





## **Assessing health risks to local population from contamination sources in and around Sulaimani province; a qualitative study**

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### **Abstract**

There are many physical, chemical and biological agents either naturally present or produced by human activity that can be hazardous for human health. Environmental pollution in and around Sulaymaniyah city is caused by several factors including untreated wastewater, contaminated agricultural fields, untreated solid waste, industrial waste and contamination of Tanjaro River and Darbandikhan Lake from these sources of pollution. Populations, especially those living closer to the above-mentioned pollution sources are at risk of both short and long-term effects of biological, physical and chemical contaminants, especially south of the city and around Tanjaro River and Darbandikhan Lake. Neglecting these problems means that buildup of contaminants in the environment and endangering population health will continue.

Monitoring and responding to environmental health hazards requires collaborative efforts of relevant departments, professional institutions, NGOs, community-based organizations and affected populations. To reduce risk of water-borne diseases is strengthening water management in relation to maintaining quality while the ultimate solution to wastewater pollution is establishment of sewerage treatment plants. Solid waste is a major problem and the ultimate solution is recycling and the establishment of a controlled landfill in an area. Immediate measures need to be taken to prevent further pollution of the Tanjaro River, by isolating the polluting sources. Industrial activities need to be regulated and monitored in terms of environmental and occupational safety operations and standards. Using Sulaymaniyah wastewater for farming must be prohibited by law and enforced. Protection of Darbandikhan Lake from major sources of pollution should be made a higher priority and measures should be taken as soon as possible to isolate and minimize major pollutants. There is also a need for extensive research and the establishment of sustained research systems on population health and environmental pollutants, especially in relation to the food chain, and the Tanjaro River, Darbandikhan Lake and air pollution. If urgent consideration is not given to the above areas and problems, the situation may get considerably worse in the coming years.

### **Introduction**

There are many physical, chemical and biological agents either naturally present or produced by human activity that can be hazardous for human health. Rapidly expanding urban populations without proper plans

and organized services are especially at risk of the hazardous effects of these agents produced in excess and not safely disposed. The urban centers of Iraq that have emerged from decades of war and poor services are suffering from the accumulation of a variety of these environmental risks generated by the population, urban services and industrial and agricultural activities. The WHO reports that out of 102 diseases reported from the country of Iraq, 85 are related to environmental health and that 25% of childhood deaths are related to preventable water-related diseases [1]. Access to safe water is approximately 50%, access to improved sanitation is round 70% and there are no sewerage treatment plants outside of the city of Baghdad with 50% of waste water directly flowing into natural waterways [1].

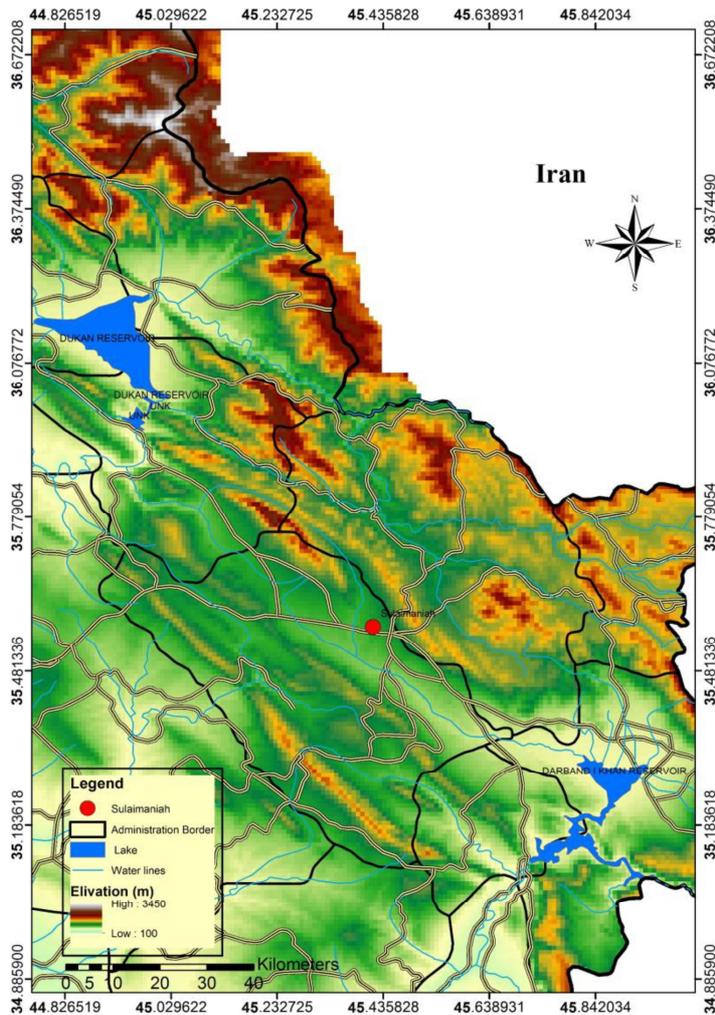


Figure 1 Map of Sulaymaniah governorate

In relation to economic activity, over 50% of the employed population work in the public sector, and the vast majority of the labor force work in the service sector (76%), followed by industrial activities (18%) and agriculture (6%) [2]. In 2014, there were 89 big industrial enterprises, 182 medium and around 10,400 small enterprises in the region. In terms of agricultural indicators, the arable area of Kurdistan region is estimated at around 1.65 million hectares, forest area around 1 million, wheat planted areas about 800,000 hectares and areas planted with summer crops was around 60,000 hectares [3].

The situation in Kurdistan may be a little better than average for the country in terms of development indicators including access to safe water and sanitation, but the same environmental problems exist. The Kurdistan Region of Iraq has an estimated population of 5.6 million, with approximately 80% living in urban areas. According to the Statistics Office, in 2012 around 97% of the population had access to safe drinking water and improved sanitation [2]. However, the situation has likely deteriorated since then due to government budget cuts and economic recessions in recent years; solid waste is still dumped outside the major cities and there are no treatment plants for wastewater. According to the same source in 2011, poverty prevalence was 3.5%, literacy in young people (15-24 years old) was 90% (males 94%, females 85). Infant mortality was 28 per 1000 live births, under 5 mortality was 32 per 1000 in 2011, moderate and severe underweight was 6.7% and moderate and severe stunting was 21% [2].

