide (0.0204 normal)	Mixed indicator
pH meter	Silver nitrate solution (0.0138 normal)	Potassium chromate
TDS meter	Sodium thiosulphate solution (0.01 normal)	Eriochrome Black T
EDTA solution	Sodium carbonate(anhydrous) – 1 % aq. solution	Starch solution
Sulphuric acid (0.0221 normal)	Sodium bicarbonate - 1 % aq. solution	
	Slaked lime - 1 % aq. saturated solution	

B. Method

pH measurement: The pH of drinking water was measured electrochemically by using pH meter of EUTECH INSTRUMENTS (CyberScan pH 2100).

Total Dissolved Solids(TDS): TDS was measured by using TDS meter of EUTECH INSTRUMENTS(CON700)

Total Alkalinity/Acidity, Total Hardness, Chloride, Sulphate, Free residual chlorine and Nitrate are determined by IS method 3025- parts 23, 21, 32, 24, 26 and 34 respectively.

3. Results

Table 1

S.No.	Nature of Sample	Date of Analysis	pH	TDS	Total Alkalinity	Total Hardness	Chloride	Sulphate	FRC
1	Well water	03.12.2019	5.93	75.9	13.26	14.0	37.18	Nil	Nil
2	Well water	03.12.2019	5.46	138.9	16.32(acidity)	8.0	39.14	Nil	Nil
3	Well water	03.12.2019	4.74	212	12.24(acidity)	74.0	70.45	30	Nil
4	Well water	03.12.2019	4.87	211	12.24(acidity)	40.0	88.06	Nil	Nil
5	Well water	05.12.2019	5.45	128.0	12.24(acidity)	38.0	39.14	30	Nil
6	Well water	05.12.2019	4.77	169.0	12.24(acidity)	40.0	88.06	Nil	Nil
7	Well water	09.12.2019	6.20	84.9	17.68	36.0	46.96	10	Nil
8	Bore well	09.12.2019	6.45	121.5	48.62	72.0	33.27	20	Nil
9	Well water	09.12.2019	7.86	75.6	185.64	120.0	21.53	10	0.2
10	Well water	09.12.2019	8.17	215.1	35.36	32.0	37.18	Nil	0.4
11	Well water	09.12.2019	7.85	93.8	44.2	56.0	56.75	30	0.3
12	Bore well	09.12.2019	6.29	107.4	30.94	16.0	70.45	Nil	Nil
13	Bore well	09.12.2019	5.92	204.3	13.26	24.0	156.63	Nil	Nil
14	Pipe water	09.12.2019	6.89	49.5	44.2	40.0	39.14	40	0.3
15	Well water	09.12.2019	7.58	122.6	61.88	92.0	93.93	20	0.4
16	Well water	09.12.2019	7.46	89.7	26.52	24.0	37.18	20	0.2
17	Well water	09.12.2019	7.70	206.3	185.64	60.0	193.73	Nil	0.4
18	Bore well	09.12.2019	6.14	132.5	35.36	64.0	80.23	Nil	Nil
19	Well water	11.12.2019	4.08	376.0	28.56(acidity)	48.0	119.37	Nil	Nil
20	Well water	11.12.2019	5.60	101.0	8.16(acidity)	24.0	37.18	10	Nil
21	Well water	11.12.2019	5.37	98.6	16.32(acidity)	20.0	54.79	10	Nil
22	Well water	11.12.2019	5.95	59.9	17.68	12.0	27.40	40	Nil
23	Well water	14.12.2019	4.51	151.0	16.32(acidity)	16.0	58.70	60	Nil
24	Well water	14.12.2019	5.57	205	16.32(acidity)	56.0	68.49	30	Nil
25	Well water	14.12.2019	5.37	142.0	12.24(acidity)	18.0	43.05	20	Nil
26	Well water	14.12.2019	5.13	105.0	16.32(acidity)	10.0	48.92	Nil	Nil
27	Bore well	19.12.2019	6.36	84.9	22.1	38.0	19.57	Nil	Nil
28	Well water	19.12.2019	6.07	72.7	44.2	24.0	13.70	30	Nil
29	Well water	19.12.2019	5.65	79.0	17.68	22.0	23.82	20	Nil
30	Bore well	20.12.2019	6.23	108.0	53.04	28.0	33.75	10	Nil
31	Bore well	20.12.2019	6.28	94.3	22.1	32.0	23.82	20	Nil
32	Well water	03.12.2019	8.37	259.0	88.4	60.0	52.83	20	0.5
33	Well water	03.12.2019	8.22	262.0	229.8	12.0	43.05	30	0.4
34	Well water	03.12.2019	8.06	82.2	35.40	24.0	27.40	Nil	0.4
35	Well water	03.12.2019	7.93	48.6	26.50	8.0	3.91	30	0.4
36	Well water	03.12.2019	7.56	259.0	22.1	68.0	66.53	Nil	0.5
37	Pipe water	03.12.2019	6.70	116.0	30.94	44.0	43.05	10	0.2
38	Well water	05.12.2019	8.05	384.9	274.0	56.0	23.82	10	0.4
39	Well water	05.12.2019	7.68	243.5	176.8	32.0	19.57	10	0.3
40	Well water	05.12.2019	7.66	168.4	57.5	28.0	9.78	60	0.3
41	Well water	05.12.2019	7.46	421.2	203.32	48.0	43.05	120	0.4
42	Bore well	05.12.2019	7.11	344.6	198.48	52.0	13.70	60	0.2
43	Packaged drinking water	05.12.2019	6.90	76.9	13.3	36.0	13.70	Nil	Nil
44	Well water	09.12.2019	8.17	82.5	35.36	12.0	23.82	Nil	0.5
45	Well water	09.12.2019	7.86	261.2	185.64	64.0	5.87	Nil	0.4
46	Well water	09.12.2019	7.85	97.9	44.2	28.0	13.70	Nil	0.2
47	Well water	09.12.2019	7.70	295.0	185.64	72.0	19.57	Nil	0.3
48	Well water	09.12.2019	7.58	132.7	61.88	44.0	19.57	Nil	0.3
49	Well water	09.12.2019	7.46	78.4	26.52	32.0	5.87	20	0.4
50	Pipe water	09.12.2019	6.89	101.5	44.2	24.0	9.78	20	0.3
51	Bore well	09.12.2019	6.45	174.6	48.62	20.0	48.92	40	Nil
52	Well water	09.12.2019	6.29	99.9	30.94	24.0	9.78	30	Nil
53	Bore well	09.12.2019	6.20	42.5	17.68	16.0	5.87	Nil	Nil
54	Well water	09.12.2019	6.14	97.2	35.36	12.0	23.82	10	Nil
55	Well water	09.12.2019	5.92	50.4	13.26	20.0	9.78	Nil	Nil
56	Well water	11.12.2019	7.78	78.7	22.1	12.0	19.57	Nil	0.2
57	Well water	11.12.2019	7.39	138.3	22.1	16.0	31.31	30	0.3
58	Pipe water	11.12.2019	7.00	120.1	30.94	28.0	43.05	Nil	0.3
59	Pipe water	11.12.2019	6.82	289.0	57.46	132.0	86.10	Nil	0.4
60	Well water	11.12.2019	6.34	262.0	114.92	60.0	103.71	Nil	Nil
61	Well water	16.12.2019	7.40	241.7	172.38	36.0	23.82	20	0.2

