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Water Supply Network in Rajshahi City Corporation: Water Quality, Regeneration Effect and Pump Performance

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ABSTRACT

Urban water supply systems are currently facing considerable challenges posed by rapid population growth and the constraints of limited resources. Across many urban areas, pumping stations are tasked with providing drinking water; however, the quality of this water often falls short of the rigorous standards set by Bangladesh's Drinking Water Standards (BDS) and the World Health Organization (WHO). This situation is alarming, as water quality can have dire implications for public health. The efficiency of numerous pumping facilities is significantly lower than the optimal benchmarks established in laboratory tests. As a result, city residents frequently face inadequate access to safe drinking water, a critical resource for daily living. The present study focuses on the performance evaluation of pumping sites within the Rajshahi City Corporation (RCC). This study aims to uncover specific issues that hinder the effective operation of these pumping stations and to propose viable solutions. The analysis investigates essential parameters, including static water levels, the conditions of aquifers, and the impacts of drawdown—each factor playing a pivotal role in the overall performance of water supply systems. The investigation reveals that many pumps fall short of established laboratory standards, with significant seasonal fluctuations in groundwater levels and the effects of drawdown being prominent factors contributing to this inefficiency. By addressing these critical issues, the study seeks to pave the way for sustainable water management practices that ensure equitable access to safe drinking water for all residents, ultimately improving the quality of life in resource constrained urban areas.

Keywords: Water Supply Network in RCC, Water Quality, Regeneration Effect, Pump Performance.

1. Introduction

Bangladesh, with 160 million people living in 57,000 square miles, has one of the greatest population densities in the world. Out of the 160 million individuals, 13% do not have access to clean water, and 39% do not have better sanitation [1]. Freshwater is becoming more and more in demand worldwide due to unchecked development and population growth [2]. Particularly in an urban area of a nation, the situation is more complicated [3]. The Rajshahi Water Supply and Sewerage Authority (RWASA) is responsible for providing only 72 MLD of the 118 MLD of freshwater that RCC is expected to use daily in 2018. The estimated amount of water shortfall is 46 MLD, and by 2031, it is predicted to increase to 67 MLD [2]. A set of hydraulic and hydrologic components that are constructed to provide water delivery is called a water supply system or network. A water supply system consists of a drainage basin, an above-ground or below-ground raw water collection point, water purification facilities, water storage facilities like reservoirs, tanks, or towers, extra water pressurizing components, a water distribution pipe network, and connections to the sewers. The average annual rainfall during the monsoon season is 1625 mm, significantly less than the 2550 mm national average. The summertime temperature can occasionally reach over 40 °C, and in January, the mid-winter temperature drops to below 5 °C. Rajshahi City Corporation (RCC) is one of Bangladesh's largest urban and educational hubs, covering 98 km². With a population of 926,000 living in 145,482 houses in 30 Wards, the RCC region is highly populated (8900 people/km^2). Here, the primary source of water for residential and drinking needs is groundwater. Using groundwater as the source, the Water Supply Section of the Ministry of Works in Calcutta, India, established the Rajshahi Water Supply System in 1937. The Rajshahi Water and Sewerage Authority (RWASA) is currently in charge of maintaining the area's water supply and management system. It currently supplies 72 million liters of groundwater per day, meeting 84% of the region's entire demand out of a current demand of 135 million liters. For maintaining proper fluid pressure 112 pumps are running every day where pipeline network length is 760.55 km. All the water quality parameter is not within the WHO standard because of climate change, socio–economic instability and others parameters. Any kind of geographical data can be collected, stored, processed, analyzed, managed, and presented using a geographic information system (GIS). It has the unique capability of integrating data to provide the analytical information for decision-making aspects with special reference to optimum location of pumps and tube-wells. PC Arc/Info software has been utilized to perform the Buffer analysis. Water level is decreasing day by day but demands are increasing. The main aim of this paper is to study of the present water supply network in RCC as well as performance investigation of various pump site. Moreover, quality of water supply is compared with BDS and WHO standard to ensure pure as well as safe drinking water to city dwellers. In addition, the regeneration effect of various pumping sites has been investigated.

