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Assessment of drinking water quality in Narangi and surrounding areas of district Swabi, Pakistan

Muhammad Tariq[1], Sardar Khan[2], Liaqat Ali[1], Seema Anjum Khattak[1], Khalid Latif[1] Rahib Hussain[1] and Saeeda Yousaf[2]

[1]National Centre of Excellence in Geology, University of Peshawar

[2]Department of Environmental Sciences, University of Peshawar

Abstract

Contaminated drinking water is the main cause of many health problems in different regions of the world and is responsible for serious diseases such as nervous system damages, kidney failure and stomach cancer. This study was conducted to investigate the quality of drinking water sources present in Narangi and its surrounding areas (Permooli, Merali and Sherdarra). Water samples were collected from different sources (dug wells, tube wells, hand pumps and springs) in the study area and analyzed for physico-chemical parameters and toxic metal concentrations. Physical parameters such as pH, Electric conductivity, total dissolved salts turbidity, and temperature were determined with the help of electro-chemical analyzer on the spot, while anions including nitrate, nitrite, sulfate, phosphate and chloride were determined using spectrophotometer HACH (DR2800). Heavy metals such as copper (Cu), Nickel (Ni), cadmium (Cd), cobalt (Co), chromium (Cr), zinc (Zn), lead (Pb), manganese (Mn) and iron (Fe) were determined using atomic absorption Perkin Elmer (AAnalyst-700). Among the toxic metals Pb was found above the WHO permissible limits, while in physic-chemical parameters nitrite was found above the WHO standard. It is concluded that drinking water of Narangi and its surrounding areas could pose potential health risk due to Pb and NO_3 presence. We strongly recommend further detail study for drinking water sources in the adjacent areas as well as the installation of water treatment plants in the Naranji area to protect the local population from serious health hazards.

Keywords: Drinking water quality; Heavy metals; Health hazard; Swabi; Pakistan.

1. Introduction

Drinking water pollution either due to heavy metals (HM) or other different chemical elements has become the matter of concern for environmental scientists of the recent years. Water contamination with various chemicals and heavy metals, released from different anthropogenic sources has become a global issue (Rapant and Krcmova, 2007). Weathering, erosion of rocks, mining, industries, wastewater irrigation and ore deposits were the main sources of HM contamination in water (Muhammad et al., 2011).

Drinking water contaminations with different anions and HM have shown adverse effects on human health through deficiency or toxicity due to excessive intake (Khan et al., 2013). Nitrate (NO_3), nitrites (NO_2), sulfate (SO_4) and phosphate (PO_4) occur naturally in water (Jordao et al., 2002). Heavy metal concentrations in drinking water can be attributed to both geogenic and anthropogenic sources. The most significant geogenic sources of metals are weathering of rocks, ore deposits and volcanic activities which release a huge amount of metals and ultimately contaminate the water bodies (Leghari et al., 2010). The excessive ingestion of heavy metals including Cd, Cr, Co, Ni, Pb and Zn has carcinogenic effects on human health (Muhammad et al., 2011). Heavy metals are extremely toxic owing to their toxicity, persistent and their bio-accumulative nature. Their toxic effects include headache, hypertension, irritability, abdominal pain, nerve damages, liver and kidney problems, sideroblastic anemia, intellectual disabilities, fatal cardiac arrest and carcinogenesis (Jarup, 2003; Muhammad et al., 2011a,b; Pekey et al., 2004). The environmental pollution caused by heavy metals is a long-term and irreversible process. The heavy metals are not required for routine functioning of human body and can be toxic even at low concentration. Natural contamination of heavy metals usually originates from weathering of minerals, rocks and aquatic environments which result in the entry of heavy metals into water.

This study was therefore aimed to analyze drinking water (e.g. spring water, tube wells and dug wells) for physico-chemical parameters and heavy metal concentrations and their associated health risk on the local population was also assessed.

