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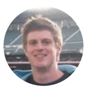

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Determination of trace metals in harvested rain water after the November 2012 bombing in Gaza by using ICP/MS

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Abstract
Rain water samples harvested for drinking and agriculture from Gaza collected after the November 2012 bombing, were analyzed for different trace metals (Ba, Cu, Zn, Co, Mn, V, Al, Pb, Cr, Ni, As, U, and Cd) as well as phosphorous content by ICP/MS. This study was conducted to determine the water quality of harvested rain water used for drinking in Gaza after the 2012 bombing, and to assess the potential effect of bombing on the amounts of trace metals in harvested rainwater. A total of 43 water samples were collected in November 2012 during the first rain after eight days of bombings from 43 house wells and rain water pools. The samples were analyzed for their pH, temperature, electrical conductivity, total dissolved solids, and different trace (heavy) metals content. The pH of all water samples was within the U.S. Environmental Protection Agency limits. The concentrations of the metals detected in the collected harvested rainwater vary significantly between the 43 samples, and all of them were detected in all water samples analyzed in this study. The concentration of eight trace metals (Pb, Ni, As, Cd, Cr, Ba, Mn, and Al) is higher than the allowed WHO limits in drinking water, and the rest of metals and phosphorous were detected in all water samples analyzed in this study. Overall our findings revealed that bombing in Gaza 2012 may have detrimental effects on the quality of harvested rain water used for drinking and agriculture in this part of Gaza where it is contaminated with metals that affect human health.

Keywords: Heavy metals, Harvested rain water, Gaza strip, Bombing, Lead, ICP/MS.

1. Introduction
Drinking water contamination with trace metals is one of the most important environmental issues as they are toxic even at low concentrations [1,2,3]. There are 35 metals that concern us because of occupational or residential exposure; 23 of these are heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc [4]. Trace metals and especially heavy metals are well known to be toxic to human beings, where health risks of heavy metals include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Exposure to some metals, such as mercury and lead, may also cause development of autoimmunity, in which a person's immune system attacks its own cells. This can lead

to joint diseases such as rheumatoid arthritis, and diseases of the kidneys, circulatory system, and nervous system. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Heavy metals may enter the human body via food, water, air, or absorption through the skin in agriculture, industrial, or residential settings [5-6].

Human activities have increased the concentrations of heavy metals in the environment. For example, anthropogenic activities e.g. industry, agriculture increase the contents of heavy metals in different environmental matrices e.g. water, soil, air, fruits, vegetables, fish..etc [7-10). In addition to these human activities, the use of weapons over the last century in conflicts and in training has polluted the environment with toxic compounds and heavy metals [11, 12). Studies, which are discussed below, following explosions and bombing in inhabited areas of different countries have shown that a range of pollutants (organic and inorganic e.g. trace metals) can be released to the soil, causing environmental and health consequences for human. The use of metals and heavy metals in weapons is implicated as the cause of the injuries without fragments. Also, the enhancement of already existing weapons of war by the utilization of particulate and potentially toxic metals has been described. This has led to the commissioning of weapons utilizing metals as augmenters, or as primary effective agents (small smart bombs, thermobaric grenades and shape charged weapons, to produce a molecular sieve of metal powder, capable of severing the human body) [13). It is an important question whether the toxic and genotoxic potential of metals used in weapons could be a cause for long-term environmental (soil, water, air..etc), and health damage in exposed populations and the military.

Many studies have investigated the contamination of environment and human health following bombing. Alaani S. et al (2011) have determined trace metals in hair samples from parents of children with congenital anomalies in Iraq and correlated this with the content of these contaminants in water samples. They have found high concentrations of heavy metals in hair samples, and have found a correlation between the metals found in the hair and in the drinking water, and concluded that the metals in drinking water is the sole source of these heavy metals in hair [14). Another study was conducted in Gaza where (Manduca P. et al (2014)) hair samples of newborns with congenital birth defects or developmentally premature birth were analyzed in a cohort of couples with documented parental exposure to military attacks in Gaza, and found high concentration of some heavy metals in hair samples. This study showed that the occurrence of birth defects is correlated to documented exposure of parents to weapons containing metal contaminants during attacks in 2009 [15). Skaik S. et al (2010) showed that metals, in particular known toxic and carcinogenic metals (e.g. lead, mercury, chromium, copper, arsenic, uranium, cadmium, zinc) were detected in wound tissues of victims from Gaza after bombing in 2006 and 2009. This study recommended also to conduct investigations on the effect of such bombing and weapons in Gaza on the environment (soil, water, air..etc) [16). Other studies were also concerned with the significance of bombing in changing trace elements status in soil, water and even in plants [17,18,19).

The objective of the current study is therefore to study the effect of 2012 bombings and explosions of inhabited areas of Gaza strip on the quality of harvested rain water by determining content of trace metals in different harvested rainwater samples collected from bombed area of Gaza. Harvested rain water was selected as rainwater harvesting is a common practice in Gaza strip due to the shortage of water and to the high population density of Gaza. In Gaza, rain water is collected in tanks from roofs and used for both landscape irrigation and indoor purposes. Additionally and in a large scale, rain water is collected from urban areas and stored in infiltration ponds. During the past twenty years, nearly 6300 cisterns were constructed in West bank and Gaza benefitting more than 132,000 residents, and 434 ponds targeting 230,000 beneficiaries in the West Bank and Gaza. Captured rainfall can be stored either in cisterns as drinking water, in the soil for plant production or in the aquifer through artificial recharge to improve the water resources in the region [20).