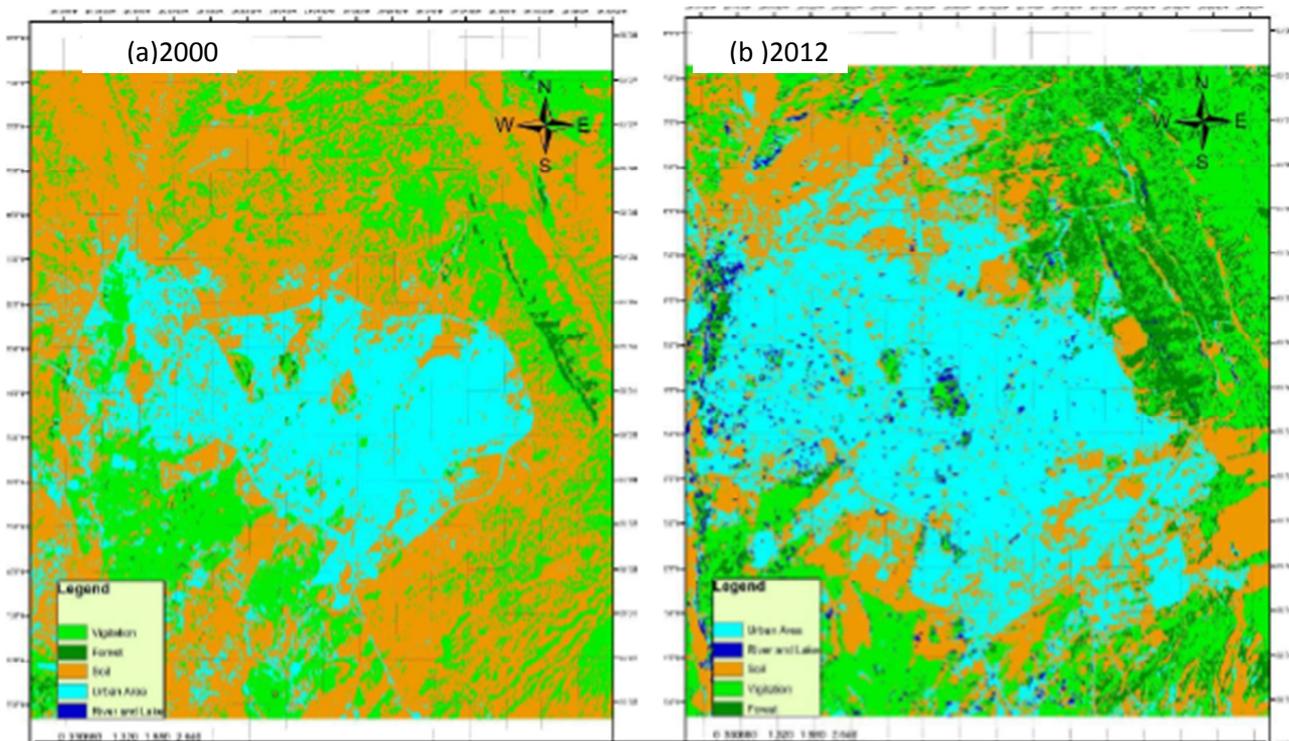


Figure 2 Map of Sulaymaniyah city showing expansion of urban area between (a) 2000 and (b) 2012

Sulaimani city, its map shown in figure 1, is one of the 3 major urban cities of Kurdistan Region with an estimated population of around 1 million people. The city is located approximately 370 kilometres north-east of Baghdad at coordinates 35.557, 45.443. The city is located in a valley at the foot of Goizha Mountain stretching over an area of around 470 km<sup>2</sup> and extending southwards to the lower lands surrounding Tanjaro River. The urban area in Sulaymaniyah city is expanded irregularly because of lack of urban policy figure 2. Topography of the city is hilly and steep making the southern parts of the city at risk of floods and pollution more than higher parts. The city has seen tremendous but poorly planned residential expansion during the past 2 decades (especially after 2003), stretching its boundaries in all directions and putting pressure on many public services including water, sanitation, health, education and transportation facilities. The city sewerage flows down to Tanjaro River south of the city. The solid waste is dumped without treatment near the same river and partially covered with earth. Hundreds of small and some large industrial areas are established around the river and the river flows to Darbandikhan Lake causing its contamination as well. There was historically one industrial area southwest of the city, but with the post-2003 boom of economy, a large number of small and medium industrial projects were initiated and a new area was allocated for these activities south of the city by the Tanjaro River. This slowly became the center of all kinds of industrial and private sector activities. As a consequence of the industrial expansion in this area, many workers and their families moved to the area causing a considerable increase in the population of these sub-urban areas. Many internally displaced people working in the area also settled there. Thus, these southern outskirts of the city are at high risk of environmental hazards from industrial activities, urban waste and pollution of the river.

Despite its importance, environmental health research remains scarce in the region. There have been a few studies on water pollution around the city and on the impact of Sulaymaniyah wastewater on contamination of water and soil around and in the Tanjaro River, including the reporting of high levels of some heavy metals in the soil and water samples [4-6]. There have also been reports on contamination of Darbandikhan Lake indicating high heavy metal content of the lake water [7]. Pollution of the environment around the city from solid and liquid waste has also been subject of several newspaper articles [8-10].

Despite the fact that successive wars, rapid urbanization and the poorly planned expansion of the major cities and industrial areas have contributed to increased health risks in the environment, these problems have not been sufficiently appreciated and researched. Air pollution, water pollution, industrial hazards, heavy metals, risks from urban solid and liquid waste, and other general physical, chemical and biological hazards are topic areas that need sustained and organized research efforts. More research on all of these environmental and occupational hazards is urgently needed. Research findings are crucial to provide evidence for action and strong arguments to advocate for healthy and environment-friendly public policies and regulations. The current environmental health assessment and capacity-building project could help initiate work in this direction. The main aim of this study was to undertake a rapid assessment of the environmental health hazards around the city of Sulaymaniyah and Tanjaro River. The current document reports on the results of the rapid assessment study which was undertaken during the October 2016-January 2017 time period as part of the project to achieve the following objectives: (i) Assess the environmental health situation in relation to solid waste disposal and possible risks to the population, (ii) Assess the environmental health situation in relation to liquid waste disposal and possible risks to the population, (iii) Assess the environmental health situation in relation to industrial activities and possible risks to the population, (iv) Assess the farming practices around the city and possible risks to the population and (v) Assess the sources of pollution to Tanjaro River and possible risks to the population.

## **Methodology**

The environmental assessment was undertaken during the period from October 2016 to January 2017 using a variety of research methods including desk reviews, site observation visits using checklists, key informant interviews (KII), in-depth interviews (IDI) and quantitative estimation and analysis of soil and plant samples for relevant contaminants. This combination of qualitative and quantitative methods allowed for a more detailed, objective and in-depth understanding of the situation from different perspectives, viewpoints, and data sources. Design of data collection instruments, sampling strategy, training of the environmental assessment team and the pretesting of data collection instruments were carried out in primarily during the month of September and in early October 2016.

Initially a consultation meeting was organized on October 2nd, 2016 with relevant stakeholders including relevant departments/ sections of water, solid waste and liquid waste in the municipality of Sulaymaniyah, Department of Health, Department of Environment, Chamber of Industry, Directorate of Water, and NGOs and others.

## **Desk review**

A literature search was done manually for articles on environmental health hazards, water quality and water pollution in Sulaymaniyah city and on pollution of Tanjaro River. Online search was done through Google and PubMed for key words such “Pollution”, “Tanjaro River”, “Environmental Health”, combined with “Sulaymaniyah”. A PubMed search was done separately to retrieve relevant literature on environmental health hazards in other countries related to the themes of the current study.

