Assessment of Municipal Solid Waste Landfilling Practices on the Ground Water Quality and Associated Health Risks: A Case Study of Mardan-Pakistan

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Research Article

Keywords: Total coliform, ground water, municipal solid waste, health risks

Posted Date: August 17th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-723929/v1>

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Abstract

This study was conducted to investigate the effects of municipal solid waste (MSW) used as landfilling on the ground water quality and health effects on the community. The study was carried out in Mardan, Khyber Pakhtunkhwa province- Pakistan. To assess the impacts, 13 ground water samples were collected from Solid Waste Dumping Sites (SWDS) and 13 from Safe Sites (SS). Ground water was analyzed for pH, Turbidity, Electrical Conductivity (EC), Total Hardness (TH), Cl^- , Ca^{+2} , K^{+1} , NO^{-2} , NO^{-3} , SO_4^{-2} ; heavy metals such as Pb, Cr, Mn, Cu, Ni, Zn, Cd, Fe; biological parameter such as Total Coliform. Waste sample collected from SWDS showed that food and garden waste were present highest percentage by weight (30.5%) followed by fines (17.3%). The two groups (SWDS and SS) differ significantly for the parameters like EC, TH, COD, Na, Ca, NO_3^- and SO_4^{-2} Ni and TC. Samples collected from SWDS (84%) were found contaminated with TC ranged 2–22. It was analyzed that pH, EC, TDS, COD, TH, NO_3^- , SO_4^{-2} , NO_2^- , Ca^{+2} , Na^+ , TC, Cr, Ni, Zn, Cd and TC were more in the sample collected from 70–130 feet than 140–200 feet. TC found in 70–80 feet depth was significantly different from rest of the groups. Similarly, significant difference regarding different parameters for various depths was found for K^{+1} , Ca^{+2} , NO_2^- , Pb, Cu and Fe. The results of the questionnaire survey revealed negative correlation between the diseases and distance from the landfilling sites and significant correlation was observed for typhoid, cholera skin allergies and gastro enteritis. The study confirmed that using MSW as a fill material has contaminated the ground water quality and leveling of land through MSW is not safe. Deep drilling is recommended for extraction of ground water in the contaminated area to minimize the associated health risks.

Introduction

Water is an important factor of life sustainability on earth and without it, existence of life is not possible. Assessment and monitoring of water quality is important and variability of physicochemical parameters of drinking water quality are directly concerned with human health (Muhammad et al., 2010). Due to growing population, the demand for fresh water has increased throughout the world, especially in arid and semi-arid regions (Raju et al., 2011). The water quality on the other hand is getting deteriorated due to many factors and solid waste is one such factor. Solid waste has increased due to the increase in population and race to improve the living standards (Usmani et al., 2020). Solid wastes are classified into hazardous, clinical, municipal and radioactive waste while, municipal waste is characterized as domestic, industrial or institutional (Tang et al., 2020). The poor management of municipal and industrial effluents as well as solid waste contaminates the natural water resources because large amount of toxins along with other chemicals are mixed with water bodies when these waste come in contact with it (Leoni et al., 2005; Mishra et al., 2019). Predominantly in urban areas of developing countries, solid waste dumps pose great threats to the ground water source which is a key source of domestic water supply in these areas (Farid et al., 2012). Municipal solid waste dumps can contaminate the ground water resources with bacteria and other pathogens (Al-Sabahi et al., 2009). Generally MSW contains biological waste apart from paper, glass, plastic and metals (Mohsenizadeh et al., 2020) and the presence of different contaminants and coliform bacteria and other pathogens in drinking water indicate their contact with contamination (Farooq et al., 2008). A large variety of pathogens including coliform bacteria are present in the degraded material of MSW (Beffa et al., 1996). Further, presence of toxic heavy metals in MSW are also reported by literature which are carcinogenic in nature (IARC, 2018).

Pakistan is among the world's arid regions and most of the population is dependent on ground water to fulfill their water requirements for drinking and other domestic purposes. On the other hand, due to prevailing climatic conditions, water scarcity is increasing day by day. Pakistan has been listed among the countries that will have renewable water resources below the calculated threshold of 1500 m³/capita/year by the year 2030 (Rijsberman, 2006). The

availability of water has been dropped from 2172 m³/capita in 1990 to 1306 m³/capita in 2015 (Hassan, 2016). In these circumstances protection of available water sources is of utmost importance for Pakistan. In Pakistan ground water quality has become a serious concern over the last few decades. Dependence on groundwater and indiscriminate usage has led to overexploitation of this resource. Moreover, threats to water contamination have been increased with the increase in population and industrialization (Khan et al., 2018). Lack of awareness among the general public regarding proper management of municipal solid waste further worsen the situation.