A significant portion of Gaza's population is likely to have been exposed to these pollutants from bombings directly through inhalation. Additionally, airborne pollutants would have settled on surfaces in a considerable portion of the densely inhabited areas of Gaza. In this regard, it is expected that the harvested rain water collected in the bombed area of Gaza would be contaminated with different metals. In the scientific literature, studies have been conducted to study the contamination of harvested rainwater with heavy metals; and according to Luke Mosley from SOPAC Water Quality Office [21), heavy metals are contaminants commonly found in rainwater collection systems, where they come from dust particularly in urban and industrialized areas (21).

2. **Experimental**

2.1. *Study area*

Gaza Strip is a strip of land on the eastern coast of the Mediterranean Sea, located in the Middle East (at latitudes 31°16" and 31°45"N and longitudes 34°20" and 34°25"E) [22) bordered by the Mediterranean Sea in the West and the Negev Desert and Egyptian Sinai Peninsula in the South with a total area of 365 Km^2. For administrative purposes; the area has been divided into five regions: North, Gaza, Middle, Khan Younis and Rafah. Each governorate consists of municipalities that varied in number depending on the number of towns or villages and the population of each. Gaza Strip is one of the most densely populated areas in the world, 4505 people per km^2. Gaza's water resources are essentially limited to that part of the coastal aquifer that underlies its area [23).
Regarding the topography of Gaza strip, it is a coastal foreshore plain according to a Topography that refers to the altitude of the land surface. The topography of the area is flat, where the altitude of the Gaza Strip land surface ranges between zero meters at the shore line to about 90 meters above means sea level in some places .The height increases towards the east from 20 to 90 meter above the sea level.
Generally; the climate of Palestine is of East Mediterranean type; identified as being hot and humid in a summer and cold in winter. The US Environmental Agency has classified regions into arid and non-arid regions based on rainfall of 12.5 in/yr (312.5 mm/year) to be the reference [24).
The area has a Mediterranean dry summer sub topical climate with mild winter; this is because of its locations as transitional zone between semi-humid Mediterranean climate and arid desert climate. The highest mean annual temperature is 30.85 °C in August, while the lowest mean annual temperature is 13.50 °C in January, with the mean annual temperature of 19.90 °C [24).

2.2 *Sampling and analysis*

Sampling has been carried out in November 2012 (the beginning of the rain season and after the end of war on Gaza) where 43 water samples were collected from 43 house wells and rain water pools. Figure 1 shows the location of the part of Gaza where the samples were taken, and the location of the cisterns analyzed in this study. The water samples were collected in 1-liter high density polyethylene bottles (pre-cleaned with 10% nitric acid followed by repeated rinsing with bi-distilled water), stabilized with ultrapure nitric acid (0.5% HNO_3), preserved in a cool place (about 4 °C) and transported to the lab of AlQuds University for further analysis. Temperature, pH, electrical conductivity, total dissolved solids, and dissolved oxygen were measured in the lab immediately after the arrival of the samples according to standard methods [25). The samples were then analyzed for trace metals content and phosphorous by ICP/MS (Agilent technologies 7500 series).
For accurate quantitative determination of heavy metals in water samples, an internal standard method was used using Nd as internal standard and a multi-standard calibration method (29 metals standard, matrix 5% HNO_3). Samples were prepared by dilution of 1.0 ml of the water samples to 10.0 mL with 0.3% ultrapure nitric acid and analyzed by ICP/MS. Each sample was analyzed three times and the results are expressed as mean ± SD (SD: standard deviation). Relative standard deviation (RSD) of the three results are calculated and found to be less than 5% for all samples for all heavy metals analyzed in this study, reflecting the precision of the method for the analysis of these heavy metals. Calibration curves for all heavy metals analyzed were constructed by plotting the ratio of the intensity of the analyte heavy metal to that of the internal standard vs. concentration of the heavy metal (in ppb), and results showed that the calibration curves are linear with correlation coefficient (r^2) greater than 0.999 for the heavy metals analyzed with a concentration range of 1-1000 ppb.