## **Observation**

Observation visit were undertaken by the research team members for different sites using a checklist guide to record objective information observed at the sites and about possible risks to human health. The sites were selected in relation to waste water disposal, solid waste disposal, farming, and industrial activities. Observation visits were undertaken to the following sites in and around Sulaymaniyah City using observations checklist guides:

- 1- Solid waste disposal area (near Tanjaro River)
- 2- Wastewater disposal area (channels from the city to the Tanjaro River)
- 3- Farms near solid waste disposal area
- 4- Farms near wastewater disposal area
- 5- Factories near Tanjaro River

### Key informant interviews

Key knowledgeable officials and professionals working in areas related to the theme of the study were interviewed in-depth to gather information on specific aspects of the situation, services and policies/standards available in the area. Semi-structured questionnaires specifically prepared for each interview was used to guide the interviewer obtain the relevant information that was available with the informant. Fifteen such KIIs were undertaken as shown in table 1:

Table 1: Key informant interview (KIIs)

Category	Sub-category	sample	Number
Sulaymaniyah city	Resident	Male	4
		Female	4
Sub –urban, Tanjaro, Industrial area	Resident,	Male and female	8
	Factory worker	Male/Female	8
Farmer near tanjaro river and industrial area	Farmers	Male	4
		Female	4
Darbandikhan lake	Resident/	Male and female	8
	Fishermen	Male	4
Total IDIs			44

### In-depth interviews

Citizens, workers and farmers living in and around the city and Tanjaro River were interviewed to assess their knowledge, attitudes and behaviors about environmental hazards and activities they might be exposed to. Semi-structured questionnaires specifically prepared for each purpose, were used to guide the researcher undertake the interview. Thirty such IDIs were undertaken as shown in table 2 using the specific guide for each interview:

Table 2 In-depth interviews (IDIs) undertaken during the study

	Person/Positins	Number
1	Chamber of Commerce and Industry	1
2	Darbandikhan Lake Management	1
3	Department of Environment	1
4	Department of liquid waste management	1
5	Department of solid waste management	1
6	Directorate of Agriculture	1
7	Directorate of Industry	1
8	Directorate of Statistics	1
9	Directorate of Water	1
10	Factory manager	1
11	Iraq Nature (NGO)	1
12	Monitor of solid waste disposal site	1
13	Preventive health professional	1
14	Solid waste disposal Company	1
15	Official on fuel distribution	1
16	Total	15

Separate IDI question guides were used for the following categories:

- 1- Residents of Sulaymaniyah
- 2- Suburban Tanjaro residents
- 3- Residents of Darbandikhan
- 4- Farmers near Tanjaro
- 5- Factory workers
- 6- Fishermen

## **Findings and Discussion**

### **The context**

According to officials from the Directorate of Statistics (DoS), the population of Sulaymaniyah governorate including Halabja and Garmyan areas is estimated at 2,210,708 and that of Sulaymaniyah city is estimated at about 907,000 in 2017. It should be mentioned, however, that there has been no census in the Kurdistan region of Iraq since 1987, and these figures are extrapolations from estimated population figures used during the Oil-for-Food program in the late 1990s. Sulaymaniyah governorate spans over an area of 21,000 km<sup>2</sup> while the city stretches over an area of 470 km<sup>2</sup>. The city has seen an unprecedented expansion of population settlements during the past 10 years, for example in 2009 there were 113 neighborhoods but in 2014 they increased to 162. The average family size in Sulaymaniyah is 4.7 and the governorate has a relatively young population with around 50% of the population being below 22 years of age. According to the same source, the annual population growth rate is 3%. Temperature fluctuations in Sulaymaniyah are extreme, ranging from as low as -8 Celsius in the winter to as high as close to 50 Celsius in the summer. The rainy season usually starts from October and continues until early May with a variable amount of rainfall, sometimes as high as 900 mm such as occurred in the 2015-2016 rainy years and sometimes as low as 300 mm in drought years; but the average annual rainfall would be around 600 mm per year.

In the view of the DoS, the biggest problems in relation to Sulaymaniyah environment are untreated solid and liquid waste, hospital waste which is largely not sterilized or incinerated but disposed with municipal waste, waste of factories and cars, all of which contaminate the air, soil and water around Sulaymaniyah. The concern is clear expressed with a tone of helplessness “Sulaymaniyah environment is really polluted and we are in danger. It’s a big problem but who cares or pays attention?”

This concern was also reiterated by the public health professional we interviewed who said “we know generally the environment has been polluted by several sources such as cars, factory smoke, medical waste, and others kinds of waste which is not properly disposed.” These unresolved problems are globally known to have immediate and long-term impact on the health of populations, and in Sulaymaniyah too, as the professional stated that “several disease are related to these environmental hazards such as asthma, typhoid, diarrhea and cholera which occur repeatedly. Contamination of water and food and failure to properly treat the city’s wastewater which sometimes mixes with drinking water are responsible for some of these infectious diseases.”

The health professional said ‘in the past “there was a section called environmental health but this section was closed several years ago, and the mandate was given to the Board of Environment.” The Board of Environment has departments in major cities including Sulaymaniyah. However, they currently do not seem to have the sufficient capacities and professional expertise in relation to environmental health to monitor environmental risks and lead environmental protection efforts. Lack of emphases on environmental issues in the department of health has also led to scarcity of research on sources of pollution, environmental risks and health problems that could be related to acute and chronic environmental exposures.

### **Characteristics of the Study Respondents**

Total of 15 key informant interviews with relevant officials and 30 in-depth interviews with citizens as shown in table 2 were conducted. To have an indicator of respondents general feeling of being protected from environmental hazards, we included a question for each study participant to rate their feeling of being protected “On a scale of 10 where 10 is feeling completely protected and zero is not feeling protected at all, how much do you think you are protected from environmental health risks in general, not only related to your work?”. The analysis of the main characteristics of the respondents and the scores for the above question are presented in Table 3. In total, there were 45 interviews in the study (15 KII and 30 IDI). Of these 44 answered the rating question. The age of participants ranged from 23-56 years with a mean age of 36.2 years (SD 8.8). All KII but one was males while 67% of IDIs were male. The score ranged from 0-9 with a mean score for feeling protected from environmental hazards was 3.83 (SD 0.38) out of 10. The score

was not significantly different between IDI and KIIs (KII 3.1, IDI 3.7,  $p=0.62$ ) or between males and females (male 3.92, female 3.46,  $p=0.67$ ).

**Table 3 main characteristic of the participants**

	All	KII	IDI
	Number (%)	Number (%)	Number (%)
All	45 (100%)	15 (33%)	30 (67%)
Male	34 (76%)	14 (93%)	20 (67%)
Female	11 (24%)	1 (7%)	10 (33%)
Age in years,(mean)SD	36.2 (8.8)	-	
Mean score for feeling protected (SD)	3.83 (0.38)	4.1 (0.57)	3.7 (0.49)

The low score indicates that all participants irrespective of gender and role were highly concerned about the environment and considered themselves poorly protected from environmental health hazards. While this concern indicates that most respondents consider the environment not to be healthy and that their lives are at risk of environmental hazards, it also indicates awareness about the problem which could be a positive factor for future programs to address the problem.

### Drinking water and associated health hazards

The main sources of Sulaymaniyah drinking water are Dukan Lake (two pipe lines: project 1 and project 2), Sarchinar ground water and a few small sources in the city. Some peripheral neighborhoods lack piping and are still supplied through tankers. Transport of water from source to the city is done using GRP (Glass Fiber Reinforced Plastics), steel and iron pipes all of which are permitted under global practices. The city water network is mainly composed of polyethylene pipes. The network has been continuously renewed and repaired. According to the department of water, mixing of wastewater with the drinking water network is still a problem although rare compared to the past and happens 4-5 times a year.

One of the problems of the water supply that is also a concern for the population is the yellow tint of the water in certain times of the year. According to the water official, “this mainly occurs in autumn and spring when rains and flooding stirs the lakebed causing suspension of the residues containing high levels of H<sub>2</sub>S with yellow tint and bad odor. Contamination of the lake water with wastewater from the towns on the lake and the feeding rives also contributes to this problem.”