Mardan is one of the populous cities of Pakistan where population is dependent on ground water and in spite of all the above mentioned facts, in some regions of district Mardan, the locals are using municipal solid waste, preferably having high percentage of inert and earth particles, for leveling ups and downs of their residential lands without adopting any safety measures. Houses have already been constructed on such lands and hence best suited for identifying the impacts of MSW on ground water quality. This practice of the locals may pose threats to the ground water sources and ultimately to human health. Previously no research work has been carried out on this issue. Therefore, this research study was designed to assess the impacts of municipal solid waste landfill practices on ground water quality and associated health risk. Findings of this study will be beneficial for creating awareness in the countries where solid waste dumps are located near the water resources.

Methodology

Study area

This study was conducted in the urban region of district Mardan which is the second most populous district of the Khyber Pakhtunkhwa province, Pakistan. It lays between latitude 34° 05' to 34° 32' North and longitude 71° 48' to 72° 25' East; located about 14km northeast of Peshawar (Tufail et al., 2013). The study was focused on the small residential setting where most of the people were using MSW for leveling their residential lands. According to the TMA Mardan total estimated population of the area was 4000 to 5000 inhabitants; mostly belonged to middle class. Ground water is used for drinking and other domestic purposes in the area. Hand pumps and pressure pumps are used for extraction of ground water.

Collection of waste samples at dumping sites

Wastes from dumping sites which were not leveled yet and used for residential purpose were collected and analyzed through European commission methodology (user version 2004) and guidelines EPA, Ireland for MSW characterization to understand the types of wastes used for leveling of the ground.

Samples collection

Total 26 drinking water samples were collected from the study area. Samples were collected from SWDS (n=13) and SS (n=13) (Fig. 1). Those areas where the locals have used municipal solid waste for leveling their residential lands were termed as Solid Waste Dumping Sites (SWDS) in this paper. While the areas where municipal solid waste was not used for leveling residential lands were termed as Safe Sites (SS). The SS was selected at least at 1000 m distance from the solid waste sites. All the samples were collected in 1.5 liters (L) poly propylene bottles. The bottles were rinsed with 1:1 concentrated HNO₃ and triple distilled water of Milli Q prior to use. The depth of the source was also recorded. The samples were taken from 70 to 200 feet depth. The samples were stored at < 08 °C and transferred to the laboratory within 04 hours for analysis.

During field survey district headquarter hospital (DHQ) Mardan was also visited and information was collected regarding water borne diseases in the locals of SWDS. This data was used to assess the health impacts of the ground water sources on the local inhabitants.

Analysis of Physicochemical Parameters

Ground water was analyzed for pH, Turbidity, Electrical Conductivity (EC), Total Hardness (TH), Cl^- , Ca^{+2} , K^{+1} , NO^{-2} , NO^{-3} , SO_4^{-2} . pH, chlorides and hardness were measured with pH meter, Chloride test kit (Hanna 3815), hardness turbidity meter (HI96735 Hanna), respectively. Ca^{+2} , K^{+1} and NO^{-2} were measured with Hanna model No. HI83200, TDS with HI98129 and EC with HI98130 meters. Portable turbid meter (2100P ISO, Hach), sodium meter (HI 931101), nitrate meter (HI96786) and sulphate meter (HI76751 and HI38001) were used for the measurement of Turbidity, sodium, nitrate and sulphates, respectively. The permissible limits set by Pakistan, National Environmental Quality Standards'2010 (Pak-NEQS) were used for drinking water quality.

Analysis of Heavy metals

For analysis of selected heavy metals such as Pb, Cr, Mn, Cu, Ni, Zn, Cd and Fe were analyzed through atomic absorption spectrophotometer (Perkin Elmer AAS 700) as per American public health association (APHA), 1998 guidelines. The permissible limits set by Pakistan, National Environmental Quality Standards'2010 (Pak-NEQS) were used for drinking water quality for above mentioned parameters.

Analysis of total Coliform

Total Coliform tests were conducted using membrane filter method (method no. 9222-B) according to the procedure of American Public Health Association (APHA), 1998. Analytical grade chemicals and materials were used for analysis. The permissible limits set by Pakistan, National Environmental Quality Standards'2010 (Pak-NEQS) were used for drinking water quality for TC.