2. Present Water Supply Situation of Rajshahi City

The city of Rajshahi is situated on the north bank of the Padma River, with the Sib-Barnai River flowing beside it on its southern bank. The region between the rivers is generally elevated between 17 and 18 meters PWD and slopes generally from south to north. RCC area is located in the sub-tropical monsoon zone according to climate. The seasons are categorized as follows: hot and dry pre-monsoon or summer (March–May) with recurrent drought episodes; rainy days or monsoon (June–October); and chilly and dry winter (November–February). The average annual rainfall during the monsoon season is 1625 mm, significantly less than the 2550 mm national average. In terms of hydrogeology, the subsurface lithology of the region consists of two layers: (1) a top soil cover of silty-clay layer (Gray to brown color) of semi-impervious nature, with a thickness ranging from 10 to 25 m; and (2) very fine-coarse sandy mixed with gravel (Gray and light brown color) and inter-bedded with clay and silt comprises an aquifer layer of thickness ranging from 25 to 85 m, which is regarded as the primary source of groundwater. Between 1019 and 6000 m2/day are the ranges for the aquifer's transmissibility (T), and between 5.54 × 106 and 0.673 are the measurements for its storage coefficient (S). The aquifer here has a hydraulic connection to the Padma River and has opened up beyond the river's edge, which aids in supplying the aquifer during periods of high river water. The three primary water sources in the RCC are surface water, ground water, and rainwater. Nearly 93% of the population in the RCC uses tube wells or deep tube wells (which feed water through pipe lines) to obtain subsurface water [4]. Ground water is pumped through these types of wells. Approximately 85% of freshwater originates from groundwater sources and some rural areas, according to Haque et al.'s assessment [5]. In Bangladesh's northwest, on the bank of the Padma River (Ganges), sits Rajshahi City Corporation (RCC), a significant urban and educational hub spanning 98 km². The RCC region is divided into 30 Wards (Ward is the lowest level of governance in the municipal corporation territory in Bangladesh) and is heavily inhabited (8900 person/km^2), with a total population of 926,000 in 145,482 homes. Water for drinking and domestic use is primarily obtained from groundwater in this area. Using groundwater as the source, the Rajshahi Water Supply System was established in 1937 by the Water Supply Section of the Ministry of Works in Calcutta, India. In this drought-prone region, drinking water scarcity was being addressed at the time by Rajshahi's Great Empress (Moharani), Hemonto Kumari. Over 100 street water reservoirs with a combined capacity of 1779 liters were part of the system. Due to growing urbanization, the iron and hardness removal plant located at the street reservoirs was abandoned. It had a 700 m3/day supply capacity. In accordance with the Rajshahi Water Supply Master Plan, a new distribution system was then developed between 1981 and 1990 by the Department of Public Health Engineering (DPHE). Currently, 99.96 million litres of groundwater are supplied daily to meet the current demand of 127.13 million litres by the Rajshahi Water and Sewerage Authority (RWASA), which is responsible for maintaining the area's water supply and management system [6].

Table 1 Demand of water with population in various year of Rajshahi City Corporation [7]

Year	Population	Growth rate (%)	Water demand (MLD)
2010	786,000	1.55	106.66
2011	797,000	1.40	108.15
2012	808,000	1.38	109.65
2013	820,000	1.49	111.27
2014	831,000	1.34	112.77
2015	843,000	1.44	114.40
2016	855,000	1.42	116.02
2017	868,000	1.52	117.79
2018	880,000	1.38	119.42
2019	893,000	1.48	121.18
2020	908,000	1.68	123.22
2021	924,000	1.76	125.39
2022	940,000	1.80	127.13

There are three kinds of pipelines that make up the RCC area's water distribution system. Among them are 37.5 km of AC pipeline, 1.5 km of GI pipeline, and 495.5 km of PVC pipeline. There is only one PVC pipeline where the maximum velocity, 2.4 m/s, is found to exist. For GI pipelines, the maximum velocity is determined to be 1.9 m/s, whereas the maximum velocity for AC pipelines is found to be 2.29 m/s.