The pH value, alkalinity/acidity, total hardness, chloride, sulphate, residual free chlorine(RFC) and TDS of analysed samples are given in Table 1. The permissible limits of these parameters under IS 10500: 2012 and WHO guidelines for drinking water are also given as reference in Table 2.

Table 2
Drinking Water Specifications – IS 10500: 2012 Second Revision

S.No.	Quality Parameters	Permissible Limit
1	pH	6.5 – 8.5
2	Total Dissolved Solids	500 *mg/l* , max
3	Total Alkalinity	200 *mg/l* , max
4	Total Hardness as $CaCO_3$	200 *mg/l* , max
5	Chloride	250 *mg/l* , max
6	Sulphate	200 *mg/l* ,max
7	Free Residual Chlorine	0.2 *mg/l* ,min

Alkalinity and Acid neutralization: Thirty samples (30) were analysed for studying the lowering pH values of water samples using sulphuric acid (0.0221 normal). The results are given in Table 3.

Comparison of pH improvement by different alkalies: Twenty samples (20) were analysed for studying increasing pH value to approximately 7 using four different alkalies. The results are given in Table 4.

Successive treatment with acid and alkali: Five samples (5) were analysed for acid treatment to reduce pH followed by sodium carbonate/sodium bicarbonate treatment for increasing pH. The results are given in Table-5