Questionnaire Survey

Questionnaire survey was conducted from 500 respondents living at different distance (living on the sites leveled by MSW (0-100m), 101-400 m, 401-700 m, 701-1000m) from the dumping sites. The age of the respondents ranged 15 – 40 y and 250 males and 250 females were selected. Different diseases were selected from the literature including Diarrhea, Dysentery, Typhoid, Ringworm, Cholera, Malaria, any skin allergies, Gastro enteritis. The respondents were asked to select from any one option (Never, at least once in 2 months, once in 4 months, once in 6 months, once in a year and more than a year) against the mentioned diseases.

Statistical analysis

Statistical analyses and graphical representation of the data was conducted through SPSS v. 23. Pearson correlation was conducted to find out the relationship between depth and different parameters and to analyze the relationship between distance from the dumping sites and diseases.

Results And Discussion

Waste sample collected from the solid waste dumping sites (n = 13) showed that food and garden waste were present highest percentage by weight (30.5%) in the SWDS followed by fines (17.3%). Beside these, paper and cardboard (3.4%), glass (3.7%), metals (0.3%), plastics and rubber (3.9%), wood (2.7%), textile and rags (3.7%), leather and non-recyclable plastic (5.9%), complex products (4.2%), inert (6.4%), healthcare waste (2.2%) and other (15.8%) constitutes the waste identified in the SWDS (Fig. 2).

Physicochemical Parameters

Comparison between water samples taken from SWDS and SS

Water samples collected from SWDS and SS showed that there was no significant difference in the mean values of pH, turbidity, TDS, Cl^- , K^- and NO_2^- for both sites and pH, Cl^- and NO_2^- were within the permissible limit for all the sites (both SWDS and SS). Only 8% and 31% SWDS showed turbidity (range: 0.6–8.96 NTU) and TDS (range: 390–1206 mg/L) beyond the permissible limit set by Pak-NEQS, respectively. While all the SS were within the limits for the above mentioned parameters (Table 1). The two groups (SWDS and SS) differ significantly for the parameters like EC, Total hardness, COD, Na, Ca, NO_3^- and SO_4^{2-} . The SS showed these mentioned parameters within the permissible limit. But 54%, 15%, 15%, 23%, 8% and 15% SWDS showed that EC (Range: 705–2380 $\mu\text{S}/\text{cm}$), Total hardness (range: 170–573), Na (range: 46–276), Ca (range 40–95), NO_3^- (range: 14–52) and SO_4^{2-} (range: 89–376) were beyond the permissible limit (Table 1). The high value of EC is due to the high concentration of dissolved ions in the ground water and clearly indicates that leaching of waste has taken place from the landfill sites (Kumar and Alappat, 2005). The high value of COD in the SWDS samples indicate the high fraction of biodegradable waste (Somani et al., 2019). For heavy metals, drinking water of SWDS and SS showed that Pb, Cu, Zn, Fe, Mn were within the permissible limit. While for Cr only 8% and for Ni 38% drinking water samples for SWDS showed results beyond the permissible limit. The results for the Cd showed that 46% samples from SWDS and 38% SS were beyond the permissible limit. However, SWDS and SS differ significantly ($P < .05$) for Ni only (Table 1).