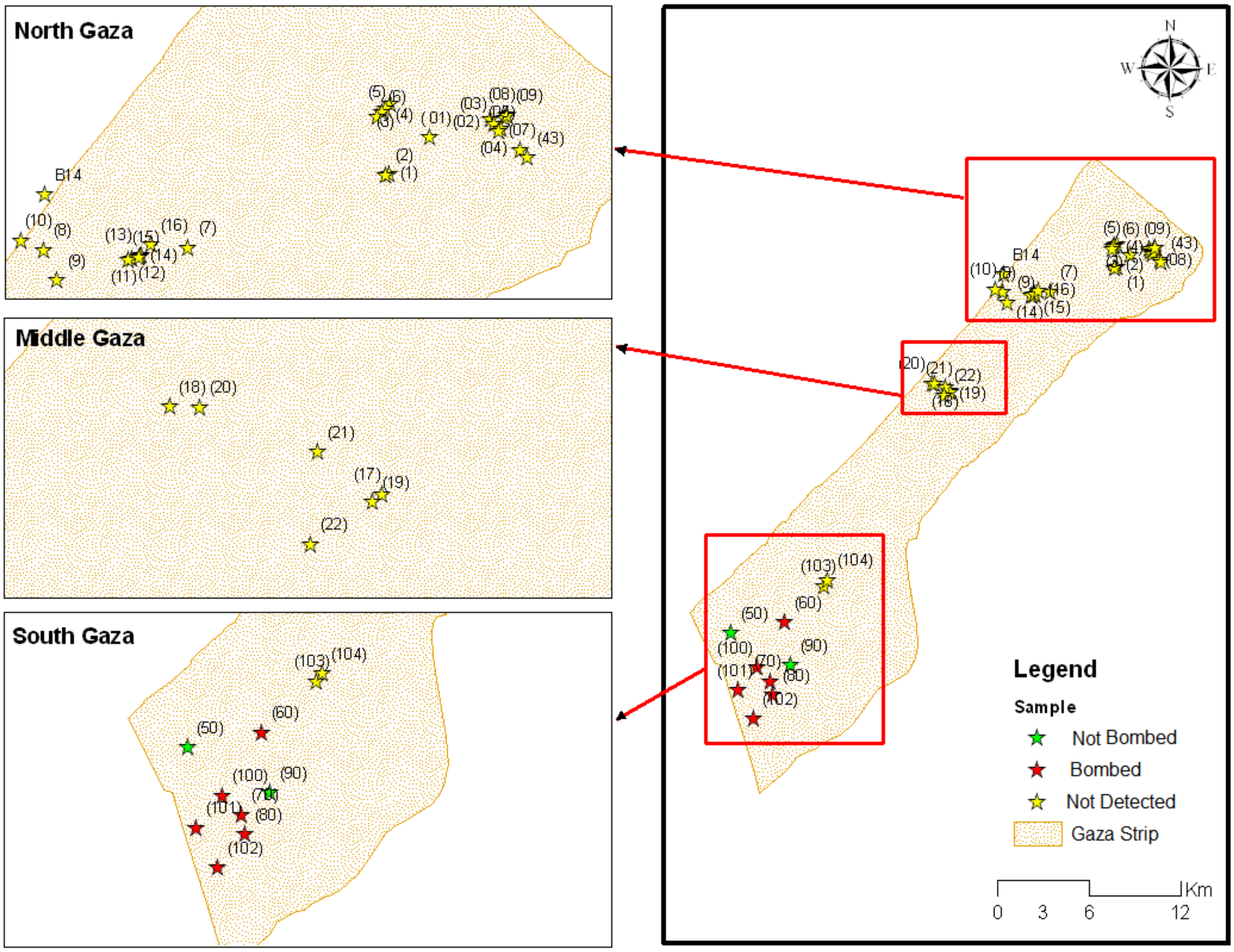

Figure 1: Map of Gaza strip showing the location of house wells and rain water pools (marked with *) containing harvested rain water analyzed in this work.

2.3 *The instrument*

The Agilent Technologies 7500 Series ICP- MS (Agilent 7500) can measure trace elements as low as one part per trillion (ppt) and quickly scan more than 70 elements to determine the composition of an unknown sample with a MassHunter Workstation software automates the analysis and accurately interprets the resulting data. The ICP/MS instrument consists of an on- board peristaltic pump that controls the flow of sample solution into and waste (drain) out of the instrument, a nebulizer (Micro Mist nebulizer) that uses a stream of argon to disperse the sample, an ICP Argon plasma torch using Argon as plasma gas, auxillary gas and nebulizer (carrier) gas, two pumps for evacuation, Quadrupole mass analyzer with unit resolution, an octapole reaction system (ORS), and electron multiplier detector.

3. **Results and discussion**

This study was conducted to investigate the effect of bombings and explosions of Gaza during Israeli war on Gaza strip in November 2012 on the quality of harvested rain water. Harvested rainwater is used for drinking and agriculture in Gaza as it is located in the semiarid region and it is one of the scarce water countries.

The pH of all water samples ranged between 7.2-7.9 (with mean temperature of 19.0 °C) which is neutral to slightly basic and in the allowed limit (6.5-8.5) according to WHO regulations. Electrical conductivity, total dissolved solids, and dissolved oxygen for water samples ranged from 340-2010 μs/cm, 190.4-1125 mg/l, and 8.3-9.15 mg/l, respectively. The limit for total dissolved solids in drinking water according to WHO is 1000 mg/L [26), where our results showed that ten samples have exceeded this limit indicating high amounts of dissolved salts e.g. heavy metals.

3.1. *Heavy metals content*

Results showed that twelve trace metals (Ba, Cu, Zn, Co, Mn, V, Al, Pb, Cr, Ni, As, and Cd) were detected in all water samples analyzed (43 samples) in this study. All of them are heavy metals except aluminum and barium. The concentration (in ppb) of these metals were found to be in the range of : 142.2-3483.6, 2.87-672.4, 0.3-1703.7, 1.3-125.2, 54.9-13148.6, 4.0-155.1, 40.9-50840.4, 0.05-450.7, 0.67-112.2, 2.3-133.0, 0.43-25.0, and 0.06-12.61, for Ba, Cu, Zn, Co, Mn, V, Al, Pb, Cr, Ni, As, and Cd respectively. Figures 2-5 show the concentrations of Pb, Mn, Al, and Ba in the water samples analyzed in this study (logarithmic scale of concentration was used since there is a significant difference in the concentrations of these metals within the samples).