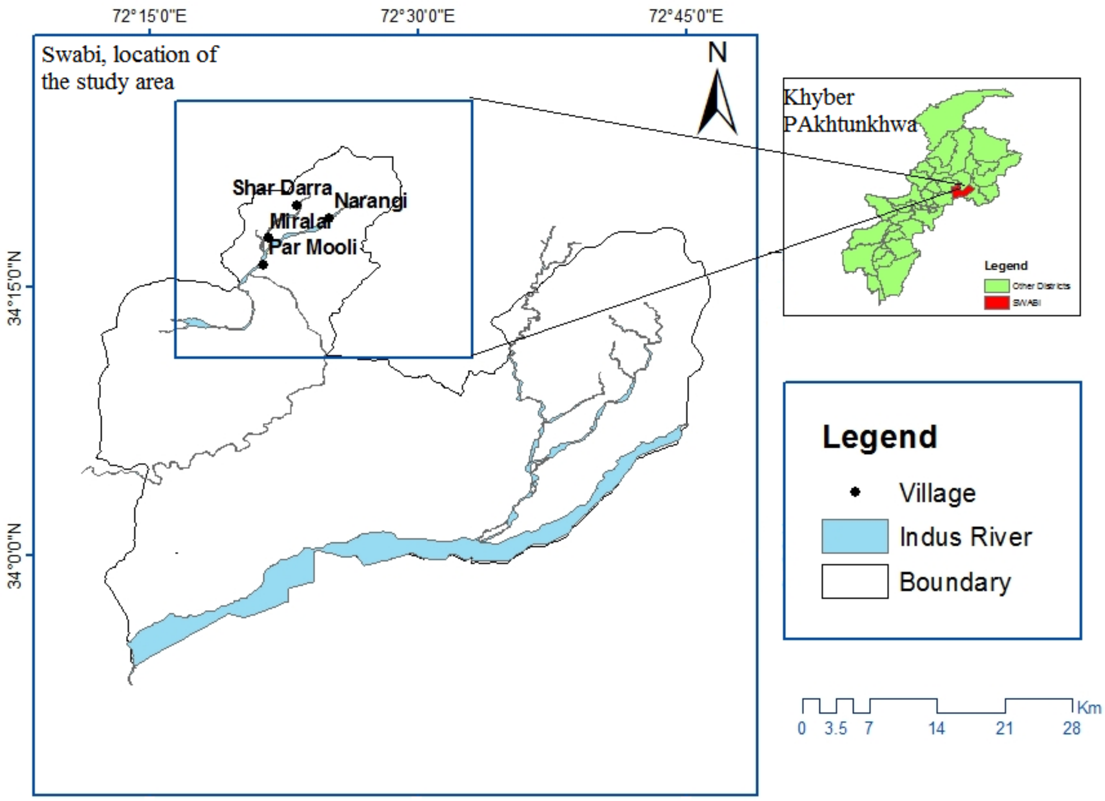

Fig. 1. Map showing location of the study areas and sampling sites (after Hussain et al., 2004).

2. Materials and methods

2.1. Study area

This study was conducted in district Swabi (Fig. 1) in order to assess the effect of heavy and toxic metals in the drinking water of the Narangi (Latitude: 34° 19' 07.17" N and Longitude 72° 24' 59.12" E), Mehr Ali (Latitude: 34° 17' 36.13" N and Longitude 72° 21' 00.0" E), Parmoli (Latitude: 34° 16' 18.32" N and Longitude 72° 21' 12.10" E) and Sher Dara (Latitude: 34° 19' 31.98" N and Longitude 72° 23' 18.72" E) areas. This district is divided into northern hilly areas and southern plain area. The important hills are in north-western corner of the district known as the Narangi hills. The plain area of the district is intersected by numerous streams like an important stream known as "Narangi Khawar". Narangi is located 65 km northeast of the city of Peshawar. Most of the rocks in the study area include syenites, feldspathoidal syenites, fenites, carbonates and associated rocks (Siddique, 1965, 1967). These rocks have contributed high concentration of fluoride-bearing minerals to the drinking water of Narangi and its surrounding areas (Shah and Danishwar, 2002).

