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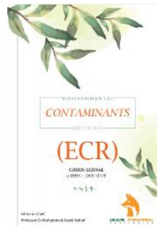

RESEARCH ARTICLE

DRINKING WATER QUALITY ASSESSMENT OF UNION COUNCIL DHAMNI, POONCH, AZAD JAMMU AND KASHMIR, PAKISTAN, USING WATER QUALITY INDEX AND MULTIVARIATE STATISTICAL ANALYSIS

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ABSTRACT

Access to safe drinking water is an emerging issue in Pakistan, both in urban and rural settlements. The water quality in the region is mainly declined by population explosion, vehicular and industrial emissions and agricultural activities. The aim of the study was to assess the water quality of the study area through integrated approach of water quality index and multivariate analysis. Water samples from the study area were analyzed for physicochemical and microbiological parameters using standard methods. The study site was divided into eight (8) different locations and the water samples were collected from commonly used water sources. The results of study indicated that the concentration of all studied chemical parameters were within the permissible limits when compared with WHO recommended standards except lead (Pb). Major cations were found in the order of Ca^{2+}> Mg^{2+}>Na^{+} whereas the trend of anions was HCO^{-}_{3}>Cl^{-}>SO_4>NO_3.Overall water was estimated to be of $CaHCO^{-}_{3}$ type. Water quality index illustrated that all water samples were unsuitable for drinking purposes. Microbiological assessment showed that water is contaminated with coliform bacteria and fungal spores. Multivariate techniques were found to be ideal tools in identifying spatial variability through cluster analysis (CA) and reducing the dimensionality of huge data set through PCA/FA. It is briefly, concluded from the results of current study, that water of the study area was unsuitable for drinking purposes due to presence of some biological and chemical contaminants. Results recommend that developing efficient water quality monitoring programs, promoting ceramic filters technology, and raising awareness about the issue in communities are the most important steps that might help the people of the study area to resolve the problem.

HIGHLIGHTS

- Safe drinking water is the prerequisite to public health.
- Biological and chemical contaminants deteriorate the quality of drinking water.
- Water quality Index is an ideal tool in assessing the suitability of drinking water for human consumption.
- Multivariate techniques were ideal tools in determining spatial variability, minimizing the dimensionality of huge data sets and identifying the possible source of pollutants i.e. natural or anthropogenic.
- Regular monitoring of water quality is of dire importance for the safeguarding of the health of local communities and for the prevention of the further loss of water resources through different sources of contamination.

KEYWORDS

Sanitation, Water quality index, Cluster analysis, Multivariate techniques, Mortality.

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1. INTRODUCTION

Pollution of drinking water is global issues and its consequences on human health have been highlighted by several international organizations (Orosmarty et al., 2015). According to an estimate of World Health Organization, 900 million people each year suffer from waterborne diseases which are caused by various biological and chemical agents (WHO, 2015). The consumption of contaminated water ultimately leads to various health related issues that takes life of millions of people each year- majority of which are children (UN-Water, 2014). Based on the type of contaminants, the water pollution is categorized into: physical, chemical and biological water pollution. The change in the concentration of any constituents of water deteriorates the quality of water; by altering taste, color and odor of water samples.

The most problematic chemical contaminants that significantly influence the hydrochemistry of water of certain area are; Total Dissolved Solids, Nitrates, Fluoride, Heavy metals, Phosphate, Sulfate, Carbonates, Bicarbonates, Pesticides and Fertilizers, whereas the most hazardous microbiological contaminants are different types of bacteria, protozoan, viruses, and parasites (Kumar et al., 2016; Rasool et al., 2016; Nickson et al., 2005; Mahmood et al., 2016). Problems concerning water resources in developing countries always remained a challenging issue for management (Pandit et al., 2015; Guerrant et al., 2015). The major issues regarding water resources are; unavailability of safe drinking water due to water pollution, inadequate sanitation services and improper management of existing water resources (Shields et al., 2015). The main barriers that retard the potential of developing countries to deal with these problems are illiteracy, poverty, exponential population growth, ineffective policies and zero performance of institutions responsible for the conservation of water resources (Bhowmik et al., 2015).

The scenario of water pollution in Pakistan is not so different from other developing counties where the provision of safe drinking water is one of the leading problems, not more than 25% of population has easy access to safe drinking water (Neils, 2005; Batool et al., 2015). The major problems of water management in Pakistan are; water scarcity, water pollution, exponential population growth and urbanization, lack of wastewater treatment plants, inadequate water resources management system (Pak-EPA, 2005a; Brahman et al., 2016). The consumption of contaminated water is therefore major problem in the region, degrading the health of millions of people each year. Children are more prone to such water borne diseases (Rasool et al., 2016). In Pakistan, about 40% of communicable diseases are reported to be water borne diseases and 60 percent of child mortality is attributed to water borne diseases, the highest rate in Asia (UNDP, 2003; NIH, 2004).

The most common waterborne diseases associated with polluted water consumption include gastroenteritis, diarrhea, typhoid, cryptosporidium infections, intestinal worms, giardiasis, and some strains of hepatitis (Kazmi et al., 2015). In a study reported that 70% of water supplied by government authorities is contaminated with different chemical and biological agents, responsible for high rate of health disorders in the region (WWF, 2007). Lack of water disinfection treatments and regular water monitoring program are main culprits enhancing the intensity of problem (Ullah et al., 2014). Regular water quality monitoring is utmost priority of any environmental management program and essential for maintaining the water quality of any area. Quality of water is fragile component of environment that alters with passage of time and makes it crucial to assess the quality of water at regular intervals to ensure the safety of water for drinking purposes. Therefore, aim of the current study was to assess the suitability of water of study area for drinking purpose through an integrated approach of water quality index and multivariate analysis.