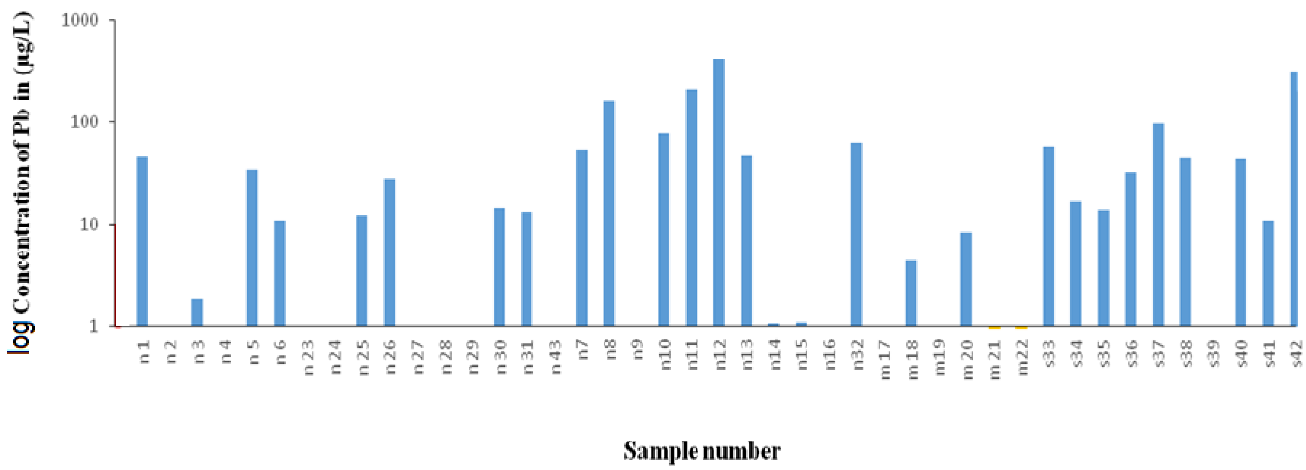

Figure 2: log concentration of Pb (in μg/L) vs. sample number of all water samples.

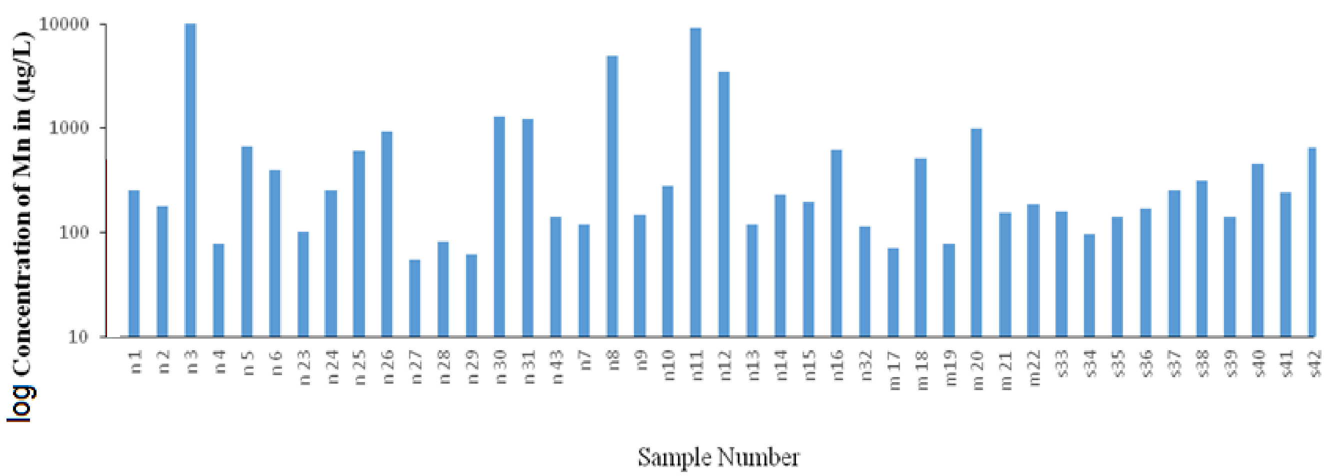

Figure 3: log concentration of Mn (in μg/L) vs. sample number of all water samples.

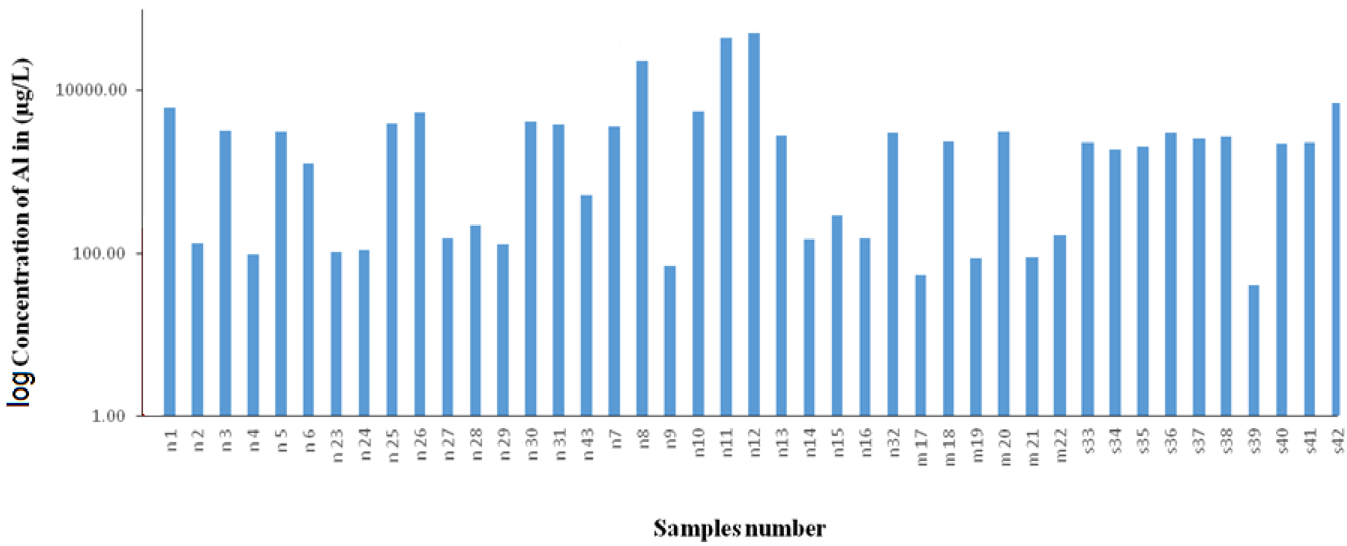

Figure 4: log concentration of Al (in µg/L) vs. sample number of all water samples.