2.2. Sampling

Drinking water samples were collected from different sources including hand pumps, tube wells and springs in 2011 from Narangi and its surrounding areas of the district Swabi. Each sample was stored in polythene bottles in acidified form for the determination of heavy metals and in non-acidified form for the determination of physico-chemical parameters.

2.3. Analytical procedure

Temperature, electric conductivity, pH were measured on the spot using respective electrode (CONSORT C931 Turnhout, Belgium) electrochemical analyzer,, while anions such as nitrate (NO_3), nitrite (NO_2), sulfate (SO_4), phosphate (PO_4) and chloride (Cl) using (DR2800 spectrophotometer, HACH Company, USA). Total dissolved solids and salinity were determined using electrochemical analyzer (CONSORT C931, Turnhout, Belgium) and turbidity was determined using turbidity meter (Model 6035, Jenway, UK). Acidified water samples of the study areas were analyzed for heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) using graphite furnace atomic absorption spectrometer (Perkin Elmer, AAS-PEA-700) under standard operating conditions.

Each sample was analyzed in triplicate and after every 10 samples two standards and one blank were used for quality assurance. The reproducibility was found to be at 95% confidence level. Therefore, the average value of each water sample was used for further interpretation.

Standard solutions of all heavy metals were prepared from stock standard solution of 1000 ppm for the calibration of the atomic absorption spectrometer. Certified standard solutions of corresponding metals were analyzed for quality control measures.

All these analyses were performed in the Geochemistry laboratory of the National Centre of Excellence in Geology (NCEG), University of Peshawar.

2.4. Statistical analysis

The data were analyzed using statistical analysis (SPSS 16) and excel for mean and standard deviation (Steel and Torrie, 1980).

3. Results and discussion

Results of the water samples from Narangi and surrounding areas (Permooli, Mirali, Sherdarra) are shown in Figures and Tables below. Table 1 and Figure1 show the pH, EC, TDS, turbidity and salinity concentrations of the drinking water samples collected from Narangi and its surrounding areas. EC, pH, TDS, turbidity and salinity are considered as the important water quality parameters in the aquatic systems. Power of hydrogen ion has no direct effects on human health but it has some indirect effects, which brings changes in water quality parameters such as metal ion solubility and aquatic life survival. High range of pH attributes bitter taste to drinking water. In Narangi and its surrounding areas, the pH of the water ranged from 6.1 to 7.4 with a mean value of 6.67.

Electrical conductivity ranged from 90.2 mS/cm to 585 mS/cm with a mean value of 238.15 mS/cm, TDS ranged from 47.9 to 304 ppm with a mean valve of 126.34 ppm, turbidity ranged 0.10 to 100 NTU with a mean valve of 5.77NTU and salinity ranged from 0.1 to 0.3‰ with a mean valve of 0.12‰. The results show that pH, EC, TDS, turbidity and salinity concentrations of the water samples were observed within the permissible limits set by WHO (2004).

Table 2 and Figure 2 show anion concentrations of drinking water samples of the study areas. Nitrate ranged 0.4 to 12.5 ppm with mean valve of 2.31ppm. Nitrite ranged from 4 to 48 ppm with mean valve of 29.10 ppm. Chloride ranged from 0.5 to 32.5 ppm with mean valve of 9.90 ppm. Sulfate ranged from 5 to 88 ppm with mean valve of 14.62 ppm. Phosphate ranged from 0.18 to 1.45 ppm with mean valve of 0.42 ppm. The test result shows that nitrite in drinking water of the study areas are exceeds the permissible safe limits set by WHO (2004).