Table 2 Water supply network description of RWASA [6]

Number of pumps	112
Surface water treatment plant	01
Water demand	127.13 MLD
Generating capacity	99.96 MLD
Coverage	84%
Buyer	46,250
Pipeline network length	760.55 km
Duration of water supply	12 hr./day
Motor power	25 kW

3. Quality of supplied water by RWASA

To meet up the water demand of the city, Rajshahi WASA has been completed various project and plan for some new project. The DPHE already has been installed three- water treatment plant, each with approximated capacity of 400 m^3/hr, designed to simple lime softening followed by aeration flocculation, sedimentation and rapid sand filtration. The locations of three water treatment plants are: Srirampur (Central Park near Boalia Club), Raninagar (Ramchandrapur) and Shalbagan (Paba). But, unfortunately only one water treatment plant (Srirampur) is working now due to various problem. The functions of the water treatment plant are to remove some impurities of water distribution line. Here the supply water treatment procedure can be depicted by flow diagram is given **Fig. 1**. The operating time of every plant is 20 hr./day and the source of water is ground water. Actually, five deep tube-wells are connected to each plant in which four deep tube-well feed the plant and one of them remains standby for sudden stop of anyone. After treating the deep tube wells water, it is being sent to the pump house and then serves to the dwellers through the pipe line.

Quality is a fundamental issue of the supplying water in order to ensure safe and pure drinking water. **Table 3** represents the BDS and WHO standard for drinking water. Therefore, RWASA should focus on the standard for supplying fresh and clean drinking water as well.

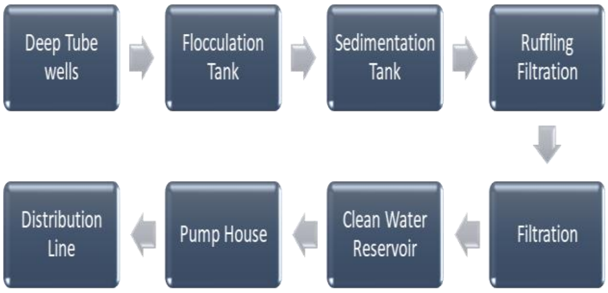

Fig.1 Water filtration network in Rajshahi City Corporation**.**

Table 3 Drinking water quality standard [8], [9].

Selected parameters	Experimental methods	Bangladesh drinking water standard (BDS)	World Health Organization (WHO)
P^H	P^H meter	6.5-8.5	6.5-8.5
turbidity	Turbidity meter	10	5
Iron (Fe) (mg/l)	AAS (atomic absorption spectroscopy)	0.3-1	0.3
Odor	Threshold odor number (TON)	odorless	Odorless
Hardness (mg/l)	Soda reagent method	200-500	500
Manganese (Mn) (mg/l)	AAS	0.1	-
Arsenic (As) (mg/l)	AAS	0.05	0.01

Table 4 and Table 5 represents the water quality of various pump site of RCC for the year 2010 and 2015. From **Tables**, it is clear that, most of the pump site water are far away from BDS and WHO standard. Therefore, the water supply authority should need proper monitoring. Impure water is responsible for various water diseases like cholera, typhoid, diarrhea etc. As a result, the RWASA should focus on this issue for supplying water maintaining the BDS and WHO standard.

Table 4 Year wise water quality fluctuation in various pump sites of RWASA (2010).

Pump Location	Water quality results (Jan 2010)				
	pH	Hardness (mg/l)	Arsenic (mg/l)	Iron (mg/l)	Manganese (mg/l)
Dargapara	7.3	370	0.001	0.07	0.89
Pathanpara	7.1	465	0.001	0.06	2.00
Ghoshpara	7.2	455	0.005	0.10	1.10
Kajla	7.2	463	0.006	1.16	0.74
Budhpara jiya school	7.1	425	0.001	0.55	0.23
Chakpara	7.1	435	0.009	0.99	0.30
Sadhurmor	7.1	400	0.013	1.85	0.39
Talaimari bash adda	7.2	383	0.024	2.35	0.20
Horogram munsipara	7.0	409	0.036	4.54	0.10
Tikapara	7.0	460	0.003	0.25	1.23
Horogram pir sheb para	7.1	447	0.027	2.97	0.95
Kathalbaria hatuvanga	7.1	455	0.018	0.14	1.00
Mollapara	7.1	375	0.014	0.06	1.06
Mollapara koroitola	7.0	434	0.013	0.43	0.45
Bohorampur	7.1	458	0.001	0.65	1.29
Bilsimla eidgah	7.1	490	0.001	0.06	0.81
Keshabpur police line	7.1	360	0.006	0.12	1.19
Bulonpur eidgah	7.2	447	0.022	1.53	0.68
Mohisbathan uttar para	7.0	430	0.010	0.07	1.40
Mohisbathan adorso school	7.2	409	0.021	0.60	1.09
P T I	7.1	443	0.008	0.06	1.60
TB Pukur	7.1	459	0.003	0.05	0.70
Paramedical -2	7.1	440	0.001	0.12	0.69
Srirampur WTP	7.0	425	0.017	0.57	0.30
Central Park	7.2	430	0.024	1.26	1.20
DPHE	7.3	442	0.011	0.64	0.65
Compound Circuit house	7.3	435	0.001	0.47	0.47
RDA rest house	7.1	434	0.001	0.06	0.04
Sonadighi	7.2	340	0.001	0.05	0.05
Pathanpara Eidgah	7.1	392	0.001	0.06	0.06