2. MATERIALS AND METHODS

2.1 Description of the study area

The state of Azad Jammu and Kashmir lies between longitude 73^{o} – 75^{o} and latitude 33^{o} – 36^{o} and comprises an area of 13,297 sq. km. According to the 1998 census, Azad Jammu & Kashmir had a population of 2.973 million, which has grown to 4.257 million in 2013. Azad Kashmir is divided into three divisions (Muzaffarabad, Poonch and Mirpur) and ten administrative districts with Muzaffarabad as the capital of the State. AJK falls within the Himalayan organic belt. As such, its topography is mainly hilly. The northern districts Neelum, Muzaffarabad, Hattian, Bagh, Haveli, Poonch, and Sudhnoti are generally mountainous while southern districts (Kotli, Mirpur, and Bhimber) are relatively plain. In the northern district 30% to 60% precipitation is in the form of snow (Baig et al., 2009). In winter snow line is around 1200 meters while in summer it is 3300 meters. Average maximum temperature ranges from 20°C to 32°C while the average minimum temperature range is 04°Cto 07°C (Pak – EPA, 2005b). District Poonch is divided into four subdivisions Rawalakot, Hajira, Thorar and Abbaspur.It is divided into 25 union councils, one municipal committee and 122 villages and has an area of 855 sq.Km. The current research study been conducted in Union Council Dhamni which is located at a height of 5200 feet from sea level (Kostyla et al., 2015; Ma et al., 2016).

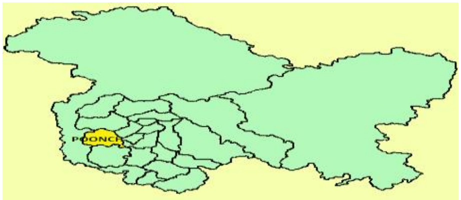

Figure 1: District, Poonch AJK, Pakistan

2.2 Water sampling

Twenty-four water samples were collected from various sources (Tap and spring) of Union Council Dhamni Poonch, Azad Jammu and Kashmir, Pakistan in 2015. Water from these sources is commonly used for different human consumption i.e. drinking, agriculture and domestic purposes in the study area (Singh et al., 2004). All the samples were collected in pre-sterilized and acid washed polyethylene bottles with three replicates. Some parameters like pH, EC and TDS were measured on spot with the help of portable multimeter. Samples were then immediately brought to the nearby laboratory at University of Poonch, Rawalakot Azad Kashmir for further analysis. Water samples were kept refrigerated at 4˚C prior to chemical analysis i.e. chlorides, sulphates, nitrates and phosphates (APHA, 1998). Samples for metals analysis were first acidified by adding 2ml of HCl (37%) and then filtered prior to the analysis by atomic absorption spectrophotometer.

2.3 Physicochemical analysis

2.3.1 Physical parameter

All the physical parameters were assessed following different standard analytical methods. Total hardness, bicarbonates and alkalinity were measured by employing APHA standard methods (APHA, 1998). Color of the samples was determined by sensory evaluation.

2.3.2 Chemical analysis

The concentration of chlorides, sulphates, nitrates and phosphates was determined by employing standard methods (APHA, 2005).The concentration of different metals (Ca, Na, Mg, Pb) was determined by Atomic Absorption Spectrophotometer (Mastoi et al., 2008).

2.4 Biological parameters

For the biological analysis, three different biological parameters i.e. Fungal load, Total Bacterial load (MPN) and Total Coliforms as Colony Forming Units (CFU) were tested according to standard methods recommended (WHO 2004). The presence of fungus species was confirmed through Sabouraued Dextrose Broth by autoclaving the prepared media and poring it in sterilized petriplates. The plates were incubated at 37˚C for 24- 48 hours. The total bacterial load was counted using Tryptone soy broth that allowed the growth of a number of bacteria. The total Coliform were assessed through, two agars i.e.Macckonkey Agar and Eosine Methylene blue Agar. These were used to differentiate Lactose fermenting and Non-lactose fermenting bacteria employing streak plate method.

2.5 Water Quality index (WQI)

Water quality index is one of the most valuable tools to attain a clear picture of the quality of the water. Water quality index is widely used to determine the suitability of water for human consumption especially for drinking purpose (Sahu and Sikdar, 2008). It is important in denoting the integrated effects of various physicochemical parameters on the quality of water (Sadashiviah et al., 2008). Water quality index relates a set of water quality determinants to a common scale and then computes the values to a single number according to standard method (Ramesh and Elango, 2011). Water quality index is calculated following three key steps:

In the first step, weight is assigned to the most important parameter having vital role in deteriorating the overall quality of water for human consumption i.e. drinking and domestic purposes. In the current study water quality index has been calculated considering the ten (10) key physicochemical parameter that included pH, EC, TDS, HCO_3, Cl^-, SO_4, NO_3, Ca, Mg, Na and Pb. Depending upon their relative importance in effecting the water quality, weight (wi) was assigned to each studied parameter based on this criteria, number 5 was assigned to TDS and NO_3 due to their main role in water quality determination. Mg was allotted with number1 due to its less importance in affecting water quality (Logeshkumaran et al., 2014).

1. The relative weight (Wi) was determined by following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}, \qquad (1)$$

Whereas "Wi" is the relative weight, "wi" is the weight of each individual parameter and "n" is the number of parameters.

2. In the 2ndstep a quality rating scale (qi) was developed by dividing the observed concentration of each parameter by its respective WHO standard and then multiplying the result by 100.

$$q_i = (C_i/S_i) \times 100 \qquad (2)$$

Whereas "Ci" is the observed concentration of each parameter and "Si" are WHO standards

3. In the final stage of WQI, SI was determined for each water quality parameter by multiplying Relative weight with quality rating scale. The sum of SI is equivalent to the water quality index.

$$\mathrm{SI} = W_i q_i \qquad (3)$$

$$\mathrm{WQI} = \sum \mathrm{SI}_i \qquad (4)$$

2.6 Statistical analysis

Multivariate analysis of water quality data set was performed through PCA/FA and CA techniques using XLSTAT 2015, package for Microsoft Office. These techniques enable the identification of the natural and anthropogenic sources of components/pollutants. These also help to determine the possible interrelationships among the variables. PCA and CA techniques are widely used by many researchers to establish the possible relationship between the polluting agents and their sources. In PCA, Eigen values are of great importance illustrating the associated variance due to different elements in data set.