Table 3

S.No.	Nature of Sample	Date of Analysis	Original pH	Original Alkalinity	Original TDS	Volume of acid used(ml)	Resultant pH
1	Sample no 32 Table 1	03.12.2019	8.37	88.4	259.0	8.7	4.99
2	Sample no 33 Table 1	03.12.2019	8.22	229.8	262.0	23.5	5.04
3	Sample no 34 Table 1	03.12.2019	8.06	35.4	82.2	2.6	4.99
4	Sample no 35 Table 1	03.12.2019	7.93	26.5	48.6	2.4	5.03
5	Sample no 36 Table 1	03.12.2019	7.56	22.1	259.0	2.2	4.93
6	Sample no 37 Table 1	03.12.2019	6.70	30.94	116.0	2.2	4.97
7	Sample no 38 Table 1	05.12.2019	8.05	274.0	384.9	22.8	5.01
8	Sample no 39 Table 1	05.12.2019	7.68	176.8	243.5	13.4	5.02
9	Sample no 40 Table 1	05.12.2019	7.66	57.5	168.4	3.9	5.03
10	Sample no 41 Table 1	05.12.2019	7.46	203.32	421.2	17.6	4.98
11	Sample no 42 Table 1	05.12.2019	7.11	198.48	344.6	16.3	5.03
12	Sample no 43 Table 1	05.12.2019	6.90	13.3	76.9	1.8	5.09
13	Sample no 44 Table 1	09.12.2019	8.17	35.36	82.5	3.3	5.04
14	Sample no 45 Table 1	09.12.2019	7.86	185.64	261.2	16.8	5.02
15	Sample no 46 Table 1	09.12.2019	7.85	44.2	97.9	3.7	5.00
16	Sample no 47 Table 1	09.12.2019	7.70	185.64	295.0	16.1	5.02
17	Sample no 48 Table 1	09.12.2019	7.58	61.88	132.7	6.3	5.04
18	Sample no 49 Table 1	09.12.2019	7.46	26.52	78.4	2.0	5.02
19	Sample no 50 Table 1	09.12.2019	6.89	44.2	101.5	3.0	5.00
20	Sample no 51 Table 1	09.12.2019	6.45	48.62	174.6	4.0	5.02
21	Sample no 52 Table 1	09.12.2019	6.29	30.94	99.9	1.0	5.02
22	Sample no 53 Table 1	09.12.2019	6.20	17.68	42.5	0.8	5.00
23	Sample no 54 Table 1	09.12.2019	6.14	35.36	97.2	0.9	5.00
24	Sample no 55 Table 1	09.12.2019	5.92	13.26	50.4	0.7	5.01
25	Sample no 56 Table 1	11.12.2019	7.78	22.1	78.7	1.7	4.51
26	Sample no 57 Table 1	11.12.2019	7.39	22.1	138.3	1.6	4.49
27	Sample no 58 Table 1	11.12.2019	7.00	30.94	120.1	2.1	4.53
28	Sample no 59 Table 1	11.12.2019	6.82	57.46	289.0	3.7	4.53
29	Sample no 60 Table 1	11.12.2019	6.34	114.71	262.0	6.6	4.49
30	Sample no 61 Table 1	16.12.2019	7.40	172.38	241.7	16.5	5.04