Contamination of rivers and agricultural fields with the untreated wastewater in the Sulaymaniyah governorate exposes the population to all those risks in varying degrees. Populations around Tanjaro River could be at a higher risk because of their vicinity to the polluted river and agricultural fields, and waste dump sites and sewerage channels. Populations supplied by water from Darbandikhan Lake could also be at a higher risk because the polluted surface water is piped to houses without proper treatment.

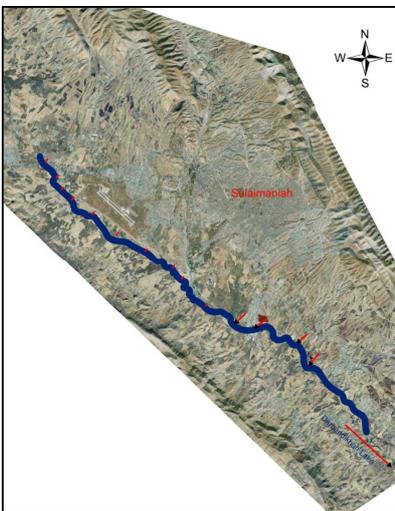
All the eight residents of Sulaymaniyah City that we interviewed were using tap water in their homes for washing and cooking, and mostly for drinking, except two participants who said they were using bottled water for drinking. The four main themes which emerged from the interviews about drinking water in Sulaymaniyah City were: (1) General satisfaction about water supply; (2) Interrupted supply (water open once 3-5 days and only for a few hours each time) and hence the need for storage in overhead and other tanks; (3) The presence of yellow tint to the water, especially in autumn; and (4) An odor and taste of chlorine.

### Liquid waste disposal and associated health hazards

The wastewater of Sulaymaniyah city is collected via a network of pipes that join into 19 separate concrete underground box channels (Fig 3) . These box channels flow outside the city and open to let the wastewater pass through the fields in narrow gullies southwest of the city. The wastewater of fourteen of

these boxes finally flows into Tanjaro River in Sarchinar, Awall and southern parts of the city. The total length of the wastewater network is around 200 km. The openings of some of these channels are located inside the boundaries of the city according to the new master plan. When the concrete boxes open and flow through fields, there is no protection; the wastewater makes its ways as an open stream through the narrow gullies which are not fenced or protected by any other means. Some of these open streams are now located in villages (such as Kani Goama) and urban residential areas because of the expansion of the city.

According to the Municipality official interviewed, one of the problems of the city is that “wastewater of hospitals, factories, slaughterhouses and the industrial area all mix with the household wastewater and flow to Tanjaro where it is used for irrigation.” Only two newly built hospitals (Shar Hospital and Faruk Medical City) have their own wastewater treatment systems; all other private and public hospitals including Hiwa Cancer Hospital mix their wastewater with the municipal channels. Over 90% of the city is covered with this sanitary waste disposal system. Some areas on the outskirts of the city and villages that were recently engulfed by the city’s expansion are not yet covered by the city’s wastewater system and the residents use self-dug pits to dispose of their wastewater. These areas contain an estimated to 2000 households.



All eight residents of Sulaymaniyah City that were interviewed in our assessment reported that they were generally happy about the liquid waste disposal in their houses and neighbourhoods; they did not voice any major concerns and expressed satisfaction about the sewerage system and an absence of any health problems related to that system because, in the words of one respondent resident, “the sewerage is covered, all pipes flow to an underground box channel which flows out of the city but I don’t know where to”. Residents living inside the city reported that there were no visible problems unless some breakage or blockage occurred in the neighborhood, which they said is usually repaired soon by the residents in the related houses or by the municipality depending on where the breakage or blockage occurs.

Figure 3 Location of wastewater channel outlets south of Sulaymaniyah City

During our site visits and interviews, we even observed one of these streams going into a fenced plastic greenhouse. We also observed several farmers watering their vegetable fields with the wastewater. The local authorities acknowledged that this as a health problem, including the health authorities, municipality officials, and the agriculture department. However, none of them have been able to prevent it, “we have tried and continue to try preventing this but the practice is still there and it has increased recently. This is a major problem which we have to monitor continually and destroy all those crops,” said the Municipality official. Similar opinion was expressed by the agriculture official, “yes we are aware of people using the wastewater for farming; we have encouraged those who are using well water to continue developing their farms and those using wastewater to stop their cultivation but they continue to use the wastewater and we have even been threatened trying to stop them.” Lack of alternative water sources, the free availability of the wastewater, and the perceived beneficial quality of the wastewater were some of the main reasons for this continuing risky and unhygienic practice by the farmers, despite the health risks and the continuous discouragement of this practice by the authorities.

Health risks of exposure to wastewater are related to the presence of inorganic toxic chemicals, organic chemicals and biological hazards. A review of studies on wastewater exposure pathways states that uptake of contaminants into the food chain is the most widespread pathway of concern in relation to wastewater irrigation [11]. Figure 4 from the same study shows the pathways that harmful exposures could take from wastewater to human beings. Even small amounts of heavy metals disposed in the soil would be of concern because of their accumulation and the impact of long-term exposures. Soil type and type of vegetables are

the main factors that determine the extent of uptake of the contaminants by plants. A study from India reported high concentrations of heavy metals in vegetables grown with wastewater, and also reported that uptake of heavy metals in the vegetables was highest for iron followed by Cobalt, Copper, Cadmium and Lead, and that the concentrations of all the metals were highest in leafy and tuberous vegetables, and less in the fruit vegetables, except for iron [12].

Farm lands irrigated with wastewater can retain high concentrations of these heavy metals years after cessation of wastewater exposure as reported by a study from China which reports persistence of heavy metals in soil, plants and hair of farmers from farms irrigated with wastewater three years earlier [13]. In addition to heavy metals, occurrence of active pharmaceutical compounds, detergents, oil gasoline, insecticides, and fertilizers in surface water, groundwater, manure, soil and plants is a global concern [16]. In places like Iraqi Kurdistan where medical waste is disposed in and with municipal waste, and the sewer and solid waste are left untreated and then mix in with rivers, relevant officials should be more concerned about the long-term effect of unsafe disposal these compounds as well.

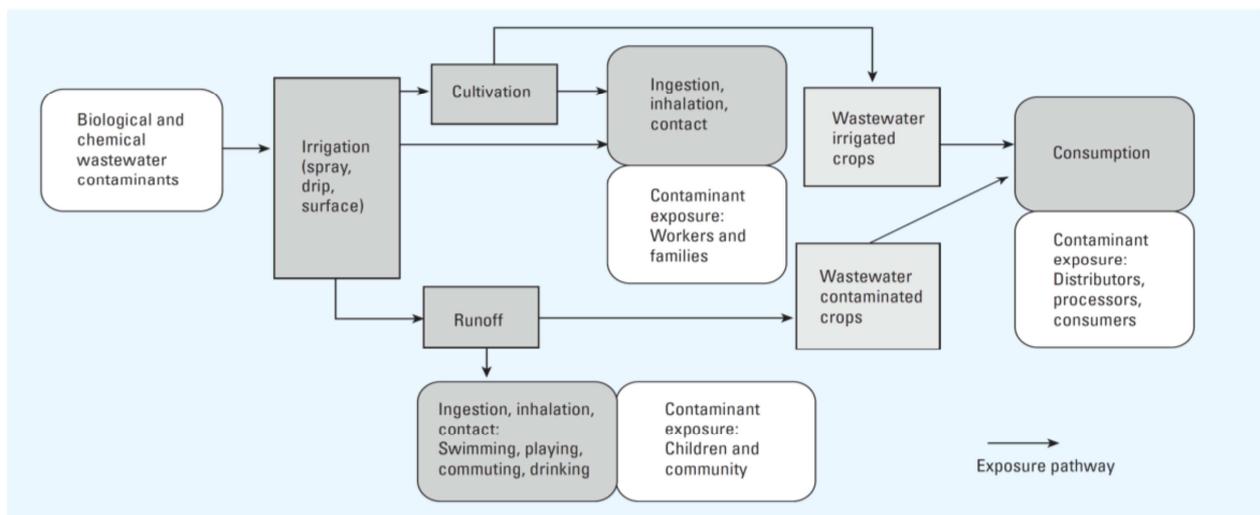


Figure 4. Exposure pathways from wastewater irrigation to consumers, agricultural workers and communities Source: [11]