3. Results and Discussion

3.1 Physicochemical analysis

The results from descriptive statistics of physicochemical parameters of water are summarized in Table 1. The results from this study indicate that the concentration of all the studied parameters except lead was within safe range of WHO. However, the concentration of copper was below the detection limits in all studied water samples therefore it was not included in the results. On the basis of the physicochemical analysis it was concluded that the water of the study area was slightly alkaline in nature. The high concentration of lead in the water samples of study area might be attributed to the supply of water through leaded water pipes and vehicular emissions. This study also justified that human innervations are the major problem in degrading the quality of environment (Memon et al., 2011). The abundance of cations in study area were in order of, Ca^{2+}> Mg^{2+}> Na^+ whereas the abundant anions in water samples were in order of, HCO^-_3>Cl^- >$SO^2{}_4$>NO^-_3 (Figure 2). The high concentration of $Ca^{2+}$and possible source of minerals may be attributed to weathering of rocks in the study area.

The high concentration of HCO^-_3in the study area might be due to the percolation of water through HCO^-_3rocks i.e. dolomite and limestone. The solubility of $CaCO_3$ and Na_2CO_3in the water is also the main factor that might influence the concentration of HCO_3 in water. The high concentration of cations i.e. Ca^{2+} and Mg^{2+} and anions such as bicarbonate, carbonate, chloride and sulphate impart hardness to water (Al-Ahmadi and El-Fiky, 2009). Hardness of water is classified into two i.e. permanent hardness and temporary hardness. Temporary hardness is caused due to the abundance of Ca^{2+} and HCO^-_3 (Ravikumar et al., 2011). The water of the study area was found to be of $CaHCO^-_3$ type and showed temporary hardness based on the abundance of ions. Temporary hardness is not so problematic and can be removed by boiling of water (Trivedy and Goel, 1986).

Table 1: Descriptive statistics of physicochemical analysis of water samples of Study area

Variable	Range	Mean	WHO Standards
Color	colorless	-	-
Temperature	12-18	15.9	-
PH	6.3 - 7.4	6.84	6.5 - 8.5
EC(micro-S/cm)	32 -554	293.8	500
TDS mg/l	21-443	254.1	500
Cl^- mg/l	5.1-15	10.52	250
Total Hardness(mg/l)	10.2 -349	190.4	500
HCO^-_3mg/l	6.4- 338	152.5	500
SO_4mg/l	1 -16.3	8.6	250
NO_3mg/l	0.5-4	2.43	45
$PO^{2-}{}_4$mg/l	0.03-2	0.9	0.1 -1
Ca^{2+}mg/l	2.1 -89	46.4	75
Mg^{2+}mg/l	1-87.4	45.8	50
Alkalinity(m.mol/l	6.4- 338	152.5	120
Pb mg/l	0.13- 0.51	0.4	0.01
Na^+mg/l	22.1- 74	45.1	200

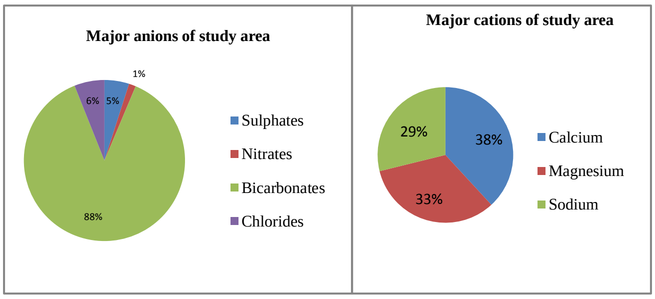

Figure 2: Dominance of anions and cations in water of the study area

3.2 Biological analysis

Concerns over the prevalence of different pathogenic organism in the drinking water is one of the alarming issue in the developing countries especially in Pakistan (Hashmi et al., 2009).This issue has been highlighted in different forms in Pakistan and the presence of microbial organisms are regarded as one of the major agents deteriorating the quality of potable water and great risk to the health of common people (Memon et al., 2011). These biological pollutants are most common cause of water borne diseases in developing countries, resulting in deaths of millions of people due to drinking unsafe water.

Selected water samples were investigated for the presence of microbial contamination and were found positive for the presence of coliform bacteria (Enterobactereacae family) Table 2. The national standard of drinking water quality of Pakistan propose that coliform test for water quality must be negative. The total bacterial count from the bacterial colony gave a maximum value of 70 colonies (Figure 3) in the studied water samples which were quite less than the studies reported in the same area where the maximum number of colonies reported were 600 (Hussain, 2010). The presence of coliform bacteria represents biological contamination, as it is regarded as water quality indicator (Ali et al., 2015). The results of test conducted for the presence of fungal spores, were also positive for about (66.66%) of water samples Table 3.

The main source of water contamination due to fungal spores might be due to airborne spores. The presence of fungal spores in the drinking water might degrade the health of people and its effects depend upon the individual's vulnerability and it may cause allergic reactions in individuals with a weak immune system. However no national or international standards are followed for analysis of fungi in drinking water. Most commonly found fungal species in water are *Aspergillus*, *Cladosporium Penicillium*etc (Paterson and Lima, 2005). Ample literature exists which showed that biological contamination is associated with different health disorders i.e. gastroenteritis (Smith et al., 2000; Hageskal et al., 2009; Al-Gabr et al., 2014). The results of current study are in line with several other studies carried out in other parts of the region and support that biological contamination is great risk to the health of communities (Oyedeji et al., 2010; Aamir et al., 2015).