Table 4

S.no.	Nature of sample	Original values for parameters	Sodium carbonate treatment	Sodium bicarbonate treatment	Sodium hydroxide treatment	Lime treatment
1	Sample 1 Table 1	pH – 5.93 TDS-75.9 Alkalinity-13.26 Hardness-14.0 Chloride-37.18	Volume used-0.4 ml Resultant pH-7.02 Resultant TDS-100.2 Resultant Alkalinity-44.2 Resultant Hardness-14.0 Resultant Chloride-37.18	Volume used-1.0 ml Resultant pH-7.01 Resultant TDS-119.0 Resultant Alkalinity-70.72 Resultant Hardness-16.0 Resultant Chloride-37.18	Volume used-1.8 ml Resultant pH-7.02 Resultant TDS-89.9 Resultant Alkalinity-35.36 Resultant Hardness-14.0 Resultant Chloride-39.14	Volume used-0.7 ml Resultant pH-7.07 Resultant TDS-88.5 Resultant Alkalinity-35.36 Resultant Hardness-24.0 Resultant Chloride-37.18
2	Sample 2 Table 1	pH – 5.46 TDS-138.9 Acidity-16.32 Hardness-10.0 Chloride-39.14	Volume used-1.0 ml Resultant pH-7.04 Resultant TDS-166.0 Resultant Alkalinity-92.82 Resultant Hardness-10.0 Resultant Chloride-39.14	Volume used-2.4 ml Resultant pH-6.99 Resultant TDS-209.0 Resultant Alkalinity-159.12 Resultant Hardness-12.0 Resultant Chloride-41.09	Volume used-4.7 ml Resultant pH-7.06 Resultant TDS-112.5 Resultant Alkalinity-79.56 Resultant Hardness-14.0 Resultant Chloride-39.14	Volume used-2.1 ml Resultant pH-7.02 Resultant TDS-109.2 Resultant Alkalinity-79.56 Resultant Hardness-24.0 Resultant Chloride-39.14
3	Sample 3 Table 1	pH – 4.74 TDS-212.0 Acidity-12.24 Hardness-74.0 Chloride-70.45	Volume used-0.7 ml Resultant pH-7.13 Resultant TDS-218.0 Resultant Alkalinity-44.2 Resultant Hardness-72.0 Resultant Chloride-82.19	Volume used-1.3 ml Resultant pH-7.04 Resultant TDS-255.0 Resultant Alkalinity-70.72 Resultant Hardness-76.0 Resultant Chloride-62.62	Volume used-2.4 ml Resultant pH-7.04 Resultant TDS-189.3 Resultant Alkalinity-30.94 Resultant Hardness-74.0 Resultant Chloride-70.45	Volume used-1.2 ml Resultant pH-7.11 Resultant TDS-189.3 Resultant Alkalinity-30.94 Resultant Hardness-144.0 Resultant Chloride-72.40
4	Sample 4 Table 1	pH – 4.87 TDS-211.0 Acidity-12.24 Hardness-42.0 Chloride-93.93	Volume used-0.7 ml Resultant pH-7.02 Resultant TDS-240.0 Resultant Alkalinity-57.46 Resultant Hardness-60.0 Resultant Chloride-74.36	Volume used-1.4 ml Resultant pH-6.99 Resultant TDS-266.0 Resultant Alkalinity-92.82 Resultant Hardness-40.0 Resultant Chloride-70.45	Volume used-2.6 ml Resultant pH-7.08 Resultant TDS-209.4 Resultant Alkalinity-44.2 Resultant Hardness-42.0 Resultant Chloride-78.27	Volume used-1.1 ml Resultant pH-7.03 Resultant TDS-208.9 Resultant Alkalinity-44.2 Resultant Hardness-74.0 Resultant Chloride-80.23
5	Sample 5 Table 1	pH – 5.45 TDS-128.0 Acidity-12.24 Hardness-38.0 Chloride-39.14	Volume used-0.4 ml Resultant pH-7.09 Resultant TDS-136.0 Resultant Alkalinity-17.68 Resultant Hardness-38.0 Resultant Chloride-37.18	Volume used-0.8 ml Resultant pH-7.13 Resultant TDS-137.0 Resultant Alkalinity-22.10 Resultant Hardness-40.0 Resultant Chloride-37.18	Volume used-1.7 ml Resultant pH-7.06 Resultant TDS-97.6 Resultant Alkalinity-8.84 Resultant Hardness-40.0 Resultant Chloride-39.18	Volume used-0.6 ml Resultant pH-7.01 Resultant TDS-98.1 Resultant Alkalinity-8.84 Resultant Hardness-72.0 Resultant Chloride-39.18
6	Sample 6 Table 1	pH – 4.77 TDS-169.0 Acidity-12.24 Hardness-40.0 Chloride-88.06	Volume used-0.4 ml Resultant pH-7.03 Resultant TDS-176.0 Resultant Alkalinity-17.68 Resultant Hardness-48.0 Resultant Chloride-50.88	Volume used-0.9 ml Resultant pH-7.07 Resultant TDS-180.0 Resultant Alkalinity-22.1 Resultant Hardness-36.0 Resultant Chloride-52.83	Volume used-1.6 ml Resultant pH-7.02 Resultant TDS-100.8 Resultant Alkalinity-13.26 Resultant Hardness-44.0 Resultant Chloride-50.88	Volume used-0.7 ml Resultant pH-7.09 Resultant TDS-100.1 Resultant Alkalinity-13.26 Resultant Hardness-76.0 Resultant Chloride-50.88
7	Sample 13 Table 1	pH – 5.92 TDS-204.3 Alkalinity-13.26 Hardness-24.0 Chloride-156.63	Volume used-0.4 ml Resultant pH-6.98 Resultant TDS-279.0 Resultant Alkalinity-44.2 Resultant Hardness-24.0 Resultant Chloride-156.63	Volume used-0.9 ml Resultant pH-7.02 Resultant TDS-318.0 Resultant Alkalinity-70.72 Resultant Hardness-20.0 Resultant Chloride-156.63	Volume used-1.6 ml Resultant pH-7.07 Resultant TDS-213.8 Resultant Alkalinity-30.94 Resultant Hardness-24.0 Resultant Chloride-156.63	Volume used-0.7 ml Resultant pH-7.09 Resultant TDS-209.5 Resultant Alkalinity-30.94 Resultant Hardness-56.0 Resultant Chloride-156.63

