

QUALITY OF POTABLE WATER IN DIFFERENT CITIES OF PAKISTAN : PRESENCE OF ARSENIC AND ITS' REMOVAL BY INDIGENOUS ACTIVATED CARBON

By

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ABSTRACT

Quality of potable water in circulation within different cities of Pakistan was determined through physiochemical analysis. Physical analysis included color, pH, electrical conductivity and odor while Chemical examinations involved the quantitative determination of Arsenic, Carbonate, Bicarbonate, Calcium, Chloride, Magnesium, Potassium and Sodium. The quality of water samples was evaluated against National standards. Arsenic has been especially focused. This pollutant was successfully removed through activated carbon prepared from local Pakistani Lignite coal.

INTRODUCTION

High population growth rate has socio economically effected the third world countries. The alarmingly high multiplication figures have affected almost all the sectors adversely. Pakistan has also suffered tremendously especially in energy production versus consumption rate. Pollution has likewise risen especially in cities. Water levels have fallen down and drinking water quality has been reduced to a bare minimum. Industries throw various pollutants in water bodies i.e., metals and non-metals, organic and inorganic that eventually infiltrate to ground water [1].

The links between health risks and water quality are well established [2]. Water borne diseases especially break out during the monsoon season when the drinking water sources are at the risk of mixing with sewage. Diarrhea and chronic dysentery is the major cause of infant's deaths in the third world countries globally [3]. Clean water not only supports metabolic processes but the presence of required chemicals i.e., carbonates etc. keeps the health functions go ahead smoothly. High concentration of some essential elements in water may not be required and may be a cause of disease whereas; deficiency of such minerals in water may affect health adversely. The sodium electrochemical gradient across the smooth vascular muscles effects blood pressure and hypertension. Blaustein, M.P. [4] reported that a balance in sodium is required for $[Ca^{2+}]_i$ ions to stand at supra threshold level. Infants have been considered as a potential high risk group to the toxic effects of sodium from drinking water [5]. Heavy metals are a cause of cancer [6] and can easily be delivered in body through plants grown in contaminated soil [7-8].

At present, about 20% of the world's population lacks access to safe drinking water, and more than 5 million people die yearly from waterborne diseases or inadequate sanitation. Fresh water is one of the most important resources crucial for the survival of all living beings. The quality of water changes along pipe if not installed according to the required standards [9]. The aim of this study was to evaluate the purity of potable water in circulation within local community and to recommend safety measures to lessen the incidence of water borne diseases. Arsenic was especially focused as it can cause serious illness [10-11]. Activated carbon has been found an effective way of removal of pollutants from water [12-13]. It is the need of almost all the chemical industries and imported from abroad for various purposes. Pakistan has huge reserves of lignite coal. In the present studies, possibilities of preparation of quality activated carbon from Lakhra coal has been explored followed by its use for removal of Arsenic.

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MATERIALS AND METHODS

Sampling Sites and Sources

Water samples were collected randomly from various sources from different cities of Pakistan i.e., Lahore, Okara, Hafizabad, Chinoat, Sheikhpura, Pindibhatian, Islamabad, Peshawar, Sahiwal, Sialkot, and Toba Teik Singh. The Ground water was obtained from the sources equipped with electric motors pumps. Water samples were drawn from various sources available for drinking e.g., taps water, hand pumps and tube wells. Water from taps was flown for ten minutes before sampling.

Water Sampling and Analysis

Drinking water samples were collected from various sources in a random manner for water analysis in air tight plastic bottles (1 L). These were delivered to laboratory ensuring nil contamination during transport.

Standard methods were used to perform physical and chemical analysis of the collected samples. A detailed description of physical analysis methods used for water analysis is given below.

Odor This was a sensory test to know that whether the samples were smelly or odorless.

Color This was a sensory test to evaluate yellow, muddy, greenish, or colorless.

pH pH was measured on pH meter JENCO 6173. The pH meter was calibrated using 4.0, 7.0 and 9.0 pH buffer solutions. Deionized water was used for proper washing of electrode. The value of pH was noted when the system was totally stabilized.

EC The Electrical conductance was noted by using EC meter (JENCO 3173 cond.). Calibration of EC meter was done at 25°C with the standard solution of potassium chloride, 0.01 M. Washing of the electrode was done with the help of deionized water and then by a small amount of the sample. The value was noted when the system was totally stabilized.