Table 2: Total coliform count in Colony forming Units (CFU) per mL

No.	Sample Code	CFU/mL	CFU/100mL
1.	SW_1	5.2 x 10^3	5.2 x 10^5
2.	SW_2	1.8 x 10^4	1.8 x 10^6
3.	SW_3	2.2 x 10^3	2.2 x 10^5
4	SW_4	4 x 10 ^{2}	4 x 10^4
5	SW_5	8.3 x 10^3	8.3 x 10^5
6.	SW_6	2 x 10^2	2 x 10^4
7.	SW_7	0.8 x 10^2	0.8 x 10^4
8.	SW_8	8.4 x 10^3	8.4 x 10^5
9	SW9	5.1 x 10^2	5.1 x 10^5
10	SW10	3.2 x 10^2	3.1 x10^3
11	SW11	5.5 x 10^5	5.5 x10^6
12	SW12	6.2 x10^6	7.7 x10^5
13	SW13	4.5 x10^5	6.5 x10^3
14	SW14	4.2 x10^3	5.4 x10^5
15	SW15	2.1 x10^5	3.8 x10^6
16	SW16	5.7 x10^5	4.7 x10^5
17	SW17	4.8 x10^3	6.5 x10^5
18	SW18	3.9 x10^2	7.4 x10^5
19	SW19	2.6 x10^5	6.4 x10^4
20	SW20	5.6 x10^4	7.9 x10^2
21	SW21	6.6 x10^5	7.6 x10^5
22	SW22	5.3 x10^6	4.5 x10^4
23	SW23	4.5 x10^2	5.6 x10^5
24	SW24	5.6 x10^5	3.8 x10^6

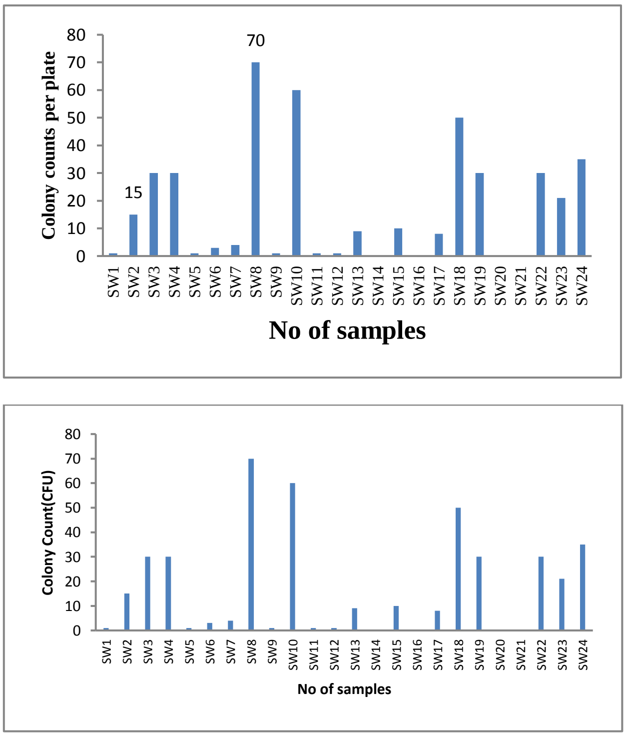

Figure 3: Total number of colonies per plate

Table 3: Sabouraud Dextrose Agar (SDA)Fungal Test

No.	Samples code	Observation	No.	Samples code	Observation
1.	SW1	+	13	SW13	+
2.	SW2	+	14	SW14	+
3.	SW3	+	15	SW15	-
4.	SW4	-	16	SW16	-
5.	SW5	+	17	SW17	-
6.	SW6	-	18	SW18	+
7.	SW7	+	91	SW19	+
8.	SW8	+	20	SW20	+
9.	SW9	-	21	SW21	+
10.	SW10	-	22	SW22	+
11.	SW11	-	23	SW23	+
12.	SW12	+	24	SW24	+

3.3 Spatial Variations

Cluster analysis was performed on the collected data set in order to evaluate spatial variation among different study sites .According to cluster analysis, the whole data set is distributed in to three main classes (Figure 4) i.e. class 1includes sample (SW1, SW2, SW3, SW4, SW5, SW6, SW7, SW8, SW9, SW10, SW11, SW12, SW14, SW16), class 2 includes (SW13, SW15),whereas the class 3 includes sample (SW17-Sw24). The cluster analysis was based on similarity among the studied water samples. In this analysis similar objects are grouped into one class. This technique is widely used to study spatial variation among different sites and similar sites exhibit similar hydrochemistry (Ayoko et al., 2007; Krishna et al., 2009).

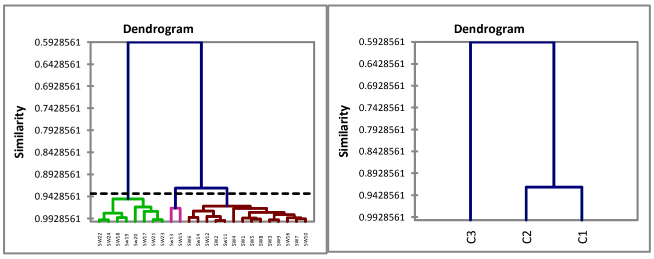

Figure 4: Dendrogram showing spatial variability of water of study area

3.4 Principal component analysis (PCA)

The function of PCA is to reduce the dimensionality of huge data set. PCA technique is routinely used to classify the important parameters of water which greatly influence the quality of water and also used to determine the sources of various pollutants (Singh etal.2004; Ma et al. 2016).PCA distributes the whole data set in to different components i.e. factors. The components explain the degree of variance in the data set. The results of current study for PCA analysis are presented in Table (4) for different physicochemical parameters. Water samples of the study were grouped into five (5) factors that stood for about 92 % variation in data set (Table 5). The F_1 represented **(**64.69%) of total variance and regarded as one of the most important component in the current data. The main parameters responsible for great variance in F_1 factors were EC(0.97),TDS(0.974),Cl(0.922),totalhardness(0.95),SO_4(0.97),$PO^3{}_4$(0.80), Ca(0.97),Mg^{2+}(0.95),alkalinity(0.94)and Na^+(0.790).