Table 5 Year wise water quality fluctuation in various pump sites of RWASA (2015).

Pump Location	Water quality results (Jan 2015)				
	pH	Hardness (mg/l)	Arsenic (mg/l)	Iron (mg/l)	Manganese (mg/l)
Dargapara	7.4	378	0.001	0.10	1.02
Pathanpara	7.2	476	0.001	0.10	2.16
Ghoshpara	7.3	460	0.005	0.16	1.18
Kajla	7.3	472	0.006	1.30	0.81
Budhpara jiya school	7.3	434	0.001	0.62	0.27
Chakpara	7.2	444	0.009	1.03	0.35
Sadhurmor	7.2	404	0.013	1.92	0.45
Talaimari bash adda	7.3	392	0.024	2.42	0.24

Horogram munsipara	7.2	416	0.036	4.60	0.13
Tikapara	7.2	468	0.003	0.30	1.32
Horogram pir sheb para	7.1	452	0.027	3.04	1.02
Kathalbaria hatuvanga	7.2	462	0.018	0.20	1.00
Mollapara	7.2	388	0.014	0.10	1.13
Mollapara koroitola	7.1	446	0.013	0.52	0.51
Bohorampur	7.2	464	0.001	0.72	1.37
Bilsimla eidgah	7.2	498	0.001	0.10	0.89
Keshabpur police line	7.2	368	0.006	0.20	1.24
Bulonpur eidgah	7.3	456	0.022	1.62	0.73
Mohisbathan uttar para	7.1	436	0.010	0.10	1.48
Mohisbathan adorso school	7.3	416	0.021	0.68	1.16
P T I	7.2	452	0.008	0.10	1.66
TB Pukur	7.2	464	0.003	0.10	0.76
Paramedical -2	7.2	448	0.001	0.18	0.77
Srirampur WTP	7.1	432	0.017	0.64	0.36
Central Park	7.2	438	0.024	1.31	1.26
DPHE Compound	7.3	450	0.011	0.71	0.71
Circuit house	7.5	442	0.001	0.54	0.54
RDA rest house	7.2	446	0.001	0.10	0.10
Sonadighi	7.3	348	0.001	0.10	0.10
Pathanpara Eidgah	7.2	402	0.001	0.10	0.10

3.1 Regeneration of various pumping site

Regeneration is techniques for increasing specific capacity of pump for same power consumption. After operation for a certain period of time, the submersible pump shows less water discharge than that its capacity. To increase the discharge capacity of a certain site pump for same energy consumption regeneration have been done. During regeneration period, the discharge capacity of various site pump was measured before regeneration and after changing and cleaning various types filters the discharge capacity were measured. It has found that after regeneration, the capacity of discharge of various pump has been increased that are represented in **Table 6**. Therefore, regeneration should be done of the pumping site for getting more specific capacity of the pumping site.

Table 6 Regeneration data of various pump site.