8	Sample 19 Table 1	pH – 4.08 TDS-376.0 Acidity-28.56 Hardness-48.0 Chloride-119.37	Volume used-1.3 ml Resultant pH-7.04 Resultant TDS-419.0 Resultant Alkalinity-92.82 Resultant Hardness-48.0 Resultant Chloride-105.67	Volume used-3.1 ml Resultant pH-7.00 Resultant TDS-469.0 Resultant Alkalinity-185.64 Resultant Hardness-44.0 Resultant Chloride-119.36	Volume used-5.9 ml Resultant pH-7.02 Resultant TDS-398.3 Resultant Alkalinity-66.3 Resultant Hardness-48.0 Resultant Chloride-119.36	Volume used-2.5 ml Resultant pH-7.08 Resultant TDS-397.8 Resultant Alkalinity-61.88 Resultant Hardness-92.0 Resultant Chloride-117.41
9	Sample 20 Table 1	pH – 5.60 TDS-101.0 Acidity-8.16 Hardness-24.0 Chloride-37.18	Volume used-0.6 ml Resultant pH-7.01 Resultant TDS-120.0 Resultant Alkalinity-57.46 Resultant Hardness-24.0 Resultant Chloride-41.09	Volume used-1.4 ml Resultant pH-7.02 Resultant TDS-149.0 Resultant Alkalinity-92.82 Resultant Hardness-20.0 Resultant Chloride-50.88	Volume used-2.4 ml Resultant pH-6.97 Resultant TDS-107.2 Resultant Alkalinity-44.2 Resultant Hardness-24.0 Resultant Chloride-37.18	Volume used-1.1 ml Resultant pH-7.04 Resultant TDS-106.5 Resultant Alkalinity-44.2 Resultant Hardness-52.0 Resultant Chloride-43.05
10	Sample2 1 Table 1	pH – 5.37 TDS-98.6 Acidity-16.32 Hardness-20.0 Chloride-54.79	Volume used-1.6 ml Resultant pH-7.01 Resultant TDS-191.0 Resultant Alkalinity-145.86 Resultant Hardness-16.0 Resultant Chloride-50.88	Volume used-3.6 ml Resultant pH-7.03 Resultant TDS-249.0 Resultant Alkalinity-221.0 Resultant Hardness-16.0 Resultant Chloride-54.79	Volume used-7.1 ml Resultant pH-7.07 Resultant TDS-134.2 Resultant Alkalinity-97.24 Resultant Hardness-20.0 Resultant Chloride-54.79	Volume used-3.4 ml Resultant pH-7.12 Resultant TDS-134.7 Resultant Alkalinity-101.66 Resultant Hardness-36.0 Resultant Chloride-54.79
11	Sample 22 Table 1	pH – 5.95 TDS-59.9 Alkalinity-17.68 Hardness-12.0 Chloride-27.40	Volume used-0.6 ml Resultant pH-7.13 Resultant TDS-83.4 Resultant Alkalinity-48.62 Resultant Hardness-10.0 Resultant Chloride-29.35	Volume used-0.7 ml Resultant pH-7.02 Resultant TDS-107.0 Resultant Alkalinity-70.72 Resultant Hardness-12.0 Resultant Chloride-29.35	Volume used-1.4 ml Resultant pH-7.10 Resultant TDS-76.3 Resultant Alkalinity-30.94 Resultant Hardness-14.0 Resultant Chloride-29.35	Volume used-0.9 ml Resultant pH-6.98 Resultant TDS-77.0 Resultant Alkalinity-30.94 Resultant Hardness-24.0 Resultant Chloride-29.35
12	Sample 23 Table 1	pH – 4.51 TDS-151.0 Acidity-16.32 Hardness-16.0 Chloride-58.70	Volume used-0.9 ml Resultant pH-6.98 Resultant TDS-188.0 Resultant Alkalinity-61.88 Resultant Hardness-16.0 Resultant Chloride-60.66	Volume used-2.2 ml Resultant pH-7.01 Resultant TDS-228.0 Resultant Alkalinity-132.6 Resultant Hardness-14.0 Resultant Chloride-62.62	Volume used-3.9 ml Resultant pH-7.05 Resultant TDS-134.2 Resultant Alkalinity-44.2 Resultant Hardness-14.0 Resultant Chloride-60.66	Volume used-1.6 ml Resultant pH-7.07 Resultant TDS-129.5 Resultant Alkalinity-48.62 Resultant Hardness-30.0 Resultant Chloride-62.62
13	Sample 24 Table 1	pH – 5.57 TDS-205.0 Acidity-16.32 Hardness-56.0 Chloride-58.70	Volume used-1.5 ml Resultant pH-7.04 Resultant TDS-263.0 Resultant Alkalinity-106.08 Resultant Hardness-56.0 Resultant Chloride-72.40	Volume used-2.5 ml Resultant pH-7.00 Resultant TDS-312.0 Resultant Alkalinity-159.12 Resultant Hardness-56.0 Resultant Chloride-80.23	Volume used-4.9 ml Resultant pH-6.99 Resultant TDS-229.4 Resultant Alkalinity-79.56 Resultant Hardness-56.0 Resultant Chloride-60.66	Volume used-3.1 ml Resultant pH-7.12 Resultant TDS-228.6 Resultant Alkalinity-79.56 Resultant Hardness-108.0 Resultant Chloride-62.62
14	Sample 25 Table 1	pH – 5.37 TDS-142.0 Acidity-12.24 Hardness-18.0 Chloride-43.05	Volume used-1.3 ml Resultant pH-7.09 Resultant TDS-160.0 Resultant Alkalinity-44.2 Resultant Hardness-20.0 Resultant Chloride-31.31	Volume used-1.2 ml Resultant pH-7.05 Resultant TDS-184.0 Resultant Alkalinity-70.72 Resultant Hardness-20.0 Resultant Chloride-52.83	Volume used-2.4 ml Resultant pH-7.04 Resultant TDS-135.7 Resultant Alkalinity-30.94 Resultant Hardness-16.0 Resultant Chloride-43.05	Volume used-2.4 ml Resultant pH-6.98 Resultant TDS-134.2 Resultant Alkalinity-30.94 Resultant Hardness-36.0 Resultant Chloride-46.96
15	Sample 26 Table 1	pH – 5.13 TDS-105.0 Acidity-16.32 Hardness-18.0 Chloride-48.92	Volume used-0.2 ml Resultant pH-7.06 Resultant TDS-113.0 Resultant Alkalinity-22.1 Resultant Hardness-16.0 Resultant Chloride-43.05	Volume used-0.7 ml Resultant pH-7.02 Resultant TDS-126.0 Resultant Alkalinity-35.36 Resultant Hardness-18.0 Resultant Chloride-43.05	Volume used-1.3 ml Resultant pH-6.97 Resultant TDS-99.4 Resultant Alkalinity-13.26 Resultant Hardness-16.0 Resultant Chloride-43.05	Volume used-0.4 ml Resultant pH-7.08 Resultant TDS-98.9 Resultant Alkalinity-13.26 Resultant Hardness-32.0 Resultant Chloride-45.00
16	Sample 27 Table 1	pH – 6.36 TDS-84.9 Alkalinity-48.62 Hardness-38.0 Chloride-19.57	Volume used-0.8 ml Resultant pH-7.06 Resultant TDS-115.0 Resultant Alkalinity-70.72 Resultant Hardness-36.0 Resultant Chloride-23.48	Volume used-0.7 ml Resultant pH-7.04 Resultant TDS-170.0 Resultant Alkalinity-123.76 Resultant Hardness-36.0 Resultant Chloride-19.57	Volume used-1.2 ml Resultant pH-7.08 Resultant TDS-106.0 Resultant Alkalinity-66.3 Resultant Hardness-34.0 Resultant Chloride-19.57	Volume used-1.5 ml Resultant pH-7.01 Resultant TDS-101.0 Resultant Alkalinity-66.3 Resultant Hardness-80.0 Resultant Chloride-23.48
17	Sample 28 Table 1	pH – 6.07 TDS-72.7 Alkalinity-79.56 Hardness-24.0 Chloride-13.70	Volume used-1.3 ml Resultant pH-7.15 Resultant TDS-144.0 Resultant Alkalinity-145.86 Resultant Hardness-28.0 Resultant Chloride-13.70	Volume used-5.3 ml Resultant pH-7.03 Resultant TDS-185.0 Resultant Alkalinity-304.98 Resultant Hardness-24.0 Resultant Chloride-13.70	Volume used-6.0 ml Resultant pH-7.06 Resultant TDS-108.0 Resultant Alkalinity-106.08 Resultant Hardness-28.0 Resultant Chloride-11.74	Volume used-2.4 ml Resultant pH-7.10 Resultant TDS-104.0 Resultant Alkalinity-101.66 Resultant Hardness-50.0 Resultant Chloride-13.70