F1 factor described that physicochemical parameters, the main attributors of variations in the water quality of the study area. The main source of different minerals (Ca, Mg, Na) in the water samples of study area were parent rock materials i.e. earth crust. Parent rock material might be rich in Ca^{2+}, Mg^{2+},Na^+ types minerals (Krishnaswami and Singh, 2005; Panda et al., 2006; Qadir et al., 2008). The parameters in F1 were interlinked to one another due to similar sources such as natural sources and some anthropogenic sources. The F_2 explained about 10.62 % of total variance. The main dominating parameters in F_2were temperature (-0.65) and Pb (0.7). Temperature may be another crucial parameter effecting the solubility of different minerals in water. The main source of lead in drinking water is the plumbing system consisting of pipes, fitting material and solder. Water supplied through these leaded pipes might be one of the major sources of lead in drinking water (Raviraja et al., 2008; Azizullah et al., 2011).

The other sources such as vehicular emission and the use of lead batteries may also accounts for degrading the quality of water (Nadeem-ul-Haq et al., 2009). The $F_3$was responsible for 6.7% of total variance in data. The contributing parameter responsible for variance in F3 was NO_3(0.61). The main sources of nitrates in the study area were natural deposits of nitrates and some other anthropogenic sources such as fertilizers ,manures and septic tanks which were widely used for agricultural purposes. Nitrates from such sources get their way into drinking water making unfit for usage (Qadir et al., 2008). The $F_4$was responsible for 6.04% variation and the major contributing parameter for variance was pH(0.805%).pH is important parameter influencing the geochemistry of water. The F5 was not so important in terms of data variation (4.46%). Scree plot showed the overall Eigen values and cumulative variability of the studied physicochemical parameters (Figure 5).

Table 4: Factor loading of PCA

	F_1	F_2	F_3	F_4	F_5
Temperature	0.503	**-0.648**	0.315	-0.098	0.275
pH	-0.450	-0.111	0.291	**0.805**	-0.161
EC	**0.965**	-0.028	-0.021	0.029	0.020
TDS	**0.974**	0.070	0.112	-0.009	-0.006
CL	**0.922**	0.053	0.122	0.049	-0.253
Total Hardness	**0.950**	0.084	-0.130	0.110	-0.117
HCO_3	**0.944**	0.027	-0.208	0.138	-0.084
SO_4	**0.907**	0.110	-0.207	-0.074	-0.058
NO_3	0.660	0.156	**0.612**	0.085	0.191
PO43−	**0.805**	0.033	0.168	-0.123	0.311
Ca^{2+}	**0.973**	0.019	0.005	-0.040	-0.054
Mg^{2+}	**0.949**	-0.031	0.062	0.044	-0.101
Alkalinity	**0.944**	0.027	-0.208	0.138	-0.084
pb	0.273	**0.700**	0.452	-0.295	-0.315
Na^+	**0.790**	0.034	-0.189	0.276	0.476

Table 5: The Eigen values and the cumulative variability of five main factors of PCA

	F1	F2	F3	F4	F5
Eigen value	9.703	1.593	1.005	0.906	0.670
Variability (%)	64.685	10.620	6.701	6.038	4.465
Cumulative %	64.685	75.306	82.007	88.044	92.509

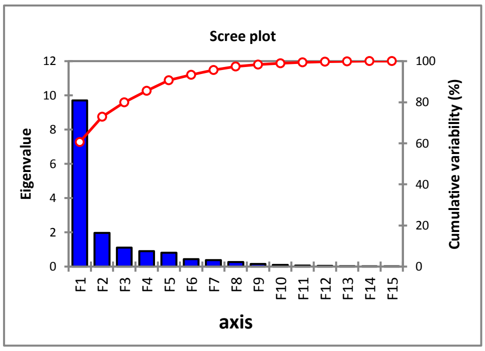

Figure 5: Scree plot showing the Eigen values (Histogarm) and cumulative variability (marked line) of physicochemical parameters of the study area

3.4 Correlation matrix (Pearsons)

The results of PCA were further supported by correlation matrix analysis Table 6.The result of correlation matrix (Pearsons Correlation) confirmed positive relationship among important water quality parameters i.e. temperature and EC,TDS, Cl^-, total hardness, HCO_3, SO^{2-}_4, PO_4^{3-},Ca^{2+},Mg^{2}+,alkalinity,conductivityand TDS were considered to be important water quality parameters because these provide a practical estimation of dissolved mineral content (Hussain, 2010). Results also demonstrated that there is strong correlation between Cl^-,Ca^{2+},Mg^{2+} ,SO^{2-}_4.it might be due to similar source like parent material. Similar results were also obtained by other researchers (Ghislain et al., 2012). Results of correlation showed that physicochemical parameters are important in effecting the quality of water i.e. TDS, EC, nitrates, phosphates and sulphate (Kazi et al., 2009; Muhammad et al., 2010).

Table 6: Correlation matrix of the studied parameters of studied water samples

Variables	Temperature	pH	EC	TDS	CL^-	Total. Hardness	HCO_3	SO^{2-}_4	NO_3	PO43−	Ca^{2+}	Mg^{2+}	Alkalinity	pb	Na^+
Temperature	**1**														
pH	-0.184	**1**													
EC	**0.516**	-0.395	**1**												
TDS	**0.500**	-0.417	**0.939**	**1**											
CL^-	0.426	-0.316	**0.868**	**0.931**	**1**										
Total Hardness	0.343	-0.384	**0.895**	**0.910**	**0.908**	**1**									
HCO_3	0.356	-0.374	**0.903**	**0.897**	**0.854**	**0.951**	**1**								
SO_4	0.336	**-0.519**	**0.871**	**0.876**	**0.857**	**0.889**	**0.861**	**1**							
NO_3	0.408	-0.143	**0.572**	**0.707**	**0.651**	**0.574**	**0.510**	0.484	**1**						
PO_4^{3-}	0.417	-0.421	**0.795**	**0.789**	**0.631**	**0.675**	**0.684**	**0.647**	**0.644**	**1**					
Ca^{2+}	0.469	-0.450	**0.935**	**0.944**	**0.899**	**0.911**	**0.906**	**0.883**	**0.607**	**0.787**	**1**				
Mg^{2}	0.471	-0.348	**0.941**	**0.902**	**0.874**	**0.894**	**0.890**	**0.807**	**0.618**	**0.762**	**0.959**	**1**			
Alkalinity	0.356	-0.374	**0.903**	**0.897**	**0.854**	**0.951**	**1.000**	**0.861**	**0.510**	**0.684**	**0.906**	**0.890**	**1**		
pb	-0.448	0.007	-0.281	-0.156	-0.106	-0.265	-0.338	-0.233	0.060	-0.188	-0.214	-0.225	-0.338	**1**	
Na^+	-0.371	-0.015	0.042	0.071	-0.031	0.098	0.083	0.121	0.112	0.065	0.017	-0.039	0.083	0.248	**1**