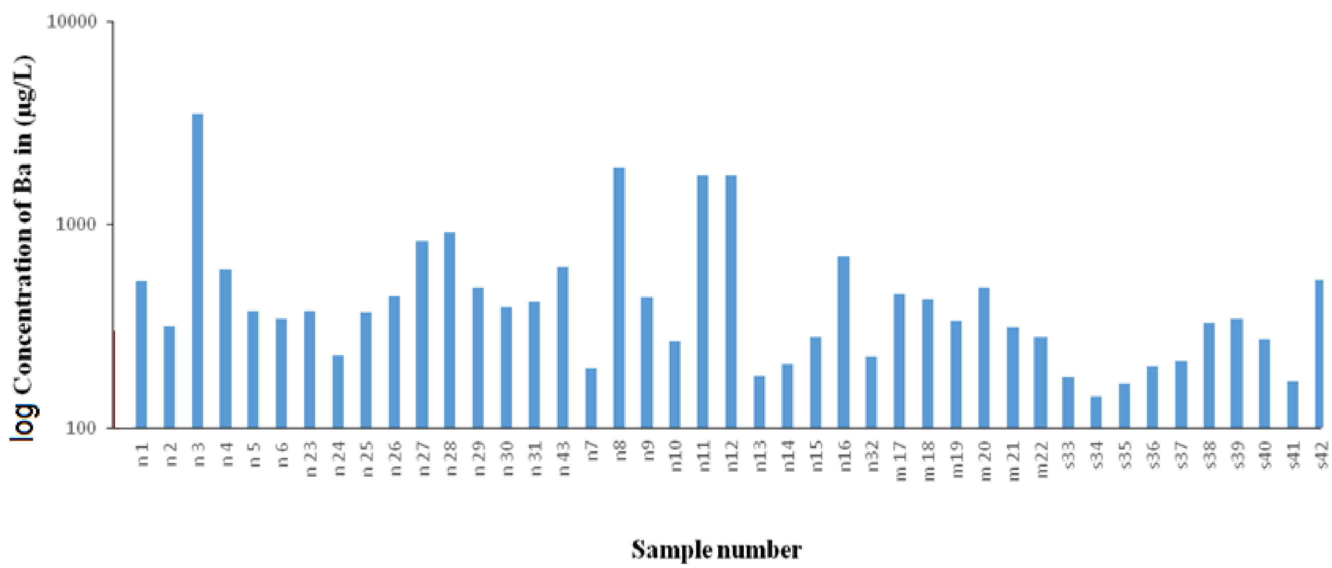

Figure 5: log concentration of Ba (in µg/L) vs. sample number of all water samples.

In addition to these metals, uranium and phosphorous were detected in all samples analyzed in this study with ranges of 0.04-6.95, and 50.25-20166.1 ppb, respectively.

The average and median of the concentration of these metals are shown in table 1. As we can see from this table, there is a significant difference between the average and median values indicating that there are differences in the concentrations of the metals in the water samples analyzed in this study. A one way ANOVA statistical test was used to test if the concentration of heavy metals is significantly different in the 43 water samples analyzed. Results showed that all metals concentrations are significantly different in the 43 water samples at 95% confidence level. This indicates that these water samples are different from each other in terms of heavy metals concentration. This result confirms locational variations of heavy metals in the water samples analyzed in this study.

The detected metals in the harvested rainwater samples analyzed in this study are of known human carcinogenic/teratogenic metals (class 1, IARC) as As, Cd, Cr, Ni [27], and of possible carcinogens (class 2B, IARC) as Co, V, and of known fetotoxic metals as Al, Cu, Ba, Pb, Mn [28,29]. Toxicological and experimental studies established that high concentrations of these metals disrupt body functions and have pathogenic effects in human respiratory organs, kidney and skin and affect sexual and neurological development and functions [28-30].

The allowed WHO limit for lead in drinking water is 10 ppb [31], however our results showed that more than 50% of the samples analyzed in this study (23 out of 43) exceeded this limit with an average of 10.9 ppb and highest value as 450.7 (45 fold of the allowed limit). It has long been known that lead in drinking water is highly toxic. Exposure to lead is cumulative over time. High concentrations of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys. This damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain. Infants, children, pregnant women, and fetuses are more vulnerable to lead exposure than others because the lead is more easily absorbed into the sensitive tissue of actively growing bodies. According to the recently released lead toxicological profile for lead from Agency for Toxic Substances and Disease Registry (ATSDR), the adverse health effects of lead range from slight increases in blood pressure at 100 ppb to severe retardation and even death at very high blood-lead levels of 1000 ppb [31].

For Cr, the allowed WHO limit is 50 ppb, however 3 water samples out of 43 found to have Chromium with concentrations higher than the allowed WHO limit. The highest Cr concentration was found to be 112.2 ppb. The health hazards associated with exposure to chromium are dependent on its oxidation state; the hexavalent form is toxic. For Mn, the allowed WHO limit in drinking water is 500 ppb; our results showed that 13 water samples were found to exceed this limit with highest concentration of 13148.6 ppb (about 26 fold of the allowed concentration) and average of 1014.6 ppb which exceed the allowed WHO limits. Regarding Nickel, our results showed that 12 water samples out of 43 have Ni concentration higher than the allowed limit (20 ppb in drinking water) with the highest concentration of 133.0 ppb.

The concentration of Barium in the harvested water samples analyzed in this study was found to be in the range of 142.2 to 3483.6 ppb (with an average of 546.1 ppb). WHO has set a maximum allowed limit for Ba in drinking water of 700 ppb [32] where six samples were found to exceed this limit with a highest concentration of 3483.6 ppb. When people are exposed to Ba for short periods at levels above the maximum contaminant level, they may experience gastrointestinal disturbances and muscular weakness. Additionally, Ba has the potential to cause high blood pressure when exposed to levels above the limit for long periods of time [33].