18	Sample 29 Table 1	pH – 5.65 TDS-79.0 Alkalinity-88.4 Hardness-22.0 Chloride-23.82	Volume used-1.5 ml Resultant pH-7.06 Resultant TDS-178.0 Resultant Alkalinity-150.28 Resultant Hardness-24.0 Resultant Chloride-31.31	Volume used-5.1 ml Resultant pH-7.07 Resultant TDS-301.0 Resultant Alkalinity-309.4 Resultant Hardness-24.0 Resultant Chloride-29.35	Volume used-6.6 ml Resultant pH-7.02 Resultant TDS-126.0 Resultant Alkalinity-106.08 Resultant Hardness-24.0 Resultant Chloride-29.35	Volume used-2.8 ml Resultant pH-7.05 Resultant TDS-124.3 Resultant Alkalinity-106.08 Resultant Hardness-48.0 Resultant Chloride-31.31
19	Sample 30 Table 1	pH – 6.23 TDS-108.0 Alkalinity-53.04 Hardness-28.0 Chloride-25.44	Volume used-1.0 ml Resultant pH-7.07 Resultant TDS-151.0 Resultant Alkalinity-132.6 Resultant Hardness-28.0 Resultant Chloride-23.48	Volume used-2.9 ml Resultant pH-7.09 Resultant TDS-262.0 Resultant Alkalinity-247.52 Resultant Hardness-30.0 Resultant Chloride-23.48	Volume used-4.9 ml Resultant pH-7.08 Resultant TDS-141.0 Resultant Alkalinity-101.66 Resultant Hardness-26.0 Resultant Chloride-21.53	Volume used-2.2 ml Resultant pH-7.11 Resultant TDS-139.0 Resultant Alkalinity-101.66 Resultant Hardness-60.0 Resultant Chloride-25.44
20	Sample 31 Table 1	pH – 6.28 TDS-94.3 Alkalinity-22.1 Hardness-32.0 Chloride-23.82	Volume used-0.5 ml Resultant pH-7.15 Resultant TDS-122.0 Resultant Alkalinity-57.46 Resultant Hardness-30.0 Resultant Chloride-31.31	Volume used-1.2 ml Resultant pH-7.09 Resultant TDS-158.0 Resultant Alkalinity-97.24 Resultant Hardness-32.0 Resultant Chloride-33.27	Volume used-1.3 ml Resultant pH-7.10 Resultant TDS-105.0 Resultant Alkalinity-35.36 Resultant Hardness-32.0 Resultant Chloride-29.35	Volume used-0.7 ml Resultant pH-7.07 Resultant TDS-102.0 Resultant Alkalinity-39.78 Resultant Hardness-56.0 Resultant Chloride-31.31