TDS The EC meter JENCO 3173 conductivity meter was used for Total Dissolved Solids (TDS). At a constant temperature of 25°C, calibration of EC meter was done with a standard solution of potassium chloride (KCl) 0.01 M. Washing of the electrode was done with the help of deionized water and then with a small amount of the sample. The TDS value of water sample was noted when the system was totally stabilized.

Calcium and Magnesium 10 ml of sample alongwith indicator EBT (Eriochrom Black T) was taken in a conical flask for the determination of $\text{Ca}^{+2} + \text{Mg}^{+2}$ ions. Ammonia buffer of pH-10, (4–5 drops) was added. Purple colour appeared that indicated the presence of $\text{Ca}^{+2} + \text{Mg}^{+2}$ ions. Sample was titrated against EDTA solution till the end point of bluish green colour. Burette reading was noted down. $\text{Ca}^{+2} + \text{Mg}^{+2}$ ions concentrations were calculated using the formula per 3500-Ca_D & 2340 C, standard methods.

Sodium and Potassium Flame Photometer Model: PFP-7 JENWAY, UK was used for the determination of sodium ions in water samples. Standard solutions of Sodium and Potassium of various concentrations were used for the calibration of flame photo meter and fine control was adjusted to have stable positive readings. Then water samples were aspirated and meter reading was noted for the ions. The concentration of ions in the water samples was calculated from the graph of standard sodium and potassium solutions.

Carbonates 10 ml of water sample in a conical flask along with 2–3 drops of phenolphthalein (indicator) was taken in a conical flask. This was titrated against 0.02M HCl solution. Used acid volume was noted when a change in colour from pink to colorless was observed. The carbonates were calculated as:

Carbonates = Vol. of acid used x 20 x 2

Bicarbonates 10 ml of sample in a conical flask along with 1–2 drops of methyl orange was added as an indicator. The sample was titrated against solution of 0.02M HCl. The end point is indicated when the colour changes from orange to pink. Used acid volume was noted for the bicarbonate calculations as follows:

Bicarbonates = Vol. of acid used x 20 x 2

Chlorides The silver nitrate titration was adopted for the determination of chlorides. 10 ml sample with 1–2 drops of Potassium chromate (indicator) was taken in a flask. The sample was titrated against 0.0141N AgNO₃ solution till color changed to pinkish yellow. The quantity of chloride was estimated:

$$\text{Chloride (ppm)} = \text{Vol. of AgNO}_3 \text{ used} \cdot N \cdot 35.5 \cdot \frac{1000}{V}$$

Where N = 0.0141N AgNO₃

V = Volume of sample

Arsenic pH of water samples was maintained below 2.0 by adding a few drops of concentrated HNO₃ and filtered. Arsenic was determined quantitatively on Atomic Absorption Spectrophotometer (AA240FS Fast Sequential Atomic Absorption Spectrophotometer).

All the water analyses results are presented in Table I.

Preparation of Activated carbon. Activated carbon was prepared from the dry distillation of Pakistani Lakra lignite coal. The proximate analyses of the lignite coal are given in Table II. The dry carbon obtained was washed several times with HCl till it passed the methylene blue test. The prepared activated carbon was tested for the removal of arsenic in water comparing with imported powdered activated carbon. The adsorption efficiency of the prepared activated carbon was calculated using the equation:

$$\% \text{ sorption} = \frac{(C_i - C_e)}{C_i} \times 100$$

Where C_i – initial concentration of arsenic

C_e - final concentration of arsenic

0.1g, 0.2g and 0.3g of the prepared adsorbent along with 20 ml of 15 ppm Arsenic solution were taken in separate test tubes. The test tubes were shaken at 150 rpm for 1 hour and then centrifuged for 4 minutes. The tests tubes were kept undisturbed for 2 hours. The solutions were filtered and the concentration of arsenic in the filtrate was determined by atomic absorption. Similar tests were performed with imported standard activated carbon to check the comparative performance of the Lignite based activated carbon. The results are presented in Table-III.

RESULTS AND DISCUSSIONS

Local communities rely on three major water service modes: a) the piped supply network of the Lahore Development Authority (LDA), b) the piped supply network of the various Cantonment authorities and c) household groundwater wells. Physico-Chemical analysis of water supplies was necessary to guarantee the quality, compliance with established quality criteria and efficiency of operation of water treatment plants and distribution systems. Physical analysis included color, pH, electrical conductivity and odor while Chemical examinations involved Alkalinity, Carbonate, Bicarbonate, Calcium, Chloride, Hardness, Magnesium, Potassium and Sodium and Arsenic.