A study from Vietnam on risk factors for diarrhoea in farmers [14, 15] reports the following significant factors which are all relevant to farmers working around the Tanjaro River: (1) Direct contact with polluted river (odds ratio = 2.4); (2) Handling human excreta in field work (OR = 5.4); (3) Handling animal excreta in field work (OR = 3.3); (4) Lack of protective measures while working (OR = 6.9) (e.g. use of gloves, boots, disinfectants, handwashing); (5) Never or rarely washing hands with soap (OR = 3.3, AF 51%); and (6) Eating raw vegetables the day before (OR = 2.4) [14-16]. Another study from Ghana reports a positive association between presence of ova of wastewater/soil-transmitted helminths and the stools of farmers exposed. The study reports that farmers and family members exposed to wastewater were three times more likely to be infected with *Ascaris* and hookworm compared to the unexposed control group [17].

The priority for farmers is irrigation of their crops and if the wastewater is more accessible, some farmers don't worry about or perceive there are health risks, as said in the words of one farmer "we use Tanjaro water because it is good for the growth of our crops, vegetables and orchards and it doesn't require fertilizers; it has no problem to our health." It appears that many farmers use this water, as another 33-year-old male farmer interviewed said, "most of the farmers use sewerage for irrigation especially in the summer when we face water shortages.

### Solid waste disposal and associated health hazards

The solid waste of Sulaymaniyah is disposed of in an open area of a few hectares of land overlooking the Tanjaro River and only 100 meters away from the river banks. The site is around 1 km southeast of the city

in close vicinity to residential areas such as the Tanjaro suburbs of Huwana and Chaqlawa villages, and an industrial area with several different kinds of factories and commercial warehouses. The solid waste dump site is not fenced off and it is completely open for cars, trucks, humans and animals to access directly. During the team visit to the city dump site, we observed over 30 people, including children, scavenging in the garbage, and municipality and private vehicles bringing in waste. Scavenging animals (dogs, cats and rats) and birds were also observed moving around in the garbage throughout the dumpsite.

The municipality official in charge of solid waste disposal told us that daily production of solid waste in the city is approximately 1,200 tons which increases to 1,250-1,300 tons during feasts and celebrations. The waste is collected and disposed by the Municipality (25%) and four private companies (75%) contracted by the Municipality. The official of one of the private companies said that “the composition of the garbage is a mixture of food, glass, paper and other materials of which we monthly collect and dispose of about 5,044 tons.” Altogether, about 1500 workers are involved in collecting and disposing the garbage for Sulaymaniyah City. An estimated 60% of the garbage is organic material, mainly food and about 4-5% are plastic and disposable containers.

Garbage from the majority of hospitals (75%) is also disposed of at the dump, along with the municipality waste. There is only one incinerator in the city which burns some medical waste and the ashes are then later disposed in the same city garbage site. Garbage of all private clinics, and there are hundreds of them in the city, is also mixed in with the household waste at the dump site. This was also confirmed by a disposal company official who stated that the garbage they collect is a mixture of all kinds of garbage, including solid waste of the hospitals, except for the waste of Hiwa Cancer Hospital and the Teaching Hospital which are disposed at the City’s Tanjaro garbage dump site directly by the hospitals themselves. The waste site monitor who we interviewed had seen this in the most dramatic way, citing “one incident which continues to haunt me is that one day I saw a dog holding a human part in his mouth which it had found inside the waste from the Emergency (Burns) Hospital.”

The northern bank of the river stretching directly below the garbage site is cultivated with vegetables. The piles of solid waste lie right next to the fields separated by a 1 meter high soil embankment which is half-filled with a filthy yellow-brown oily acid-smelling liquid leaching out from the piles of waste covering the steep hillside and valley. The team observed a black layer of asphalt covering parts of the soil. It is quite possible that during rainy periods the embankment fills and the liquid spreads into the agricultural fields and flows into the river nearby. It should also be noted that during the Environmental Health Assessment team’s visit to the dump site, cows were observed grazing in the fields just below the toxic leaching area and were walking in the river streams just below the dump site. It appears there are no written guidelines and regulations about collection and disposal of waste, or about safety procedures and guidelines for staff and local populations. As stated by one of the company officials “in relation to written guidelines, no one has given us any guidelines, only the Municipality has only designated an area for disposing the waste of the city and told use to cover it with soil.”

The people who were searching in the garbage during one of the visits, were of both sexes and all ages from as young as 6-7 years old. Some had piles of plastic bottles or cans collected and ready to be taken away. A few of these people were wearing masks, but the majority did not wear gloves and masks. When we arrived at the site and parked our car about 100 meters away from them, instantly a few young men came and warned us about taking any close-up photographs or videos. “No photos please, in the past we have seen social problems arising for some of those people because they were photographed while working,” one of the gentlemen said. According to the site monitor, those scavengers were poor people from surrounding suburban areas, some local residents and some others were internally displaced persons (IDPs) who came from conflict areas, searching to find anything that they could sell. One of the dump worker employees said that “every day, around 70-75 persons come and scavenge in the waste, they usually search for plastic, glass and iron and any material which can be used again as raw materials.”

Working with the waste has occupational risks to people handling it, whether they are waste collectors or scavengers especially if they are not using protective equipment. These problems include injuries with high risk of subsequent infection; respiratory disorders skin problems and allergies. The waste monitor had witnessed one case of an accidental death during the past 7 years (a worker run over by a garbage truck), but injuries were said to be more common and “verbal quarrels and disputes happen regularly with truck drivers and it is very annoying because they do not listen to the people who work here.” In relation to the waste collectors, the manager of one of the companies reported that during recent years they had not seen any disease outbreak or major health problem in their workers that could be related to their work.

An Indian study on waste collectors reports a 12-18% prevalence of respiratory disorders, a 5-44% prevalence of injuries and a 35-49% prevalence of allergies in waste collectors [18]. This study also reports that 22% of these workers and local residents did not use any protective gear.

Data from the literature has also suggests an increased risk of cancers of liver, kidney, pancreas, and non-Hodgkin's lymphomas in people living near landfill sites. A Canadian study assessing cancer risks in people living near a municipal solid waste landfill site in Montreal found statistically significant increase in risk of cancers of pancreas (OR 1.4), liver (OR 1.8), prostate (OR 1.5), and non-Hodgkin's Lymphoma (OR 1.5) [19, 20]. Bearing in mind the sanitary landfill site in the Montreal study area, such health risks could be expected to be much higher in the more uncontrolled and considerably less sanitary garbage sites of Sulaymaniyah.