Nitrite is also the primary health concern in different parts of the world. According to WHO (2004), nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize hemoglobin (Hb) and methaemoglobin, which is unable to transport oxygen around the body. The reduced oxygen transport becomes clinically manifest when methaemoglobin concentrations reach to 10% or more of normal Hb concentrations; the condition, called methaemoglobinaemia, causes cyanosis and, at higher concentrations, asphyxia (WHO, 2004). Exposure to high levels of nitrite has been associated with increased incidence of cancer in adults, and possible increased incidence of brain tumors, leukermia, and nasopharyngeal (nose and throat) tumors in children (Kennedy et al., 2005). The US EPA concluded that there was conflicting evidence in the literature as to whether exposures to nitrate or nitrites are associated with cancer in adults and in children (Bunin, 1994).

Table 3 and Figure 3 show the heavy metal concentrations in drinking water samples of the study areas i.e. Fe ranged from <0.05 to 188 ppb with mean valve of 53.64 ppb. Mn ranged from <0.05 to 19 ppb with mean valve of 5.7 4 ppb. Cu ranged from 0.17 to 70.7 ppb with mean valve of 13.35 ppb. Lead ranged from <0.05 to 30.66 ppb with mean valve of 5.69 ppb. Cr ranged from <0.05 to 9.43 ppb with mean valve of 1.97 ppb. Ni ranged from <0.05 to 11.15 with mean valve of 2.35 ppb. Cd ranged from <0.05 to 2.39 with mean valve of 0.40 ppb. Co ranged from <0.05 to 0.078 with mean valve of 0.19 ppb. Zn ranged from <0.05 to 2897 ppb with mean valve of 285.03 ppb. The test result shows that all the metals in drinking water of the study areas are within permissible limits set by WHO (2004) while the concentration of Pb in some drinking water samples exceeded the WHO safe limit (15 ppb).

The anthropogenic source of Pb is much higher in amount rather than the geochemical ones, but has been distributed worldwide (Oehlenschläger, 2002).

Like many other contaminants, Pb is ubiquitous and can be found occurring as metallic

Pb, inorganic ions and salts (Harrison, 2001). Children are particularly sensitive to this metal illness because of their more rapid growth rate and metabolism, with critical effects in the developing nervous system (Castro and Méndez, 2008). Beside this Pb can also causes gastrointestinal disorders, diarrhoea, stomatitis, tremor, hemoglobinuria, rust–red color to stool, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia (Vinceti et al., 2007).

3.1. Physico chemical and heavy metal correlation of drinking water quality from Mirali, Sherdarra and Permooli

The data obtained were subjected to the statistical analysis (SPSS 16) by calculating means, standard deviation (Steel and Torrie, 1980). The correlation matrix for the Physico-chemical parameters and heavy metal concentrations of the study areas are given in Table 4. The correlation was done for the selected parameters such as pH, EC, TDS, salinity, SO_4, Cl, NO_3, NO_2, PO_4, Cr, Ni, Cd, Pb, Fe, Mn, Zn and Cu. The correlation matrix shows that some of parameters like NO_3, NO_2, SO_4, and Cl had no interrelationship with heavy and toxic metals. However, strong positive correlation was found in heavy metals such as Fe-Mn (r=0.797), Cu-Pb(r=0.469), Mn-Cu(r=0.591), Mn-Pb(r=0.805), Mn-Zn(r=0.597), Pb-Zn(r=0.252), Pb-Cd(r=0.422), Pb-Fe(r=0.719), Pb-Co(r=0.442), Cl-Co(r=0.440) and Cd-Co(r=0.886). All these heavy metals correlation indicates that the impact of geogenic contamination is high in the drinking water of the area. Therefore the high concentration of Pb in the drinking water can also be associated with lithologies and mineralization.