All collected water samples were odorless and colorless. Other results are presented in Table-I.

Table-I. Table showing potable water analyses from different cities of Pakistan

Lab FC #	City / Source	pH	EC Ms/m	TDS Ppm	Ca ⁺² ppm	Mg ⁺² ppm	Na ⁺¹ ppm	As ppb	CO ₃ ⁻² ppm	HCO ₃ ⁻¹ ppm	Cl ⁻¹ ppm
NSDWQ*		6.5 - 8.5	NGV S	< 1000	< 200	NGV S	< 200	≤10	NGV S	NGVS	< 250
1/11	Toba Tek Singh	8.82	4.87	2.6ppt	40	100.8	861.3	06.93	60	616.1	316
2/11	Toba Tek Singh	8.38	1.93	1.0ppt	44	163.2	234.6	07.16	NIL	457.5	191.7
3/11	Toba Tek Singh	8.53	3.73	2.0ppt	50	84	694.6	06.93	27	591.7	198.8
4/11	Toba Tek Singh	8.44	1.90	998	92	38.4	179.4	06.14	TR	347.7	330.2
5/11	Okara	8.63	2.83	1.9 ppt	58	127.2	487.6	11.70	30	372.1	216.6
6/11	Okara	8.66	1.33	806	20	33.6	241.5	05.68	36	463.6	152.7
7/11	Okara	8.45	1.20	749	68	38.4	151.8	9.67	TRS	427	181.1
8/11	Okara	8.52	1.65	951	34	86.4	230	11.36	27	256.2	213
9/11	Hafizabad	8.45	1.50	783	36	48	255.5	04.43	TRS	561.2	184.6
10/11	Hafizabad	8.24	1.25	667	38	2.4	250.7	06.14	NIL	567.3	117.2
11/11	Hafizabad	9.00	1.50	789	18	74.4	239.2	09.77	90	494.1	106.5
12/11	Hafizabad	8.59	1.70	867	8	98.4	289.8	02.84	30	579.5	142
13/11	Chinot	8.16	1.70	957	76	120	211.6	04.77	NIL	335.5	301.8
14/11	Chinot	8.67	0.90	484	84	52.8	63.48	07.61	36	146.4	99.4
15/11	Chinot	8.57	1.44	767	62	100.8	189.5	05.57	30	85.4	198.8
16/11	Chinot	8.37	1.45	770	82	81.6	174.8	05.45	TRS	219.6	209.5
17/11	Sheikhupura	8.45	0.80	416	20	60	92	12.16	TRS	298.9	71
18/11	Sheikhupura	8.49	1.00	514	22	52.8	154.1	02.84	TRS	353.8	88.8
19/11	Pindi Bhatian	7.43	1.50	764	64	91.2	186.3	04.20	NIL	427	85.2
20/11	Pindi Bhatian	7.13	0.92	461	120	67.2	6.9	05.11	NIL	372.1	46.2
21/11	Islamabad	8.21	0.42	224	32	33.6	11.5	27.73	NIL	201.3	28.4
22/11	Islamabad	8.33	0.38	209	54	2.4	19.09	02.95	TRS	176.9	21.3
23/11	Islamabad	8.49	1.10	482	26	105.6	13.34	05.68	24	237.9	53.3
24/11	Peshawar	8.50	0.92	349	30	136.8	69	04.32	TRS	329.4	106.5
25/11	Peshawar	8.50	0.65	580	26	105.6	115	09.32	TRS	329.4	131.4
26/11	Shahkot	8.86	1.20	653	20	60	193.2	06.25	81	292.8	67.45
27/11	Shahkot	8.84	2.20	1.2ppt	10	62.4	462.3	06.02	78	500.2	195.3
28/11	Sahiwal	8.92	1.20	663	26	40.8	200.1	01.93	84	518.5	99.4
29/11	Sahiwal	8.08	1.10	556	40	96	156.4	02.27	NIL	402.6	120.7
30/11	Lahore	7.73	0.80	441	40	28.8	106.5	13.07	NIL	250.1	67.45
31/11	Lahore	7.80	1.04	556	60	43.2	5.98	06.59	NIL	335.5	71.0
32/11	Lahore	8.40	4.33	236	64	36	52.9	28.30	24	488	28.4
33/11	Lahore	8.45	0.75	395	56	566.4	66.7	05.57	TRS	225.7	31.95

NSDWQ* - National Standards for Drinking Water Quality

NGVS* - No guideline value available for standard

The pH values given in table-I show that 12 out of 33 samples are slightly beyond the permissible limit while all other samples values are in between the range in accordance with Pakistan Standard Quality Control Authority (PSQCA) which is 6.5-8.5. The pH values of these samples are in the range of 7.13 to 9.00.