The Municipality has thought of recycling the waste for years but in terms of actual plans, there was an agreement in 2015 with Lafarge Company to recycle solid waste of the city. However, this never materialized due to a lack of funds and a failure to allocate other resources such as land and electricity for the project as reported by the officials. For a relatively prosperous and rapidly growing region like Kurdistan, solid waste management should have been a priority during the past 10 years when the region was well-funded, not at this time of austerity when even basic services cannot be adequately managed. There seems to be little hope, if any, for the recycling plan to be revisited any time soon. The most appropriate plan at this time, until funds are guaranteed for recycling, could be establishing a controlled landfill in an area farther from the river banks where the flow of the leachate to the river could be minimized.

### **Industrial pollution and associated health hazards**

According the official reports, in 2014 there were 89 big industrial enterprises, 182 medium-sized enterprises, and around 10,400 small enterprises in Kurdistan Region [2]. According to the Directorate of Industry in Sulaymaniyah, around 1,650 small and medium-sized factories are registered in the directorate, excluding the big factors which are licensed by the Ministry of Industry. The main area of industrial activity is located southeast of the city near the Tanjaro River where around 900 businesses are located, including factories of plastic, Iron, oil, concrete block, asphalt, and other construction material.

The industry official interviewed acknowledged the dangers of all these factories around the river stating that “we are all aware that the establishment of all those factories in that location poses hazards to Sulaymaniyah population, but this was planned in the past; in the new master plan a different location is allocated near Arbat for industrial activities. However, it has not been implemented due to lack of budget.” Although the new location will be further away from Sulaymaniyah city, it will still be close to the Tanjaro River and overlooking the river still poses the same dangers to the environment if no proper measures are taken to protect the river and the general environment from industrial waste contaminants. Currently, the liquid waste from many of these factories flows to the river and their solid waste is disposed of at the city's solid waste disposal area that is near the riverside.

Factories, workshops and businesses of up to 75,000,000 ID also have to be registered at the Chamber of Commerce (CoC) in Sulaymaniyah. According to the CoC in 2016, there were 1,451 big projects, 1,898 small projects and 867 entrepreneur workshops in the governorate. However, many of these projects are not functional especially the small ones of which only about 700 are currently operating. The big factories are licensed by the Ministry of Industry and therefore, they are not followed-up and are not bound by CoC

regulations. Neither the Directorate of Industry nor the Chamber of Commerce seem to have any specific policies, guidelines and regulations about environmental protection and safety operations in relation to industrial activities.

The industrial directorate has a monitoring team that visits the factories mainly to ensure that they maintain a valid license. However, even these teams according to the official; have not been able to visit the factory sites during the past 6 months because of the financial crisis. The major industries in the governorate are cement and oil, but these were not focus of the current assessment. There are an unknown number of oil extraction sites and refineries in the governorate that could be a serious reason for concern on environmental pollution. According to an official from the governorate's fuel committee, the daily needs of Sulaymaniyah governorate for gasoline is estimated to be approximately 2 million liters, half of which is locally produced and half imported from neighboring countries. Gasoline is leaded and sold in 3 octane levels according to measured octane ratings, ranging from 88 to 95. There are approximately 200 modern petrol stations that follow safety standards and about 50 illegal ones.

A review of studies on health hazards of living near industrial installations [26] reports that living in the vicinity of industrial parks is associated with higher rates of perinatal health problems, neurological defects and other congenital anomalies. The study also reports higher risks of childhood leukemia and non-Hodgkin's lymphoma in people living near busy highways that could be related to exposure to higher benzene emissions. study from Ethiopia reported unsafe concentrations of heavy metals (Pb, Cr, Cu, Cd, Co and iron) in the wastewater of paper mills and unsafe concentrations of Pb in some green vegetables grown with this wastewater [21, 22]. People could be exposed to pollutants through a variety of pathways depending on the source and the type of release.

People living in the area are deeply concerned about these risks. For example, as a 32 year-old male resident living in the area put it: Many of the residents of the industrial area are poor workers living in simple houses and unsanitary conditions. A young woman, adding skin allergy to the list of health problems in the area explained "this is a residential area, we have built our houses without license from the municipality, therefore they do not let us drain sewerage to the channels; there are lots of environmental hazards here, life is impossible but we cannot afford to leave the area." Living in the vicinity of these pollution sources and being the most aware and affected people by the pollutants, any socially responsive and equity-focused program for the mitigation of the environmental health hazards should involve these populations throughout the assessment, planning, implementation, and program evaluation stages.

### **Agricultural practices and associated health hazards**

One of the important pathways of transmission of environmental hazards to humans is through the food chain. Microbiological hazards and potentially toxic elements and other hazardous compounds can get into the food products and gain access to human body through ingestion of food and water. These hazards can also accumulate on the surface of vegetables and be transmitted to humans directly. Urban and peri-urban farming around Sulaymaniyah city using the wastewater and the polluted Tanjaro River continues to be a serious issue of concern by most officials and several residents we talked to. The southern parts of the city and the areas around the Tanjaro River are cultivated with crops and vegetables with little or no control from relevant agriculture, health and law enforcement authorities.

According to an official from the directorate of agriculture that was interviewed by the team, there are around 1,000 donum of irrigated fields in the city. In relation to summer crops grown in and around the city boundaries, the area of fields cultivated with summer crops is over 2,000 donum in Bakrajo, over 9,000 donum in Tanjaro and over 1,000 in Bazyan. The area of fields cultivated with winter crops is 81,000 donum in Tanjaro, 46,000 donum in Bakrajo and 33,000 donum in Bazyan. The main winter crop produced in these areas is wheat and the main summer crops which are largely sold in the city are cucumbers, tomatoes and various kinds of other vegetables. The vegetables are consumed locally and since they include leafy vegetables eaten raw, they are of special concern in relation to transmission of infectious diseases including

diarrhea, protozoal and helminthic diseases, cholera and other water and food-borne diseases. In addition crops grown with water polluted with solid waste and industrial waste, could be source of potentially toxic elements and compounds that could have long-term effects on the health of consumers.

Addressing the problem of unhealthy practices in farming, and the mitigation of risks to human health, cannot be accomplished by the agricultural authorities alone, according to the official. Addressing these issues also requires to support and participation of the municipality government, health sector, and department of the interior, as well as the agricultural authorities and the local farmers themselves. The agricultural fields are not protected, and many are irrigated with unsafe water and there is no control of what and how fertilizers and pesticides are used. Supervision and control of these aspects require collaboration of the above authorities to establish regulations, provide guidance and awareness-raising activities, enforce regulations and impose penalties on farmers not abiding by the regulations. Even the agricultural department itself might need to establish and enforce stronger polices and regulations, especially in relation to quality control of local products, as there are currently no quality control tests for crops, and the products directly go to the market. Imported agricultural products are only subject to visual inspection. There is a center for agricultural research at the department for agriculture but in practice it does not have any significant activities.

The fields were usually small, simple and not organized and lacked any sanitary facilities such as clean water and toilets. Apart from the plastic houses observed, the farms are not physically isolated or fenced off but completely open to humans and animals. Except for plowing, it appears that all other work is done manually. Farmers were observed watering crops without wearing any gloves and masks, but some were wearing boots.