Pump site	Static water level (m)	Before regeneration				After regeneration				Increasement of specific capacity (%)
		Pumping water level (m)	Draw down (m)	Discharge (m^3/h)	SP. Capacity ($m^3/h/m$)	Pumping water level (m)	Draw down (m)	Discharge (m^3/h)	SP. Capacity ($m^3/h/m$)	
Kasheyadanga pump	38.5	58.58	6.12	65.72	15.34	54	4.73	120.14	25.42	65.72
Guripara pump	39.16	62	6.96	89.55	12.86	54.75	4.75	126.64	26.64	107.19
Bulonpur Pump	41.66	90	14.74	84.95	5.76	71	8.95	116.75	13.05	126.44
PTI Pump	43.5	66.15	6.91	98.09	14.20	59.16	4.77	120.14	25.16	77.14
Mohisban Adorshow pump	42.16	60.42	5.57	89.55	16.08	56.25	4.30	126.64	29.48	83.28
RDA Rest House pump	42.16	65	6.96	84.95	12.20	56.5	4.37	123.43	28.23	131.42
Bornali pump	46.66	62	4.68	98.09	20.97	55	2.54	126.64	49.80	137.46
Para Medical pump	43.75	63.25	5.95	93.92	15.80	55.25	3.51	116.75	33.30	110.80
DPHE Pump	39.16	80	12.45	89.55	7.19	65.33	7.98	113.27	14.20	97.40
Khoya potty pump	43.5	90	14.18	40.05	2.82	80	11.13	69.36	6.23	120.66
Binodpur Bazer pump	39.66	75	10.77	56.63	5.26	65	7.73	113.27	14.66	178.93
Kalitola pump	39.58	74	10.49	98.09	9.35	48.5	2.72	123.43	45.39	385.55
Kajla pump	39.75	90	15.32	74.92	4.89	83	13.19	102.10	7.74	58.33
Maherchondi pump	42	80	11.59	89.55	7.73	74.16	9.80	109.67	11.19	44.71
Khojapur pump	38	81.33	13.21	56.63	4.29	65	8.23	116.75	14.18	230.84
Zia school pump	40.5	89.75	15.02	89.55	5.96	80	12.04	113.27	9.41	57.71
	40.5	88.25	14.56	69.36	4.76	80	12.04	109.67	9.11	91.14

Ahmedpur pump										
Khulipara pump	40.5	74	10.21	98.09	9.60	64	7.16	141.58	19.76	105.76
Sosthitola pump	43.33	72.42	8.87	204.19	23.02	63	6.00	215.65	35.96	56.19
Hatem kha gorosthan north	41.17	75.42	10.44	204.19	109.55	61	6.05	226.53	37.47	91.61
Uposhohor water tank	44.25	62.17	5.46	196.18	35.91	54	2.97	219.34	73.79	105.49
Kadirgong Ambagan pump	43.25	80	11.20	192.05	17.14	65	6.63	210.00	31.67	84.76
Koyerdara pump	37.75	80	12.88	56.63	4.40	65	8.31	211.90	25.51	480.13
Mothurdanga pump	45.5	70	7.47	196.18	26.26	61.42	4.85	245.23	50.52	92.37
Match factory pump	45.42	71	7.80	89.55	11.48	59	4.14	129.76	31.34	172.97
Sheroil colony pump	45.17	66.42	6.48	206.15	31.82	60.17	4.57	222.97	48.76	53.22

4. Performance analysis of various pumps (RWASA) and Discussion

The performance of the various pump site of RCC has been analyzed here which are presented in **Fig. 2**. It has found that the efficiency of various pump is far away from standard lab test result. Haque et al. found more or less similar performance of various pumping site of RWASA [10]. The assessment of pump sites in RCC revealed notable inefficiencies, with average performance levels of 25% compared to laboratory standards. Fluctuations in key performance indicators, such as pH, hardness, arsenic, iron, and manganese, were noted from 2010 to 2015, showing an upward trend. Seasonal variations in groundwater and drawdown effects were identified as major contributing factors, worsened by unreliable electricity supply and ineffective pump placement. Pumps installed in regions with high transmissibility aquifers showed better performance, highlighting the importance of aquifer characteristics. Implementing practical solutions like mechanical pipe adjustments could improve efficiency and lower operating costs [11], [12].