3.5 Water quality index (WQI)

The appropriateness of water of Union Council Dhamni, Poonch, Azad Jammu and Kashmir for drinking purposes was evaluated through water quality index (WQI). WQI is an ideal tool needed for assessment of the water quality of an area. In the present study water quality index (WQI) was established from most important water physicochemical parameters Table 8. The results of study demonstrated that water quality index ranges from 101- 682 Table 9. The water quality index clearly depicted that water of the study is unsuitable for human consumption. The unsuitability of water for drinking purposes might be due to the presence of high concentration of lead and minerals from the weathering of rocks and parent material. Similar observation has also been made by various other researchers depicting that the main offender for deteriorating the water quality of certain area are anthropogenic activities carried out at different catchment areas of main water resources (Shabbir and Ahmed, 2015; Hou et al., 2016; Abtahi et al., 2016). The use of water quality index is desirable for assessing the trend of variations in water quality for various management purposes.

Table 7: Water classification according to water quality index

Water quality value	Category
< 50	Excellent
50-100	Good
100-200	Poor
200-300	very poor
> 300	Unsuitable for drinking

Table 8: Relative weight of parameters of the study area

Name of parameter	WHO standards (2004)	Weight (wi)	Relative weight(Wi)
pH	6.5 - 8.5	4	0.12
EC (lS/cm	500	4	0.12
TDS (mg/l)	500	5	0.151
HCO_3 (mg/l)	500	3	0.09
Cl^- (mg/l	250	3	0.09
SO_4 (mg/l)	250	4	0.12
NO_3 (mg/l)	45	5	0.151
Ca (mg/l)	75	2	0.06
Mg (mg/l	50	1	0.03
Na (mg/l)	200	2	0.06
Pb(mg/l)	0.01	5	0.13
		$\sum$ wi = 33	$\sum$Wi = 1.01

Table 9: Water quality index (WQI) of the study area

No of sample	Water quality Index(WQI)	Status of water quality
1	442.8	Unsuitable for drinking
2	423	Unsuitable for drinking
3	527	Unsuitable for drinking
4	553e	Unsuitable for drinking
5	101	poor
6	553	Unsuitable for drinking
7	549	Unsuitable for drinking
8	213	Very Poor
9	563	Unsuitable for drinking
10	341	Unsuitable for drinking
11	488	Unsuitable for drinking
12	589	Unsuitable for drinking
13	546	Unsuitable for drinking
14	583	Unsuitable for drinking
15	432	Unsuitable for drinking
16	682	Unsuitable for drinking
17	455	Unsuitable for drinking
18	434	Unsuitable for drinking
19	429	Unsuitable for drinking
20	561	Unsuitable for drinking
21	547	Unsuitable for drinking
22	391	Unsuitable for drinking
23	508	Unsuitable for drinking
24	495	Unsuitable for drinking

4. Conclusion

In the current research suitability of water for human consumption in the study area was checked through the application of Water Quality Index and was found to be an ideal tool in summarizing the effect of different water quality parameter, in one unit, on the overall quality of drinking water. Source determination and spatial variability was further assessed through multivariate analysis. The results from chemical analysis revealed that concentration of all studied parameters were within the permissible limits of WHO except lead. The results for the microbial parameters confirmed biological contamination as all water samples were positive for coliform test, total microbial load and fungal test. Water quality index results showed that water of the study area was unsuitable for drinking purposes. Multivariate techniques were ideal tools in determining spatial variability, minimizing the dimensionality of huge data sets and identifying the major source of pollutants i.e. natural or anthropogenic. Keeping in mind the importance of biological and chemical contaminants in deteriorating the quality of drinking water, it is the need of hour to educate the people about the health hazards of unsafe contaminated drinking water.The local people should be trained in water treatment practices that are easy to be carried out at home level such as boiling of water at high temperature, chlorination and the use of ceramic filters. Regular monitoring of water quality is also strongly recommended through proper assessment techniques not only for the safeguarding of the health of local communities but also to prevent the further loss of water resources through different sources of contamination.

References

Aamir, A., Moazzam, A.K., Palwisha, A., Maha, L., Khalid, M., Syed, S.S., Khadija, K., 2015. Occurrence of Fecal Contamination in Drinking Water available in municipal hospitals in Karachi, Pakistan. Bulletin of *Environment*, *Pharmacology* and *Life Sciences*, 4 (5), 116-123.

Abtahi, M., Yaghmaeian, K., Mohebbi, M.R., Koulivand, A., Rafiee, M., Jahangiri-rad, M., Oktaie, S., 2016. An innovative drinking water nutritional quality index (DWNQI) for assessing drinking water contribution to intakes of dietary elements: A national and sub-national study in Iran. Ecological Indicators, 60, 367-376.

Al-Ahmadi, M.E., El-Fiky, A. A., 2009. Hydrogeochemical evaluation of shallow alluvial aquifer of Wadi Marwani, western Saudi Arabia. Journal of King Saud University-Science, 21(3), 179-190.

Al-Gabr, H.M., Zheng, T., Yu, X., 2014. Fungi Contamination of Drinking Water. In Reviews of Environmental Contamination and Toxicology, 228, 121-139. Springer International Publishing.

Ali, J., Hassan, S., Rahman, I.U., Abbas, S., Ullah, S., 2015. Bacteriological Quality of Drinking Water in Mardan, Khyber Pakhtunkhwa, Pakistan. Ecoprint: An International Journal of Ecology, 21, 1-6.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 18th edn. MWWA&WPCF, Washington.

APHA. 2005. Standard methods for the examination of water and wastewater. Washington: American Public Health Association.