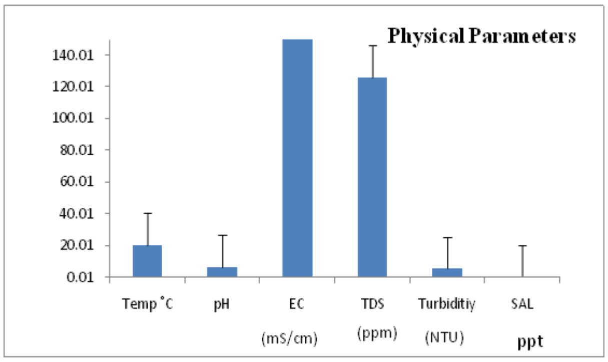

Fig. 2. Physical Parameters in drinking of Narangi and its surrounding areas.

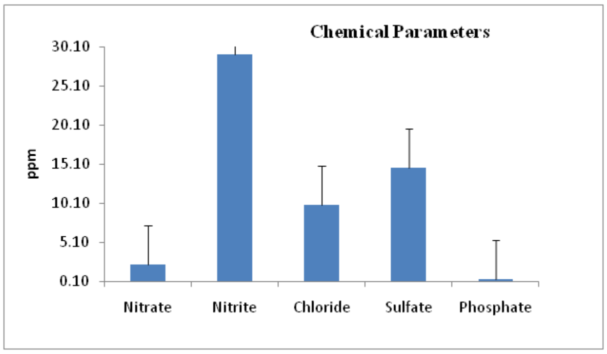

Fig. 3. Anions (ppm) in drinking water of Narangi and its surrounding areas.

Table 1. Physical parameters of the water sample collected from the study area.

Parameters	Statistics	Narngi and its surrounding areas (Drinking water) $n^a = 21$
pH	Range	6.10-7.40
	Mean	6.67
	STDV	±0.40
EC (mS/cm)	Range	90.20-585
	Mean	238.16
	STDV	±136.32
TDS (ppm)	Range	307- 1000
	Mean	126.34
	STDV	±71.89
Turbidity (NTU)	Range	0.10- 100
	Mean	5.78
	STDV	±21.61
SAL (%)	Range	0.10-0.30
	Mean	0.12
	STDV	±0.07

a Number of water samples.
STDV: Standard deviation.

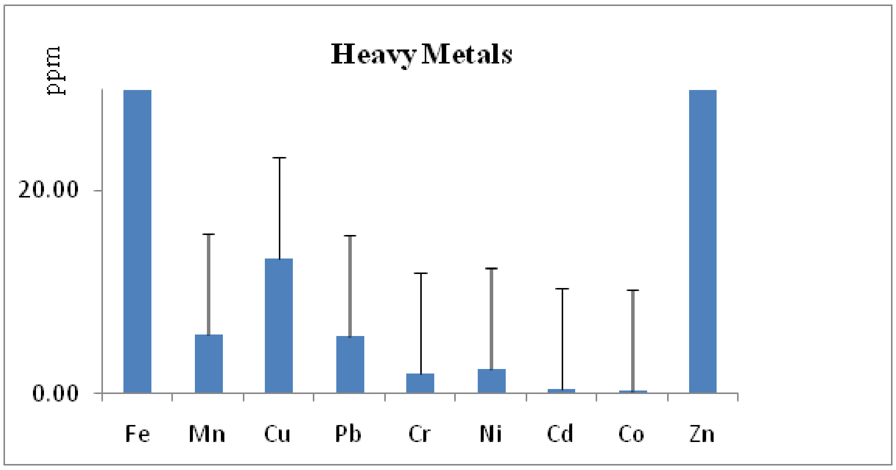

Fig. 4. Heavy metals in drinking of Narangi and its surrounding areas.

Table 2. Metal concentrations (ppb) in water sample collected from the study area.