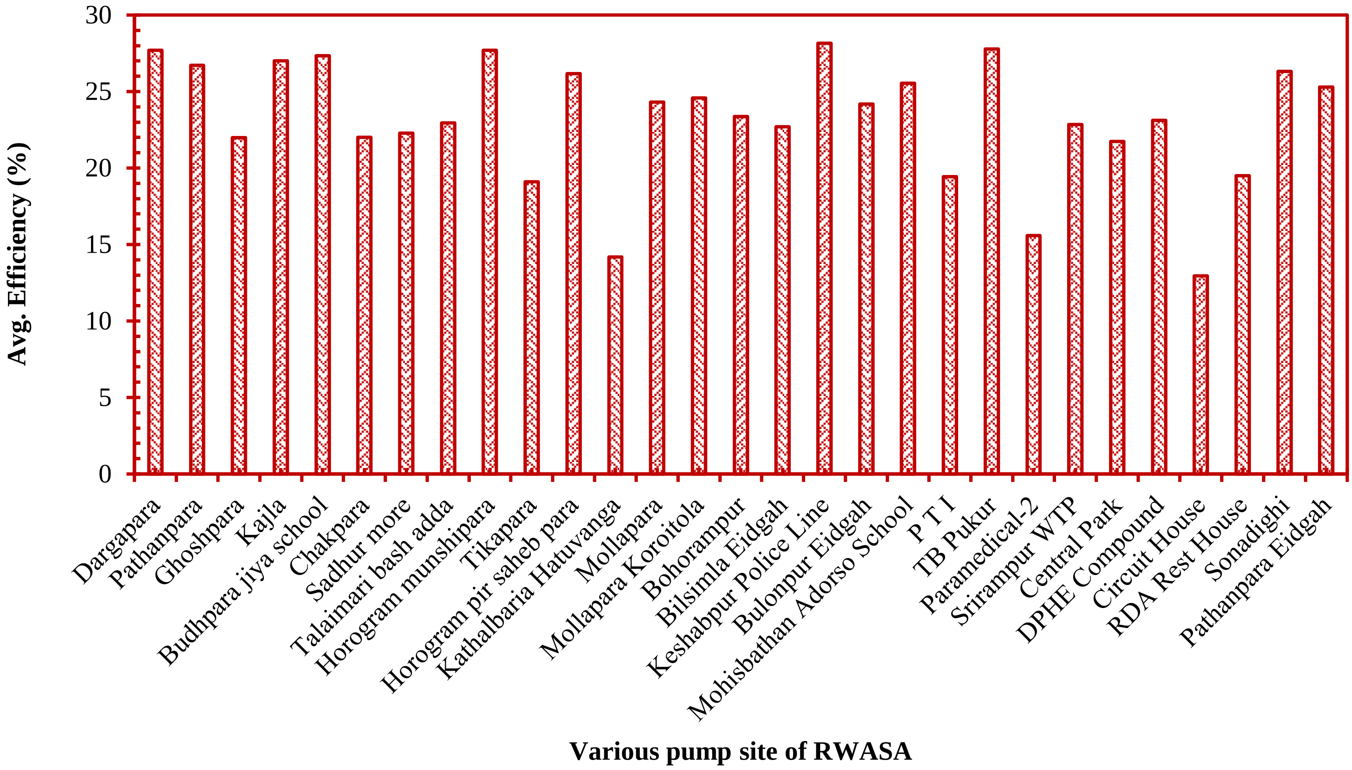

Fig.2 Performance of various pump site of RWASA.

5. Conclusion

This study aimed to analyze the performance of water supply pumps in the Rajshahi City Corporation and identify key factors contributing to inefficiencies. From 2010 to 2015, the parameters affecting drinking water quality—such as pH, hardness, arsenic, iron, and manganese—have been increasing. This trend indicates that the water is increasingly deviating from the quality standards set by the WHO and BDS, posing a major concern as the population and demand for fresh water grow daily. If this trend continues, the water may become undrinkable in the near future. To meet the rising demand, a process known as regeneration is employed to enhance the discharge capacity of various pumps, effectively increasing discharge and specific capacity. By highlighting these challenges, our study provides valuable insights for optimizing water supply systems. Recommendations include reducing drawdown by using mechanical attachments in delivery pipes and increasing overall efficiency. While our findings are specific to the Rajshahi City Corporation, they offer a framework that can be applied to address similar issues in other regions. Continued efforts in this direction are essential to ensure reliable urban water supplies amid growing demand.

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