Table 1
Results of water quality parameters collected from SWDS and SS

	pH	Turb. (NTU)	E.C ($\mu\text{S}/\text{cm}$)	TDS (mg/l)	COD	TH	Na ⁺	K ⁺	Ca ⁺²	SO ₄ ⁻²	Cl ⁻
SWDS											
Min.	6.9	0.6	705	390	3	170	46	1.3	40	89	15.6
Max.	8.2	8.96	2380	1206	15	573	276	7.6	95	376	147
Avg.	7.54	2.33	1353.31	772.38	7.77	337.23	112.46	3.69	61.85	170.62	65.34
St. dev.	0.41	2.20	596.66	295.09	3.68	141.18	68.91	1.82	16.52	83.64	45.34
SS											
Min.	6.7	0.79	837	550	2	167	43	1.8	39	79	30.5
Max.	8.2	2.2	1084	774	12	354	97	4.6	60	121	67.5
Avg.	7.2	1.4	963.0	642.4	5.3	237.1	64.4	2.8	49.9	95.4	47.7
St. dev.	0.52	0.54	104.93	71.40	3.68	70.02	19.21	0.95	8.91	15.13	14.78
NEQS	6.5–8.5	< 5		< 1000		500	200	12	75	250	250
	NO₃⁻	NO₂⁻	Cr	Pb	Cd	Cu	Zn	Fe	Ni	Mn	TC
SWDS											
Min.	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22
Max.	52	2.1	0.052	0.049	0.027	0.061	0.448	0.011	0.09	0.122	0
Avg.	28.62	0.50	0.02	0.01	0.01	0.01	0.15	0.002	0.02	0.03	4.62
St. dev.	10.13	0.65	0.02	0.02	0.01	0.02	0.17	0.004	0.03	0.04	6.70
SS											
Min.	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max.	28	0.8	0.028	0.071	0.038	0.028	0.273	0.026	0	0.08	7
Avg.	19.4	0.33	0.01	0.01	0.01	0.02	0.10	0.01	0.00	0.04	1.7
St. dev.	5.97	0.36	0.01	0.03	0.01	0.01	0.09	0.01	0.00	0.02	2.6
NEQS	50	3	0.05	0.05	0.01	2	5		0.02	0.5	

Regarding TC results, 62% SWDS and 43% SS showed the sample were beyond the permissible limits. Contamination was recorded in the samples of both zones but the level of contamination was much higher in the samples of SWDS as compared to SS (Fig. 3). TC found in the samples of SWDS ranged 2–22. While only 43.3 % of TC was found in the samples collected from SS that ranged 2–7. High percentage of TC as well as EC, Total hardness, Na, Ca, NO₃⁻

and SO_4^{-2} and Ni in the sample collected from SWDS indicates the possible percolation of leachate in the ground water from the solid waste landfills. These results are analogous to the findings of Mor et al. (2006) and Chonattu et al. (2016).

Samples collected from some areas of the safe zone also showed the presence of TC. Possible reason for this contamination may be the poor sanitary and hygiene conditions (Shar et al., 2008) as in some areas the same poor conditions were observed. However, comparatively higher concentration of TC and higher contamination percentage of SWDS samples indicates possible contamination of the ground water sources due to leachate percolation.

Depth Wise Comparison Of Water Quality Parameters In Swds

Water samples collected from various SWDS were collected from different depths. The depth where significant difference was found is given in Table 2. It is pertinent from the Table that TC found in 70–80 feet depth was significantly different from rest of the groups. Similarly, significant difference regarding different parameters for various depths was found for K^{+1} , Ca^{+2} , NO_2^- , Pb, Cu and Fe. The correlation found between depths and various parameters is given in Table 3. It is clear from the Table that most of the parameters are negatively correlated with the depths and as the depths increases the concentration of these parameters decreases. The level of ground water contamination due to MSW landfill or dumps depends upon various factors among which depth of the source is more prominent (Mor et al., 2006).

Table 2
Water quality parameters' relationship with depth

Dependent Variable	Depths	Depths	Mean Difference (I-J)	Sig.
K	115–120	160	-2.82	0.03
Ca	70–80	200	31.17	0.02
NO_2	115–120	130–140	0.68	0.04
Pb	70–80	130–140	-0.03	0.04
	115–120	130–140	-0.03	0.01
Cu	115–120	200	-0.03	0.01
	130–140	200	-0.03	0.03
	200	70–80	0.03	0.04
Fe	115–120	160	-0.01	0.05
	115–120	200	-0.01	0.02
	130–140	200	-0.01	0.05
TC	70–80	115–120	10.14	0.01
	70–80	130–140	7.40	0.05
	70–80	160	12.00	0.02
	70–80	200	12.00	0.02

Table 3
Correlation between different water quality parameters with depth

Parameters	Depth		Parameters	Depth	
	Pearson Correlation	Sig. (2-tailed)		Pearson Correlation	Sig. (2-tailed)
pH	– .284	.348	NO ₃	– .396	.180
Turbidity	.177	.564	NO ₂	– .038	.901
EC	– .447	.126	Cr	– .256	.399
TDS	– .367	.218	Pb	.307	.307
COD	– .524	.066	Cd	– .163	.594
TH	– .520	.068	Cu	.776	.002
Na	– .438	.134	Zn	.320	.286
K	.295	.328	Fe	.181	.554
Ca	– .536	.039	Ni	– .518	.070
SO ₄	– .541	.036	Mn	.427	.146
Cl	.113	.713	TC	– .592	.033

While analyzing the water samples it was found that pH, EC, TDS, COD, TH, NO³⁻, SO₄⁻², NO²⁻, Ca⁺², Na⁺, TC, Cr, Ni, Zn, Cd and TC were more in the sample collected from 70–130 feet than 140–200 feet. The percentage difference between the two is given in Fig. 4. The number of TC was assessed against the depth of sampling sources and it was found that contamination of ground water has inverse relation with depth of the source (Fig. 3). The results showed that 81.82 % samples collected from ground water sources having depth less than 140 feet were found contaminated. On the other hand only 22.22% samples, collected from sources having depth of 140 feet or above, were found contaminated.