Ayoko, G.A., Singh, K., Balerea, S., Kokot, S., 2007. Exploratory multivariate modeling and prediction of the physico-chemical properties of surface water and groundwater. Journal of Hydrology, 336 (1), 115-124.

Azizullah, A., Khattak, M.N.K., Richter, P., Häder, D.P., 2011. Water pollution in Pakistan and its impact on public health—a review. Environment International, 37 (2), 479-497.

Baig, J.A., Kazi, T.G., Arain, M.B., Afridi, H.I., Kandhro, G.A., Sarfraz, R.A., Shah, A.Q., 2009. Evaluation of arsenic and other physico-chemical parameters of surface and ground water of Jamshoro, Pakistan. Journal of hazardous materials, 166(2), 662-669.

Batool, Z., Anjum, F., Faiz, S., Akram, M., Ibrahim, M., 2015. Household Perspectives towards Integrated Management of Drinking Water in Faisalabad District, Punjab, Pakistan. Mediterranean Journal of Social Sciences, 6 (5), 503.

Bhowmik, A.K., Alamdar, A., Katsoyiannis, I., Shen, H., Ali, N., Ali, S. M., Eqani, S.A.M.A.S., 2015. Mapping human health risks from exposure to trace metal contamination of drinking water sources in Pakistan. Science of The Total Environment, 538, 306-316.

Brahman, K.D., Kazi, T.G., Afridi, H.I., Baig, J.A., Arain, S.S., Talpur, F.N., Arain, M.B., 2016. Exposure of children to arsenic in drinking water in the Tharparkar region of Sindh, Pakistan. Science of The Total Environment, 544, 653-660.

Ghislain, J.Y.A., Roger, F., Joseph, W., Emmanuel, G.E., Ghislain, M.D., 2012. Evaluation of Groundwater Suitability for Domestic and Irrigational Purposes: A Case Study from Mingoa River Basin, Yaounde, Cameroon. Journal of Water Resource and Protection, 4 (5), 9.

Guerrant, R.L., Moore, S.R., Lima, A.A., 2015. Safe drinking water: An attainable goal key to health and development appears farther away [editorial]. International Journal of Infectious Diseases, 4 (1), 1-2.

Hageskal, G., Lima, N., Skaar, I., 2009. The study of fungi in drinking water. Mycological research, 113 (2), 165-172.

Hashmi, I., Farooq, S., Qaiser, S., 2009. Chlorination and water quality monitoring within a public drinking water supply in Rawalpindi Cantt (Westridge and Tench) area, Pakistan. Environmental monitoring and assessment, 158 (1-4), 393-403.

Hou, W., Sun, S., Wang, M., Li, X., Zhang, N., Xin, X., Jia, R., 2016. Assessing water quality of five typical reservoirs in lower reaches of Yellow River, China: Using a water quality index method. Ecological Indicators, 61, 309-316.

Hussain, T., Hussain, A., Sultana, K., 2011. Study of drinking water fungi and its pathogenic effects on human beings from district Bhimber Azad Kashmir, Pakistan. Pakistan Journal of Botany, 43(5), 2581-2585.

Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Shah, A.Q., 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. Ecotoxicology and Environmental Safety, 72 (2), 301-309.

Kazmi, M., Hayder, S., Rashid, H., Rustam, M., Sulheri, A.W., Saeed, A., 2015. Evaluation of Drinking water quality parameters in the areas of East-Lahore Pakistan: A case study. Journal of Faculty Of Engineering & Technology, 21(3), 41-61.

Kostyla, C., Bain, R., Cronk, R., Bartram, J., 2015. Seasonal variation of fecal contamination in drinking water sources in developing countries: A systematic review. Science of The Total Environment, 514, 333-343.

Krishna, A.K., Satyanarayanan, M., Govil, P.K., 2009. Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: a case study from Patancheru, Medak District, Andhra Pradesh, India. Journal of hazardous materials, 167(1), 366-373.

Krishnaswami, S., Singh, S.K., 2005. Chemical weathering in the river basins of the Himalaya, India. Current Science, 89, 841–849

Logeshkumaran, A., Magesh, N.S., Godson, P.S., Chandrasekar, N., 2014. Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. Applied Water Science, 1-9.

Ma, X., Zuo, H., Tian, M., Zhang, L., Meng, J., Zhou, X., Liu, Y., 2016. Assessment of heavy metals contamination in sediments from three adjacent regions of the Yellow River using metal chemical fractions and multivariate analysis techniques. Chemosphere, 144, 264-272.

Mahmood, K., Ul-Haq, Z., Batool, S.A., Rana, A.D., Tariq, S., 2016. Application of temporal GIS to track areas of significant concern regarding groundwater contamination. Environmental Earth Sciences, 75(1), 1-11.

Mastoi, G.M., Shah, S.G.S., Khuhawar, M.Y., 2008. Assessment of water quality of Manchar Lake in Sindh (Pakistan). Environmental monitoring and assessment, 141(1-3), 287-296.

Memon, M., Soomro, M.S., Akhtar, M.S., Memon, K.S., 2011. Drinking water quality assessment in Southern Sindh (Pakistan). Environmental monitoring and assessment, 177(1-4), 39-50.

Memon, M., Soomro, M.S., Akhtar, M.S., Memon, K.S., 2011. Drinking water quality assessment in Southern Sindh (Pakistan). Environmental monitoring and assessment, 177(1-4), 39-50.

Muhammad, S., Shah, M.T., Khan, S., 2010. Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan. Food and Chemical Toxicology, 48(10), 2855-2864.

Nadeem-ul-Haq, Arain, M.A., Haque, Z., Badar, N., Mughal, N., 2009. Drinking water contamination by chromium and lead in industrial lands of Karachi. J. Pak. Med. Assoc., 59, 270–274.

Neils, R., 2005. Drinking water crisis in Pakistan and issue of bottled water. The case of Nestlé's Pure Life. Pakistan: Swiss Coalition of Development Organizations. ActionAid (ed),(Islamabad: ActionAid Pakistan).