The concentration of Cadmium in the harvested water samples analyzed in this study was found to be in the range of 0.06 to 12.61 ppb (with an average of 1.6 ppb). WHO has set a maximum allowed limit for this metal in drinking water of 3 ppb, however it was found that 5 samples out of 43 exceed this limit. Cadmium in drinking water is toxic, and exposure to it with concentrations higher that the allowed limit could experience kidney damage [34].

Regarding Arsenic which has a WHO limit of 10 ppb in drinking water, it was found that it has been detected in all samples analyzed in this study with highest concentration of 25.0 ppb and average of 5.5 ppb. Additionally this metal was found to exceed the WHO limit in 6 samples out of the 43 samples analyzed in this study. It is well known that arsenic present in drinking water is toxic and causes bladder, lung and skin cancer, and may cause kidney and liver cancer. Arsenic also harms the central and peripheral nervous systems, as well as heart and blood vessels, and causes serious skin problems. It also may cause birth defects and reproductive problems [34].

Aluminum was also detected in all water samples analyzed in this study with average concentration of 4659.2 ppb which is much higher than the allowed WHO limit (200 ppb), and was found that 67% of the samples analyzed in this study exceed this limit. Aluminium has been associated with Alzheimer’s and Parkinson’s disease, senility and presenile dementia [34].

Cobalt and Vanadium have no limits in drinking water by WHO, however they were detected in all water samples analyzed in this study. Regarding Cu, and Zn, the allowed WHO limits in drinking water is 2000, and 3000 ppb, respectively, and our results showed that these metals were found in the analyzed water samples within in these limits, but they were detected in all water samples analyzed in this study.

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Phosphorous was detected in all water samples analyzed in this study with high concentrations (range of 50.25-20166.1ppb, and average of 1620.6ppb). These high concentrations of phosphorous may be attributed to the white phosphorous munitions used in Gaza during the war. Uranium was also detected in all water samples analyzed in this study with a range of 0.04-6.95 ppb and average of 1.2 ppb, and it is attributed to the depleted uranium used in this war.

Table 1: Concentration of trace metals detected in harvested rain water after the November 2012 bombing in Gaza by using ICP/MS.

Sample #	Concentration of metals (ppb)													
	Ba	Cu	Zn	Co	Mn	V	Al	Pb	Cr	Ni	As	Cd	U	P
1	530.25 ± 1.78	126.13 ± 3.51	282.72 ± 1.69	11.66 ± 0.07	251.5 ± 1.05	29.52 ± 0.11	6101.2 ± 31.5	45.82 ± 0.22	58.57 ± 1.77	63.99 ± 1.91	9.82 ± 0.32	0.8 ± 0.05	2.48 ±0.03	901.27± 3.01
2	315.51 ± 2.06	11.65 ± 0.2	268.46 ± 1.79	4.22 ± 0.06	177.12 ± 1.57	27.45 ± 0.19	131.51 ± 3.32	0.28 ± 0.01	4.58 ± 0.23	23.2 ± 0.08	9.35 ± 0.25	0.85 ± 0.07	1.52± 0.01	411.47±2 .18
3	3483.56 ± 54.05	24.79 ± 1	509.92 ± 3.92	100.56 ± 2.19	13148.56 ± 173.15	15.04 ± 0.21	3247.31 ± 53.35	1.84 ± 0.02	6.24 ± 0.38	95.49 ± 3.39	11.37 ± 0.23	4.82 ± 0.16	0.08± 0.01	20166.1± 9.44
4	606.28 ± 4.26	6.16 ± 0.04	0.3 ± 0.02	2.9 ± 0.03	77.93 ± 0.44	4 ± 0.05	97.6 ± 7.26	0.05 ± 0.01	0.67 ± 0.1	3.71 ± 0.03	4.86 ± 0.24	0.06 ± 0.02	0.64± 0.02	2254.64± 8.98
5	373.97 ± 2.6	51.16 ± 0.46	812.9 ± 3.66	7.05 ± 0.04	675.72 ± 5.62	18.47 ± 0.16	3172.32 ± 27.99	34.13 ± 0.34	6.05 ± 0.22	20.3 ± 0.23	6.35 ± 0.02	1.26 ± 0.09	0.58± 0.01	2553.97± 7.30
6	343.87 ± 0.98	38.86 ± 0.92	515.03 ± 1.53	4.8 ± 0.05	394.92 ± 0.82	12.63 ± 0.16	1284.72 ± 2.42	10.86 ± 0.03	3.98 ± 0.19	13.64 ± 0.2	7.02 ± 0.29	1.04 ± 0.07	0.41± 0.01	3358.28± 11.29
7	196.58 ± 0.95	41.47 ± 0.23	939.1 ± 8.45	1.3 ± 0.01	118.81 ± 0.68	4.23 ± 0.02	3609.79 ± 18.2	53.13 ± 0.5	4.56 ± 0.03	11.59 ± 0.22	1.24 ± 0.04	1.71 ± 0.04	0.34± 0.01	382.13±3 .41
8	1909.57 ± 31.99	158.11 ± 4.74	1074.3 ± 12.35	70.55 ± 1.04	5012.23 ± 59.55	66.62 ± 0.6	23388.15 ± 191.83	162.42 ± 2.16	39.42 ± 1.33	87.19 ± 3.4	15.05 ± 0.29	4.25 ± 0.14	4.20± 0.03	2467.48± 8.51
9	439.78 ± 5.03	17.76 ± 0.48	9.54 ± 0.26	3.1 ± 0.05	148.63 ± 1.93	7.91 ± 0.1	68.6 ± 3.71	0.54 ± 0.01	3.8 ± 0.18	4.6 ± 0.11	6.1 ± 0.2	0.39 ± 0.04	0.89± 0.01	1018.07± 10.52
10	264.9 ± 13.97	39.68 ± 0.59	258.88 ± 6.48	3.93 ± 0.29	277.7 ± 24.48	22.68 ± 0.23	5542.9 ± 52.68	77.73 ± 0.59	23.68 ± 0.59	10.35 ± 0.3	6.13 ± 0.08	0.91 ± 0.06	0.84± 0.02	373.60±6 .29
11	1756.4 ± 50.31	258.59 ± 6.52	988.58 ± 31.36	125.23 ± 3.97	9121.81 ± 266.79	145.02 ± 4.02	44064.43 ± 1559.66	208.67 ± 6.02	109.18 ± 1.97	133.02 ± 2.68	12.06 ± 0.2	10.4 ± 0.37	6.95± 0.10	726.24±9 .46
12	1754.72 ± 17.46	672.44 ± 15.8	1001.1 ± 19.39	49.22 ± 0.49	3505.35 ± 48.68	155.11 ± 1.52	50840.44 ± 688.87	450.74 ± 5.14	112.18 ± 3.02	69.56 ± 2.01	24.99 ± 0.57	12.61 ± 0.36	6.69± 0.06	1762.24± 8.63
13	178.98 ± 2.55	82.16 ± 2.74	309.5 ± 5.13	3.51 ± 0.04	118.99 ± 1.24	15.39 ± 0.22	2802.52 ± 24.77	46.62 ±0.36	28.25 ± 0.63	17.57 ± 0.61	7.4 ± 0.32	6.28 ± 0.29	0.39± 0.01	178.01±1 .23
14	205.05 ± 0.76	19.64 ± 0.33	459.72 ± 1.66	2.67 ± 0.02	230.79 ± 1.23	5.92 ± 0.03	147.7 ± 1.58	1.06 ± 0.01	3.14 ± 0.13	7.26 ± 0.26	2.21 ± 0.12	1.13 ± 0.07	0.11± 0.01	214.63±3 .62
15	280.25 ± 3.5	30.61 ± 0.3	192.06 ± 7.91	5.75 ± 0.08	194.23 ± 1.23	19.35 ± 0.28	294.29 ± 1.6	1.08 ± 0.01	16.86 ± 0.49	8.65 ± 0.11	3.73 ± 0.09	1.18 ± 0	0.51± 0.01	113.72±1 .60
16	696.8 ± 2.95	3.16 ± 0.11	4.29 ± 0.13	2.63 ± 0.03	620.86 ± 5.05	5.89 ± 0.03	153.39 ± 2.97	0.18 ± 0.01	3.45 ± 0.03	40.27 ± 0.88	0.43 ± 0.04	0.4 ± 0.04	0.81± 0.02	167.46±2 .42