Natural filtration capability of the earth may be the possible reason for decrease in the level of contamination with increase in depth of the ground water sources. Earth layers filter the fluid when it passes through it (Kilpatrick et al., 2018). Hence, greater the travelling distance of the fluid higher will be the filtration. Therefore, the deep water sources were found safe as compared to the shallow water sources. Depending on the type of waste the including municipal solid waste, the leachate is formed and contains many contaminants which may include pathogens, organic and inorganic pollutants, toxic metals and xenobiotic organic compounds (Christensen et al., 2001; Huang et al., 2009; Joseph et al., 2020). The chemical composition of leachate is dependent on the type of waste and by published in various studies (Lü et al., 2008; Öman and Junestedt, 2008). The risk posed by the leachate containing toxic substances is the accumulation of these substances in soils and then infiltration into ground water and becoming part of the food chain when this water is consumed by the living beings (Alam et al., 2020; Ngelinkoto et al., 2014; Poté et al., 2008). Heavy metals are found to be beyond the permissible limit in the soil of landfill sites (Agbeshie et al., 2020; Essien et al., 2019; Gujre et al., 2021). The seepage from MSW landfill site has considerable impact on the quality of ground water (Singh et al., 2016). Research conducted by Yusof et al. (2009) analyzed high organic contents, Cd and Mn in the river near an active uncontrolled landfill and influences of leachate in the form of inorganic nitrogen and heavy metals such as Cr, Fe, Mn and Ni. They observed the impacts of leachate on the nearby river. The current study also confirms that high EC, Total hardness, Na, Ca, NO₃⁻ and SO₄⁻², Cr, Ni and TC were

observed in the samples taken from SWDS and few samples showed high turbidity and TDS. Leaching of the contaminants from the waste depends on the fixation of these contaminants in the soil and their transportation to the groundwater (Pejman et al., 2017). Raju et al. (2009) explained leaching of contaminants takes place due to permeation and percolation with rain water. As the dumping sites are open and rainy seasons are observed in the study area therefore, leaching of contaminants takes place due to the water percolation. According to a report published by UN-Habitat and UNESCAP (2012) on Mardan landfill sites; the observed sites were without soil cover and there were no compaction applied; almost 60 to 70 tons of wastes were dumped on these landfill sites. Further, there is no collection of leachate or gas from these sites. A report published by GoP (2021) reported that soil of the Mardan is "Very soft - soft to firm to stiff lean clay/silty clay/silt/ up to a depth of 7.0 m underlain by medium dense to very dense poorly graded sand with silt/silty sand". These facts confirm the finding of the study that the leachate percolates from the soil and contaminated the ground water. Another study conducted by Mishra et al. (2019) also showed almost same results by observing considerable amount of TDS, EC, NO_3^- and PO_4^{3-} in the ground water samples taken from near the landfill site thus concluding that ground water quality is significantly affected by leachate percolation. Similarly, Fernández et al. (2014) observed the impacts of leachate plume up to 900 m from the landfill site. As the leachate reaches the saturated zone, it forms plume which spreads in the direction of flow of water and contaminates the ground water (Vasanthi et al., 2008). The current study observes that these contaminants were more in the 70–80 feet than the 120 feet depths.

Questionnaire Survey And Data Collected From The Hospitals

According to the survey results 41% respondents suffered from diarrhea that were living at a ground leveled with MSW or 100 m within dumping sites at least once in a year. Similarly 25% suffered from typhoid and 26% suffered from skin allergies at least once in a year (Table 4). According to respondents, 18% suffered from gastro enteritis at least once in four months. The results of the questionnaire survey revealed negative correlation between the diseases and distance from the dumping site. However, significant correlation was only observed for typhoid, cholera skin allergies and gastro enteritis (Table 5). No correlation was observed between the gender and age of the respondents with diseases.