The E.C. values showed a significant variation in results among different water samples. The EC values given in Table-I demonstrate the range of 0.38 to 4.87 m / S while few samples have a high E.C. values. High values of EC indicate that these samples have large quantities of dissolved solids and cations such as sodium, magnesium, calcium etc. Pakistan Standard Quality Control Authority has given no permissible limit of E.C. in drinking water.

TDS is a procedure to check the correctness of the analysis and is applicable specifically to water samples for which relatively complete analysis are made. This check does not require additional laboratory analysis. According to the Pakistan Standard Quality Control Authority permissible limit for TDS in water is 1000 ppm. The TDS content of samples range from 1.02ppt to 1000 ppm. All the water samples fall within this range.

The salt taste created by chloride concentration is variable and dependent on the chemical composition of water. Chloride values are from 21.30 to 330.15 ppm. The limit permissible limit of chloride for drinking water by PSQCA is 250 ppm. Only 3 samples out of 33 samples have chlorides greater than 250 ppm.

Limestone, dolomite and gypsum contribute to the occurrence of calcium in water sources. The guideline values for calcium content in drinking water by PSQCA are 75ppm as the maximum acceptable concentration while 200 ppm is maximum allowable concentration. The water sample under study showed the calcium content in maximum allowable concentration although some samples in the range of 08-120 ppm

There are no standard guidelines were set for magnesium and potassium by PSQCA. The minimum value of magnesium is 2.4 ppm and maximum is 566 ppm in these water samples and potassium in water samples ranges between 0.4-10.4 ppm.

Among elements sodium is on sixth number in order of abundance and is present in most natural water. The level of sodium varied from 6.9 ppm to more than 861ppm. The normal concentration of sodium salts in potable water is usually less than 200 ppm. Mainly sodium salts were present in water. Concentration in excess of 200 ppm may give rise to unacceptable taste and can add to high blood pressure risk [14]. Water from these areas definitely needed purification.

Arsenic content was mostly found within the permissible values except in 5 samples i.e., 2 each from Okara and Lahore and 1 from Sheikhpura. Attempts were made to convert the collected water samples in potable drinking water, especially free from arsenic. Activated Carbon was prepared from Pakistani lignite Coal. The proximate analyses of coal are given as in Table II.

Table-II. Proximate analyses of lignite coal

Moisture Content - %	Volatile content - %	Ash - %	Fixed Carbon - %	Calorific value - Kcal/kg
13.89	37.92	10.5	37.69	5515.68

Courtesy: Coal department, Punjab University, Lahore

Removal of arsenic (15 ppm arsenic solution) was checked with 0.1 gm, 0.2 and 0.3 gms of prepared Lignite based Adsorbent. Results are presented in table III. It shows that percent adsorption of Arsenic is reliant on the amount of adsorbent concentration. Gode, F. et al have established the fact that there has to be a sorbent-sorbate ratio, which gives maximum adsorption [15]. About 96.5 % arsenic removal is obtained with 0.3 gms of lignite based activated carbon. The adsorbent efficiency is close to that obtained by imported standard activated carbon.

Table-III. Removal of Arsenic (15 ppm) by lignite based activated carbon

Se. No.	Sample	Concentration of adsorbent →	% adsorption		
			0.1g	0.2g	0.3g
1	Standard Activated Carbon		97.47	98.53	98.80
2	HCl Treated Lignite		94.40	95.53	96.53

These results show that indigenous activated carbon can be a cheaper material for the removal of arsenic. However, in natural waters competitive adsorption of other ions may be of concern and hence, the adsorbent concentration will need optimization.

CONCLUSIONS

The Physico-chemical analyses of drinking water collected from various cities of Pakistan indicate significant variation. Sodium ion is found beyond permissible levels in majority of samples and needs removal. Arsenic was found present in only a few water samples that can be effectively removed with indigenously prepared activated carbon. There is need for acceptable changes to be made at points where water distribution systems' integrity appears compromised.

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