17	455.74 ± 5.73	4.18 ± 0.08	1.07 ± 0.18	3.27 ± 0.04	71.36 ± 0.85	15.27 ± 0.15	53.65 ± 0.99	0.07 ± 0.01	5.31 ± 0.18	2.3 ± 0.05	0.83 ± 0.07	0.13 ± 0.01	1.65± 0.03	113.01±1.99
18	429.07 ± 7.08	8.33 ± 0.23	84.84 ± 1.43	4.46 ± 0.09	518.6 ± 10.16	13.99 ± 0.26	2363.11 ± 37.93	4.38 ± 0.08	2.82 ± 0.1	11.02 ± 0.47	1.51 ± 0.02	0.52 ± 0.02	0.46± 0.01	962.84±2.23
19	336.4 ± 3.97	3.59 ± 0.02	0.8 ± 0.13	2.64 ± 0.02	78.73 ± 0.5	7.28 ± 0.04	86.81 ± 2.1	0.05 ± 0.01	2.67 ± 0.08	2.45 ± 0.1	1.18 ± 0.01	0.14 ± 0.01	0.16± 0.01	254.91±2.79
20	491.61 ± 3.6	30.37 ± 0.18	430.32 ± 4.9	8.8 ± 0.11	1006.25 ± 9.04	4.3 ± 0.07	3155.65 ± 41.25	8.28 ± 0.11	9.52 ± 0.06	28.48 ± 0.51	4.61 ± 0.11	1.07 ± 0.03	0.63± 0.01	2855.07± 9.60
21	313.28 ± 3.74	9.02 ± 0.7	19.59 ± 0.1	3.67 ± 0.02	154.44 ± 1.37	15.02 ± 0.13	89.47 ± 4.27	0.21 ± 0.01	6.71 ± 0.14	9.16 ± 5.13	9.06 ± 2.32	0.25 ± 0.04	0.27± 0.01	1205.05± 7.48
22	277.66 ± 3.09	8.15 ± 0.32	50.23 ± 0.58	2.58 ± 0.04	189.18 ± 1.3	13.56 ± 0.11	168.4 ± 1.6	0.16 ± 0.01	5.17 ± 0.2	7.44 ± 0.28	10.31 ± 0.25	0.32 ± 0.01	0.19± 0.01	845.52±7.38
23	376.38 ± 2.3	10.44 ± 0.04	58.82 ± 1.72	3.11 ± 0.1	100.61 ± 6.17	12.62 ± 0.14	103.33 ± 34.06	0.25 ± 0.23	5.11 ± 0.23	5.45 ± 0.12	4.23 ± 0.05	1.57 ± 0.05	0.04± 0.01	4528.35± 12.11
24	226.71 ± 4.62	13.29 ± 0.21	40.27 ± 0.94	3.73 ± 0.06	256.37 ± 4.2	21.21 ± 0.51	109.73 ± 1.66	0.47 ± 0.01	14.1 ± 0.08	12.78 ± 0.39	4.6 ± 0.2	0.48 ± 0.07	1.05± 0.03	565.20±4.06
25	368.97 ± 6.36	21.1 ± 0.62	288.16 ± 5.57	8.8 ± 0.17	614.06 ± 11.81	26.36 ± 0.43	3970.67 ± 73.21	12.11 ± 0.24	19.37 ± 0.53	18.58 ± 0.53	2.94 ± 0.15	1.1 ± 0.1	0.94± 0.01	609.97±3.02
26	446.86 ± 2.91	21.14 ± 0.18	359.66 ± 1.01	17.8 ± 0.17	933.15 ± 8.01	24.7 ± 0.09	5312.33 ± 19.66	27.68 ± 0.24	26.23 ± 0.45	24.25 ± 0.63	3.24 ± 0.17	1.48 ± 0.08	1.06± 0.02	651.35±4.72
27	828.53 ± 4.3	2.87 ± 0.04	0.62 ± 0.05	2.4 ± 0.04	54.9 ± 0.14	16.69 ± 0.13	151.54 ± 12.09	0.11 ±0.01	7 ± 0.25	2.91 ± 0.11	1.41 ± 0.04	0.09 ± 0.03	1.95± 0.03	134.29±2.84