The villages in the area have different sources for drinking water. Some villages have deep wells, others have shallow wells and some get water through water tankers (trucks), especially in summer. When the village has a water project, the water from the deep well is connected to a storage tank and taps. Houses usually have private latrines connected to pits. Villagers who are served by a water project are usually happy about their drinking water especially those farther from the river. Those closer to the river have some concerns about the quality of the water as expressed by a 33 year-old male villager near the river.

Farmers living near the river and the industrial area attribute most of their health problems to the environmental pollution they see around them so visibly and they are very conscious about it. However, their own actions seem to be of less concern. They don't see much harm to themselves in using the polluted water for irrigation, using fertilizers and pesticides, and failing to use personal protective equipment in their work. It was clear from the interviews that almost all farmers whose lands are near the river use the polluted water for irrigation, and use chemical fertilizers and pesticides, without taking much precaution to protect themselves from the potential adverse effects of these unsafe practices.

Another important health-related practice in these areas near the city is using wastewater and polluted water for growing seasonal summer vegetables as discussed in an earlier section. Since seasonal crops and leafy vegetables are used on a daily basis by the farmers, and these crops are also easier to sell in the market, their cultivation is widely practiced. The danger of these vegetables such as cucumbers, tomatoes, lettuce, radishes, parsley, green onions, etc. is that their raw consumption could lead to infections with parasites and microbes. Some farmers, such as the 56 years-old woman quoted below, are aware that eating these vegetables could be associated with health risks, "eating raw vegetables is bad for our health and our children's health, like diarrhea and vomiting, but we have no choice we can only live here." Others, including this 23 year-old man did not think there were any health risks: "I think using raw vegetables does not pose any problems to human health." Vegetables are an essential part of diet in the region and cannot be abandoned. In addition, the risks to the farmers do not happen only by eating them raw but also during watering, picking and handling. Because of the absence of other water sources, at present, it may seem useless to try to discourage farmers from using the polluted water of Tanjaro River for farming. Until measures are taken to protect the river from pollution, or to provide alternate safe water sources for farmers,

only proper guidance can now be given to the farmers on safer farming practices, such as wearing personal protective equipment and proper washing of vegetables before eating. Using Sulaymaniyah wastewater for farming must be ultimately be strictly prohibited, but this is currently difficult to do as expressed by key informants the EH team interviewed, and it will require strong leadership, and additional resources, as well as enforcement actions from health and law enforcement authorities.

Exposure to and/or transmission of the potentially toxic elements and compounds from the polluted soil and water to the agricultural products is a real probability in the fields irrigated by the water from the Tanjaro River, throughout its course from Sulaymaniyah City to Darbandikhan Lake. Impact of this contamination on human health is a long-term one and is not immediately visible. This may be one reason for the absence of serious efforts and political will to recognize the problem and to adequately respond to it. As discussed in an earlier section, contamination of the food chain with these environmental pollutants could expose consumers in the long-term to serious negative health effects, including cancers. This issue should be taken seriously by the professionals, including relevant local authorities and political leaders, since its solution is not easy and requires sustained action and financial and human resources at all levels.

### **Darbandikhan Lake and associated health hazards**

According to Darbandikhan Dam officials, the dam was built during 1956-1961 time period, and it is composed of two main parts, one of reinforced concrete and the other an earthen soil-based component. The dam is 535 meters in length and its height is 128 meters. The altitude of the lake water is 485 meters above the sea level and the top of the dam is at 495 meters. The original capacity of the dam was 3 billion cubic meters, including 2.5 billion live capacity and 0.5 billion dead capacity. However, currently the capacity has been reduced to approximately 2.6 billion cubic meters because of sedimentation reducing the dead capacity to less than 0.1 billion.

The lake is the source of drinking water to for an estimated 500,000 people in Darbandikhan and a number of smaller towns nearby. The water is pumped to a pool at the river side and, from there, to three storage tanks before being distributed to the households via the city network. Checking the quality of the pumped water is done once a month using a limited number of tests such as pH, alkalinity, electric conductivity, nitrate, zinc, iron and turbidity. Although this is surface water and exposed to various sources of contamination from the feeding rivers and tributaries, there is no water treatment plant for filtration. The Dam official interviewed expressed concern about the water quality and did not believe it was suitable for drinking as such because “wastewater of Sulaymaniyah and other towns flow to the lake via the Tanjaro River; waste of a large number of factories is brought here via the same river; farmers wash their domestic animals in the lake using probably poisonous materials; and in addition, the lake is also polluted by municipal and industrial waste from Iranian towns via Sirwan River.”

Residents of Darbandikhan are equally concerned about the water in their houses. “They all get this water through the network, but that does not mean they all use it for drinking and even for washing purposes,” said the official, himself being a resident of the city. The local residents we interviewed all said they were not using the water for drinking; they usually use it for washing and cooking. A 37 year-old female resident said “we use well water, we never use water from the Darbandikhan Dam project for drinking because it is very dirty, it tastes and smells bad; but we have no choice but to use it for bathing and washing.” The residents generally use and share water from shallow wells. “We have a well, but we use a water filter for that because the water is a bit greasy and turbid, but previously we were using the government water and used to have some diseases such as sore throat, headaches and kidney problems,” said a male resident of 50 years of age. This resident was so concerned about the unhealthy water they were getting that he mentioned all the cities and towns polluting the lake, “ the government is responsible for the pollution of the lake because they do nothing while they know that waste of Sulaymaniyah, Nasr, Barkia, Halabja, New Halabja, Zarayan, Saiduadeq, Paveh-Iran and Jwanro-Iran all flow to the Lake.”

Interestingly, the lake management mandate does not include prevention of pollution of the lake water and the removal of pollutants, and therefore they do not have any professional or infrastructural capacities or guidelines to assess, monitor, and respond to lake water pollution.

Darbandikhan Lake provides livelihood for many fishermen who work on the lake throughout the year, except in seasons when fishing is prohibited. They know the lake better than anyone else and appreciate it, as it is the source of their income, as a 44 year-old fisherman stated: “I know all corners of this lake and I go fishing everywhere from the Tanjaro River to Darbandikhan Lake.” Some of the fishermen evidently consider the water to be clean and have no worries using it for all purposes. One fisherman stated: “No, the water is not dirty, I drink from this water and I have never got sick; it is true I have often seen animal corpses in the water, but I do not think that causes pollution of the water because they become food for the small fish which we call Janka.”

In relation to health problems from working in the lake water, both of the fishermen interviewed did express some concerns. The 44 year-old man said he had problems of hair loss on his legs and feet. His colleague had the same problem of hair loss in addition to fissures in the feet and skin inflammation. Apart from these skin problems, they had not experienced other diseases which they directly related to their working in the lake water.

Throughout its course to Darbandikhan Lake, the Tanjaro River is polluted by sewerage from Sulaymaniyah and a number of district towns, by leachate from the Sulaymaniyah solid waste site, by industrial waste from hundreds of small and medium-sized factories, by waste from the main slaughter houses and from pesticides and fertilizers from surrounding farms. Darbandikhan Lake needs extensive research to investigate for the presence of potentially toxic elements and compounds in the water, the lake bed and the fish population of the lake. Protection of the lake from these sources of pollution should be a priority and measures should be taken as soon as possible to separate the pollution sources from the river. The provision of safe drinking water to the people of Darbandikhan is another issue of concern. Surface water, even water that is not exposed to as much pollution as Darbandikhan Lake, requires filtration in addition to chlorination before pumping it to households. However, it should also be noted that even filtration will still not totally isolate some potentially toxic elements.