Table 4
Frequency (Percentage) of diseases suffered by the respondents

Diseases	Frequency	Distance from dumping site			
		0-100 m	101-400 m	401-700 m	701-1000 m
Dysentery	a	3	1	0	0
	b	19	16	10	4
	c	1	2	1	2
Diarrhea	c	2	1	0	0
	d	4	3	0	1
	e	41	27	14	7
Typhoid	e	25	15	8	6
Ringworm	d	15	6	3	4
	e	0	1	0	0
Cholera	c	5	1	0	1
	d	15	8	5	5
	e	2	4	0	2
Malaria	d	18	15	6	4
	e	4	1	1	1
Gastro Enteritis	b	18	10	1	3
	c	25	15	7	3
	d	10	1	0	0
	e	4	1	0	2
Skin Allergies	a	1	1	0	2
	b	0	0	1	0
	c	12	2	4	2
	d	26	21	8	3
	e	8	7	1	1
a = once in 2 months; b = once in 4 months; c = once in 6 months d = once in a year; e = More than a year					

Table 5
Correlation between distance from dumping sites and diseases suffered by the respondents

	Diarrhea	Dysentery	Typhoid	Ringworm	Cholera	Malaria	Skin Allergies	Gastro
Pearson Correlation	– .150	– .063	– .349**	– .116	– .206*	– .073	.279**	– .328**
Sig. (2-tailed)	.035	.533	.000	.248	.039	.470	.005	.001

As consumption of the contaminated water may pose health risk to the local community due to bacteriological contamination and this is among the major threats to drinking water and ultimately to human health (Azizullah et al., 2011). To assess the health risk to the locals due to consumption of contaminated drinking water, waterborne diseases data were collected from the DHQ hospital Mardan. Though, in Pakistan proper assessment and quantification of water borne diseases is a hard job due to lack of record maintenance at hospitals (Aziz, 2005). The data collected from the DHQ hospital revealed that the residents of SWDS suffered frequently from diarrhea, dysentery, typhoid and skin diseases. According to the hospital sources approx. 2500 patients/ day were visiting outpatient department (OPD), out of which 22 % suffered from waterborne diseases. During the rainy seasons this percentage raised to 35–40 % of the total patients attending OPDs wherein almost 75% were from the regions of SWDS. This high burden of waterborne diseases in the study area confirmed that the ground water sources of the study area were not safe. Similar results were reported by the United Nations International Children's Emergency Fund (UNICEF) that waterborne diseases are responsible for about 20 to 40% of all the patients in hospitals of Pakistan among which typhoid, giardiasis, cryptosporidiosis, dysentery, cholera and other gastrointestinal problems accounts for one third of all deaths in the country.

Conclusion

In this study, samples were collected from sites leveled with solid waste and compared with the samples of safe zone. The results showed that level of contamination was comparatively much higher in the solid waste dumping sites samples. Questionnaire survey and hospital data also confirmed the negative health impacts of the contaminated water. Thus, it can be concluded from the study that the use of MSW for leveling of residential lands is not safe and this practice has contaminated the ground water of the study area. Therefore, this practice should be discouraged and the concerned government departments shall play their role to ensure human health safety and to avoid any potential risk. To minimize health risk, deep drilling should be done for extraction of ground water. Regular monitoring of ground water sources in the study area is recommended.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Consent to Publish

Not applicable

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

"The authors declare that they have no competing interests".

Funding

Not applicable

Authors' contributions

Dr. Israr and Dr. Hizbullah contributed to the study conception and design. Field survey and lab analysis was performed by Dr. Israr. Questionnaire was prepared by Dr. Ali Raza and Dr. Shahla and questionnaire survey was also conducted by Dr. Jawad. The first draft of the manuscript was written by Dr. Shahla Nazneen and Dr. Israr. Figures and graphs were prepared by Dr. Shahla and Dr. Neelum. Data analysis and statistical techniques were applied by Dr. Shahla Nazneen and Dr. Sardar Khan. All the associated health risk assessment was conducted by Dr. Ali Raza. All authors discussed the results and approved the final manuscript.

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Figures

Figure 1

Sampling sites; Red bars shows samples collected from SWDS and Blue bars shows samples collected from SS; Clean bars shows samples collected from pressure pumps and pattern bars show sample collected from hand pumps

Figure 2

Categorization of the waste dumped at SWDS (in percentage)

Figure 3

Total coliform in the samples collected from SWDS and SS

Figure 4

Percentage difference between water quality parameters in drinking water (140 f below and above)