Metals	Statistics	Narangi and its surrounding areas (Drinking water) n[a] =21
Fe	Range	<0.05- 188
	Mean	53.64
	STDV	±57.79
Mn	Range	<0.05- 19
	Mean	5.74
	STDV	±6.22
Cu	Range	0.17– 70.7
	Mean	13.35
	STDV	±28.32
Pb	Range	<0.05– 30.66
	Mean	5.69
	STDV	±8.08
Cr	Range	<0.05– 9.43
	Mean	1.97
	STDV	±2.63
Ni	Range	<0.05– 11.15
	Mean	2.35
	STDV	±4.32
Cd	Range	<0.05– 2.39
	Mean	0.40
	STDV	±0.53
Co	Range	<0.05– 0.78
	Mean	0.19
	STDV	±0.24
Zn	Range	<0.05– 2897S
	Mean	285.03
	STDV	±664.72

a = Number of water samples.
STDV: Standard deviation.
c >0.05=below detection limit

Due to shortage of water, local people have installed a large number of bore holes, tube wells and hand pumps without following the governmental guidance for their installations therefore, their quality was not satisfactory. Local people have the opinion that groundwater is not safe for drinking and, they did not have any treatment for groundwater which they used for drinking and cooking purpose. The untreated drinking water is also used in all schools and houses in the study area. Previous study about Narangi have already reported fluoride pollution in the ground water and they attributed it due to high concentration of fluoride-bearing minerals to the drinking water of Narangi and its surrounding areas (Shah and Danishwar, 2002) which causes fluorosis and other serious health problem.

4. Conclusions

Majority of physico-chemical parameters including pH, EC, TDS, and heavy metals (Cu, Mn, Pb, Zn and Cd, Co, Cr, Ni) concentrations were found within the permissible limits set by WHO (2004). Nitrite in all drinking water samples exceeded the WHO safe limit (3 ppm). Pb was also exceeded WHO limit in some samples. Inter-metals correlation of selected metals in groundwater showed significant positive correlation between metal pairs indicating strong effect of lithological and mineralogical control. It is evident from the current study that the population of the area is subjected to health risk due to nitrite and lead in the drinking water. This alarming situation should be monitored regularly and the water quality be improved by applying advance treatment techniques.

Table 3. Anions (ppm) in water sample collected from the study area.

Parameters	Statistics	Narangi and its surrounding areas (Drinking water, n^a = 21
Nitrate	Range	0.4 – 12.5
	Mean	2.31
	STDV	2.57
Nitrite	Range	4-48
	Mean	29.1
	STDV	±12.03
Sulfate	Range	5-88
	Mean	14.62
	STDV	±18.45
Chloride	Range	0.5 – 32.5
	Mean	9.9
	STDV	±8.19
Phosphate	Range	0.18 – 1.45
	Mean	0.42
	STDV	±0.27

a Number of water samples.
STDV: Standard deviation

Table 4. Correlation of physico-chemical and heavy metals of Narangi, Mirali, Sherdara, and Permooli area.

	NO_3	NO_2	Cl	S04	PO4	Fe	Mn	Cu	Pb	Cr	Ni	Cd	Co	Zn
NO_3	1	0.256	-0.326	0.327	0.252	-0.164	-0.126	-0.066	-0.179	-0.269	-0.094	-0.048	-0.108	-0.154
NO_2		1	-0.108	-0.24	-0.192	-0.261	0.161	-0.127	0.022	0.01	-0.42	0.034	0.065	0.324
Cl			1	0.194	-0.028	0.038	-0.077	-0.045	0.1	0.189	-0.254	0.118	.440*	-0.224
$S0_4$				1	0.11	0.142	-0.089	-0.155	-0.187	-0.04	-0.075	-0.205	-0.089	-0.175
PO_4					1	0.011	0.033	0.001	0.048	0.095	-0.068	-0.009	0.027	-0.07
Fe						1	.797**	.454*	.719**	-0.117	-0.095	-0.085	-0.096	0.314
Mn							1	.591**	.805**	-0.011	-0.107	0.03	0.06	.597**
Cu								1	.469*	0.122	-0.075	0.126	0.108	0.048
Pb									1	-0.03	-0.064	0.422	.442*	0.252
Cr										1	-0.127	-0.119	0.011	-0.117
Ni											1	-0.007	-0.113	0.029
Cd												1	.886**	0.044
Co													1	-0.042
Zn														1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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