### **Conclusion and recommendation**

Environmental pollution in and around Sulaymaniyah city is caused by a variety of factors including untreated wastewater, contaminated agricultural fields, untreated solid waste, industrial waste and contamination of the Tanjaro River and subsequently Darbandikhan Lake with all kinds of potentially toxic waste. There is a lack of clear policies and regulations to protect the environment from potential pollutants and other actions and practices that might contribute to or exacerbate the environmental pollution and related health problems. The relevant governmental authorities are not sufficiently financed, equipped and empowered to tackle the problem. The highly polarized political system is driven by partisan interests and short-term gains rather than quality standards and long term policies and regulations which are essential for environmental protection and protection of the population from exposure to environmental pollutants. Officials and local residents are aware of the problem and are concerned to some degree about the immediate and long-term health and environmental consequences of neglecting environmental pollution problems. There is a need for urgent action at all levels. Some of main recommendations, based on the assessment findings and conclusions, are listed below:

Strengthening governmental and professional institutions those are working on the protection and monitoring of the environment. There is lack of necessary policies, regulations and guidelines in all sectors. Even existing regulations are not properly enforced and there is need to empower law enforcement authorities to apply the rules fairly and consistently, and without discrimination. Environmental protection and promotion of environmental health requires good governance and fighting corruption. Strengthening water management in relation to maintaining quality, observing regular water distribution schedules and

equitable supply to all residents of the city could serve as an immediate solution, along with infrastructural developments. In addition, further steps should be taken to protect sources of water from contamination at the source (e.g., Dukan Lake and Sarchinar).

In relation to wastewater disposal and treatment, the ultimate solution is establishment of sewerage treatment plants (for liquid wastes) and recycling of the sewerage as well as much of the solid waste. Using Sulaymaniyah wastewater for farming must be prohibited by law and enforced. A major immediate problem for the environment of Sulaymaniyah City is the solid waste disposal system and the ultimate solution must include an effective comprehensive recycling program. The Tanjaro River and Darbandikhan Lake are exposed to pollutants of all kinds, including wastewater, solid waste, industrial pollution and agricultural pollution. Immediate measures should be taken to prevent pollution of the river by eliminate the pollution from the river until a more permanent, sustainable and effective solution is found.

Industrial activities are poorly regulated and monitored in terms of environmental and occupational safety operations and standards. Contamination of the food chain around Sulaymaniyah City and the Tanjaro River with potentially toxic elements and compounds should be taken seriously by health professionals. Protection of Darbandikhan Lake from major sources of pollution should also be made a higher priority by the lake management team and other relevant authorities. Establishment of a continuous research effort is needed on the topic of environmental pollutants in and around Sulaymaniyah City and the Tanjaro River, in order to periodically quantify and monitor levels of various environmental contaminants in water, soil, plants and air. Undertaking epidemiological studies on the populations living in the vicinity of major sources of pollution is needed to investigate potential short-term and long-term health effects of human exposure to environmental hazards.

## References

- [1] Iraq. *Iraq: Environmental health* [<http://www.emro.who.int/irq/programmes/environmental-health.html>]. (2015).
- [2] KSRO, *KSRO: "Socio – Economic Monitoring System Report. In. Erbil"*. (2015).
- [3] Indicators. *Indicators* [<http://www.krso.net/Default.aspx?page=article&id=899&l=1&#krso2>]. (2005).
- [4] Mustafa, O., "*Impact of sewage wastewater on the environment of Tanjero river and its basin within Sulaimani city/NE-Iraq*". Geology MSc Thesis. Baghdad: College of Science, University of Baghdad, (2006).
- [5] Aziz, N.A., S.M. Salih, and N.Y. Hama-Salh, "*Pollution of Tanjero River by Some Heavy Metals Generated from Sewage Wastewater and Industrial Wastewater in Sulaimani District*". Journal of Kirkuk University–Scientific Studies. Vol. 7, No. 1. (2012).
- [6] Jaf, "*Overview of groundwater pollution in the Slemani City -Kurdistan Region*". (2011).
- [7] Ararat, K., et al., "*Darbandikhan lake poisoning event*". Nature. (2008).
- [8] Food, "*Circle of deat: water,land food*" [<http://kurdistantribune.com/2013/circle-of-death-water-land-food/>]. (2013).
- [9] Whitcomb, "*Recycling Gains Urgency, as Garbage Becomes Burning Problem in Kurdistan. In. Rudaw*". (2016).
- [10] Kjellstrom, T., et al., "*Urban environmental health hazards and health equity*". Journal of urban health, Vol. 84, No. 1, pp. 86-97. (2007).
- [11] Dickin, S.K., et al., "*A review of health risks and pathways for exposure to wastewater use in agriculture*". Environmental health perspectives. Vol. 124, No. 7, pp. 900. (2016).
- [12] Sharma, A., J.K. Katnoria, and A.K. Nagpal, "*Heavy metals in vegetables: screening health risks involved in cultivation along wastewater drain and irrigating with wastewater*". Springer Plus. Vol. 5, No. 1, pp. 488. (2016).

- [13] Massaquoi, L.D., et al., "*Heavy metal accumulation in soils, plants, and hair samples: an assessment of heavy metal exposure risks from the consumption of vegetables grown on soils previously irrigated with wastewater*". Environmental Science and Pollution Research. Vol. 22, No. 23. pp. 18456-18468. (2015).
- [14] Weber, F.A., et al., "*Pharmaceuticals in the environment—Global occurrences and perspectives*". Environmental toxicology and chemistry. Vol. 35, No. 4, pp. 823-835. (2016).
- [15] Pham-Duc, P., et al., "*Diarrhoeal diseases among adult population in an agricultural community Hanam province, Vietnam, with high wastewater and excreta re-use*". BMC public health. Vol. 14, No. 1, pp. 978. (2014).
- [16] Brender, J.D., J.A. Maantay, and J. Chakraborty, "*Residential proximity to environmental hazards and adverse health outcomes*". American journal of public health. Vol. 101, No, S1, pp. S37-S52. (2011).
- [17] Amoah, I.D., et al., "*Contribution of wastewater irrigation to Soil Transmitted Helminths infection among vegetable farmers in Kumasi, Ghana*". PLoS neglected tropical diseases. Vol. 10, No. 12, pp. e0005161. (2016).
- [18] Ravindra, K., K. Kaur, and S. Mor, "*Occupational exposure to the municipal solid waste workers in Chandigarh, India*". Waste Management & Research. Vol. 34, No. 11, pp. 1192-1195. (2016).
- [19] Goldberg, M.S., et al., "*Risks of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Quebec, Canada*". Archives of Environmental Health: An International Journal. Vol 54, No. 4, pp. 291-296. (1999).
- [20] Ding, N., et al., "*Respiratory cancers and pollution*". Eur Rev Med Pharmacol Sci. Vol. 19, No. 1, pp. 31-37. (2015).
- [21] Eliku, T. and S. Leta, "*Assessment of heavy metal contamination in vegetables grown using paper mill wastewater in Wonji Gefersa, Ethiopia*". Bulletin of environmental contamination and toxicology. Vol. 97, No. 5, pp. 714-720. (2016).
- [22] Ihedioha, J., P. Ukoha, and N. Ekere, "*Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria*". Environmental geochemistry and health. Vol. 39, No. 3, pp. 497-515. 2017.