Table 5

S.No.	Nature of Sample	Original values of Quality Parameters	Sulphuric acid-sodium carbonate treatment	Sulphuric acid-sodium bicarbonate treatment
1	Sample no 60 Table 1	pH – 6.34 TDS -262.0 Alkalinity – 114.92 Chloride – 103.71 Hardness – 60.0	Volume of H_2SO_4 used – 6.6 ml Resultant pH – 4.49 Volume of Na_2CO_3 used – 0.7 ml Final pH – 6.98 Final alkalinity – 50.83 Final chloride- 86.10 Final hardness – 76.0 Final TDS - 300	Volume of H_2SO_4 used – 6.7 ml Resultant pH – 4.51 Volume of Na_2CO_3 used – 1.8 ml Final pH – 6.99 Final alkalinity – 106.08 Final chloride- 85.12 Final hardness – 78.0 Final TDS - 340
2	Sample no 59 Table 1	pH – 6.82 TDS -289.0 Alkalinity – 57.46 Chloride – 86.10 Hardness – 132.0	Volume of H_2SO_4 used – 4.7 ml Resultant pH – 4.53 Volume of Na_2CO_3 used – 0.6 ml Final pH – 7.00 Final alkalinity – 40.66 Final chloride- 61.64 Final hardness – 94.0 Final TDS - 319	Volume of H_2SO_4 used – 4.9 ml Resultant pH – 4.52 Volume of Na_2CO_3 used – 1.3 ml Final pH – 7.01 Final alkalinity – 70.72 Final chloride- 61.64 Final hardness – 92.0 Final TDS - 334
3	Sample no 57 Table 1	pH – 7.39 TDS -138.3 Alkalinity – 22.1 Chloride – 31.31 Hardness – 16.0	Volume of H_2SO_4 used – 0.6 ml Resultant pH – 4.49 Volume of Na_2CO_3 used – 0.3 ml Final pH – 7.04 Final alkalinity – 13.26 Final chloride- 12.72 Final hardness – 12.0 Final TDS – 184.0	Volume of H_2SO_4 used – 0.6 ml Resultant pH – 4.53 Volume of Na_2CO_3 used – 0.5 ml Final pH – 7.11 Final alkalinity – 24.31 Final chloride- 12.72 Final hardness – 12.0 Final TDS – 208.5
4	Sample no 56 Table 1	pH – 7.78 TDS -78.7 Alkalinity – 22.1 Chloride – 19.57 Hardness – 12.0	Volume of H_2SO_4 used – 1.6 ml Resultant pH – 4.51 Volume of Na_2CO_3 used – 0.3 ml Final pH – 7.13 Final alkalinity – 11.05 Final chloride- 13.70 Final hardness – 8.0 Final TDS – 105.40	Volume of H_2SO_4 used – 1.6 ml Resultant pH – 4.49 Volume of Na_2CO_3 used – 0.6 ml Final pH – 7.01 Final alkalinity – 37.57 Final chloride- 13.70 Final hardness – 8.0 Final TDS – 126.8
5	Sample no 58 Table 1	pH – 7.00 TDS -120.1 Alkalinity – 30.94 Chloride – 43.05 Hardness – 28.0	Volume of H_2SO_4 used – 2.1 ml Resultant pH – 4.53 Volume of Na_2CO_3 used – 0.3 ml Final pH – 7.04 Final alkalinity – 33.15 Final chloride- 37.18 Final hardness – 14.0 Final TDS – 164.0	Volume of H_2SO_4 used – 2.0 ml Resultant pH – 4.52 Volume of Na_2CO_3 used – 0.4 ml Final pH – 6.98 Final alkalinity – 39.78 Final chloride- 39.14 Final hardness – 16.0 Final TDS – 196.3