Nickson, R.T., McArthur, J.M., Shrestha, B., Kyaw-Myint, T.O., Lowry, D., 2005. Arsenic and other drinking water quality issues, Muzaffargarh District, Pakistan. Applied Geochemistry, 20 (1), 55-68.

NIH. 2004. Survey by the 'Network'. Islamabad: National Institute of Health (NIH).

Orosmarty, C.J., Hoekstra, A.Y., Bunn, S.E., Conway, D., Gupta, J., 2015. Fresh water goes global. Science, 349 (6247), 478-479.

Oyedeji, O., Olutiola, P.O., Moninuola, M.A., 2010. Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria. African Journal of Microbiology Research, 4, 96-102.

PAK-EPA. 2005. State of Environment Report 2005. Pakistan Environmental Protection Agency (Pak-EPA). Govt. of Pakistan, Islamabad, Pakistan: Ministry of Environment.

Pak-EPA. 2005. Investigation of drinking water quality of water filtration plants installed at slamabad and Rawalpindi. Case Study. Pakistan Environment Programme (PEP) Component. Ministry of Environment, Islamabad Pakistan.

Panda, U., Rath, P., Sahu, K., Majumdar, S., Sundaray, S., 2006. Study of geochemical association of some trace metals in the sediments of Chilikalake: A multivariate statistical approach. Environmental Monitoring and Assessment, 123, 125–150.

Pandit, A.B., Kumar, J.K., 2015. Clean Water for Developing Countries. Annual Review of Chemical and Biomolecular Engineering, 6(1).

Paterson, R.R.M., Lima, N., 2005. Fungal contamination of drinking water. Water Encyclopedia.

Qadir, A., Malik, R.N., Husain, S.Z., 2008. Spatio-temporal variations in water quality of NullahAik-tributary of the river Chenab, Pakistan. Environmental Monitoring and Assessment, 140(1-3), 43-59.

Qadir, A., Malik, R.N., Husain, S.Z., 2008. Spatio-temporal variations in water quality of NullahAik-tributary of the river Chenab, Pakistan. Environmental Monitoring and Assessment, 140 (1-3), 43-59.

Ramesh, K., Elango, L., 2011. Ground water quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. Environmental Monitoring and Assessment, 184 (6), 3887–3899.

Rasool, A., Farooqi, A., Masood, S., Hussain, K., 2016. Arsenic in groundwater and its health risk assessment in drinking water of Mailsi, Punjab, Pakistan. Human and Ecological Risk Assessment: An International Journal, 22(1), 187-202.

Ravikumar, P., Somashekar, R.K., Angami, M., 2011. Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India. Environmental Monitoring and Assessment, 173(1–4), 459– 487.

Raviraja, A., Babu, G.N.V., Bijoor, A.R., Menezes, G., Venkatesh, T., 2008. Lead toxicity in a family as a result of occupational exposure. Archives of Industrial Hygiene and toxicology, 59, 127–33.

Sadashiviah, C., Ramakrishnaiah, C.R., Ranganna, G., 2008. Hydrochemical analysis and evaluation of groundwater quality in Tumkur Taluk, Karnataka State, India. International Journal of Environmental Research and Public Health, 5 (3), 158–164.

Sahu, P., Sikdar, P.K., 2008. Hydrochemical framework of the aquifer in and around East Kolkata Wetlands, West Bengal, India. Environmental Geology, 55(4), 823-835.

Shabbir, R., Ahmad, S.S., 2015. Use of Geographic Information System and Water Quality Index to Assess Groundwater Quality in Rawalpindi and Islamabad. Arabian Journal for Science and Engineering, 1-15.

Shields, K.F., Bain, R.E., Cronk, R., Wright, J.A., Bartram, J., 2015. Association of supply type with fecal contamination of source water and household stored drinking water in developing countries: A bivariate meta-analysis. Environmental health perspectives, 1-49.

Singh, K.P., Malik, A., Mohan, D., Sinha, S., 2004. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)—a case study. Water research, 38 (18), 3980-3992

Smith, A. H., Lingas, E.O., Rahman, M., 2000. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. Bulletin of the World Health Organization, 78 (9), 1093-1103.

Trivedy, R.K., Goel, P.K., 1986. Chemical and Biological methods for water pollution studies, Environmental Publication, Karad.

Ullah, S., Javed, M.W., Shafique, M., Khan, S.F., 2014. An integrated approach for quality assessment of drinking water using GIS: A case study of Lower Dir. Journal of Himalayan Earth Sciences, 47 (2), 163-174.

UNDP. 2003. Pakistan National Human Development Report, "Water Crisis", Karachi, 7 – 103.

UN-Water. 2014. The United Nations Inter-Agency Mechanism on all Freshwater Related Issues, Including Sanitation. [Online] available: http://www.unwater.org/statistics/statistics-detail/fi/c/ 211800/.

WHO. 1992. International standards for drinking water. Geneva: World Health Organization.

WHO. 2004. Acceptability aspects. In Guidelines for Drinking Water Quality ed. Chapter 10 World Health Organization. Geneva. Retrieved from http://www.who.int/water_sanitation_health/dwq/guidelines3rd/en/ accessed at 25th Nov, 2016 .

WWF. 2007. Pakistan's water at risk. Water and health related issues in Pakistan and key recommendations. Fresh Water & Toxics Program, Worldwide Federation, Pakistan.

WHO. 2015. Antimicrobial Resistance: An Emerging Water, Sanitation and Hygiene Issue.retrieved from http://www.who.int/water_sanitation_health/emerging/WASH_AMR/en/ retrieved at 25th Nov,2016.

Kumar, M., Rahman, M.M., Ramanathan, A.L., Naidu, R., 2016. Arsenic and other elements in drinking water and dietary components from the middle Gangetic plain of Bihar, India: Health risk index. Science of The Total Environment, 539, 125-134.

Rasool, A., Farooqi, A., Masood, S., Hussain, K., 2016. Arsenic in groundwater and its health risk assessment in drinking water of Mailsi, Punjab, Pakistan. Human and Ecological Risk Assessment: An International Journal, 22(1), 187-202.