4. Discussion

I tried to reduce the pH of samples to around 5 or 4.5 by adding H_2SO_4 solution (see Table 3). Evidently, for samples having same pH, the pH of low alkalinity water will drop immediately while the pH of high alkalinity water will drop very slowly and need more acid. The pH drops only when alkalinity (buffering capacity) is overloaded. Thus, even though the concentration of H+ increases and pH decreases on adding acid, the exact amount of acid needed to reduce pH to a particular level, depends predominantly on its alkalinity. The predominant dependence of alkalinity over pH for alteration of pH also happens in case of pH improvement (Table 4).

As seen in Table 4, I tried to increase pH of samples to around 7 by using 4 different alkaline solutions - aqueous sodium carbonate (soda ash), aqueous sodium bicarbonate (baking soda), aqueous sodium hydroxide (caustic soda) and aqueous slacked lime. All these solutions are prepared in approximately 1 % in double distilled water, except sodium hydroxide which is 0.0204 normal or about 0.08 %. These solutions have pH values.

Soda ash – 11.07 Baking soda- 8.99 Caustic soda-11.76 Lime-12.37

The results can be summarised as follows,

1. If same concentrations of all alkaline solutions are used, only very low volume of sodium hydroxide is required while high volumes of other alkalies are required to improve pH.
2. All treatments increase alkalinity and TDS.
3. No treatment has any impact on chloride, FRC and sulphate content.
4. Lime treatment increase total hardness largely while other treatments have little impact on hardness.
5. The alkalinity and TDS shows maximum increase with sodium bicarbonate.

The analysis and its result evaluation reveals a well-defined correlation of pH, alkalinity/acidity and also TDS (because TDS also includes carbonates, bicarbonates etc. as in alkalinity)) with the volume of alkali solution used for improving pH of drinking water.

From the above discussion, it is clear that the use of sodium bicarbonate (baking soda) is not recommended for pH improvements as it is required in large quantities and also increase alkalinity and TDS much higher than other treatments. It may also be risky for high blood pressure patients and may cause acidity. High hardness in water does not pose a health risk, says WHO ,but I am of the view that hardness is one of the reasons for dry skin and breakage ,dryness and thinning of hair and even leads to the formation of dandruff if used on regular basis. Hardness can also cause aesthetic problems .Common problems include formation of scales on plumbing fixtures and appliances, difficulty getting soaps to lather , faded clothes (that is, hard water strips the colour away from clothes much faster), stained sinks and bath tubs, bitter flavour, decreased water heater efficiency etc. So the use of lime for the treatment of water samples having very low pH should be avoided. It works well for samples with pH between 6 and 6.5. For samples with very low pH, it is advisable to use either sodium hydroxide or sodium carbonate. Sodium hydroxide is highly caustic alkaline, it is easier; but strongly irritating and corrosive, it can cause severe burns and permanent damage to tissues that it comes in contact with; don't use much as soda ash, hence not recommended for residential/home applications. Soda ash is a better option for very low pH samples.

5. Conclusion

The relation between change in pH and alkalinity values are well established. The amount of alkali required for improving pH is proportional to alkalinity of original sample. The use of specific alkali solutions for improving pH of different low pH water samples are recommended.

References

[1] IS 10500:2012 Second Revision
[2] WHO Guidelines for drinking water quality
[3] IS Methods 3025