28	915.08 ± 7.57	3.53 ± 0.1	3.92 ± 0.02	2.44 ± 0	81.65 ± 0.37	16.81 ± 0.05	220.45 ± 8.14	0.27 ± 0	7.63 ± 0.17	2.87 ± 0.21	1.38 ± 0.08	0.11 ± 0.02	1.77± 0.01	145.57±1.73
29	489.51 ± 4.92	3.56 ± 0.07	0.34 ± 0.15	3.21 ± 0.08	61.54 ± 0.67	12.66 ± 0.16	129.37 ± 2.6	0.17 ± 0.01	4.04 ± 0.01	2.85 ± 0.07	0.53 ± 0.01	0.2 ± 0.01	1.46± 0.04	50.25±2.0
30	393.66 ± 3.02	30.75 ± 0.48	565.45 ± 5.2	17.75 ± 0.1	1302.3 ± 17.07	19.23 ± 0.25	4165.73 ± 54.19	14.5 ± 0.15	5.35 ± 0.07	18.73 ± 0.14	1.92 ± 0.08	2.87 ± 0.12	0.52± 0.01	2996.68± 4.55
31	418.01 ± 4.3	29.62 ± 0.57	540.92 ± 3.88	17.08 ± 0.19	1245.94 ± 10.77	17.92 ± 0.14	3821.46 ± 34.72	13.13 ± 0.12	4.68 ± 0.18	19.39 ± 0.41	1.85 ± 0.02	2.73 ± 0.16	0.58± 0.01	2876.13± 8.77
32	222.91 ± 1.6	56.94 ± 1.91	246 ± 0.36	2.82 ± 0.02	115.09 ± 0.54	12.89 ± 0.1	3041.74 ± 3.65	62.86 ± 0.2	22.33 ± 0.9	8.16 ± 0.23	1.35 ± 0.04	1.54 ± 0.11	0.30± 0.01	100.86±0.36
33	176.6 ± 1.96	31.86 ± 0.11	235.91 ± 2.39	2.09 ± 0.04	157.98 ± 3.13	20.46 ± 0.51	2298.13 ± 37.49	57.24 ± 1.07	12.23 ± 0.29	17.7 ± 0.06	5.97 ± 0.19	0.41 ± 0.07	0.68± 0.02	690.61±4.23
34	142.21 ± 0.72	20.66 ± 0.45	206.75 ± 4.46	1.45 ± 0.02	96.41 ± 1.61	30.49 ± 0.39	1893.47 ± 27.18	16.73 ± 0.15	13.88 ± 0.35	7.69 ± 0.27	2.83 ± 0.07	0.35 ± 0.02	0.57± 0.01	286.61±5.88
35	164.26 ± 1.78	26.3 ± 0.59	272.82 ± 3.31	3.3 ± 0.04	142.3 ± 2.06	19.44 ± 0.23	2074.21 ± 22.19	13.86 ± 0.15	11.56 ± 0.27	10.63 ± 0.2	5.31 ± 0.16	0.27 ± 0.04	0.43± 0.01	372.27±2.93
36	200.82 ± 0.6	38.61 ± 0.51	289.27 ± 1.73	4.77 ± 0.03	169.59 ± 1.26	28.12 ± 0.19	3011 ± 18.62	32.16 ± 0.42	17.64 ± 0.39	12.14 ± 0.18	6.98 ± 0.17	0.41 ± 0.03	0.68± 0.01	453.94±3.26
37	212.93 ± 2.75	51.95 ± 0.96	474.75 ± 5.38	3.82 ± 0.06	253.96 ± 3.15	21.52 ± 0.26	2600.05 ± 35.1	98.07 ± 0.81	14.97 ± 0.33	15.67 ± 0.13	5.37 ± 0.06	0.83 ± 0.03	1.17± 0.08	829.14±6.29

38	325.73 ± 2.21	25.74 ± 0.36	381.87 ± 5.12	3.78 ± 0.05	317.1 ± 2.62	17.29 ± 0.18	2695.46 ± 43.41	44.56 ± 0.51	7.11 ± 0.08	9.42 ± 0.21	2.75 ± 0.07	0.75 ± 0.07	0.83± 0.01	914.66±5.59
39	344.92 ± 1.11	10.81 ± 0.13	4.15 ± 0.05	2.33 ± 0.01	141.48 ± 1.14	27.17 ± 0.26	40.92 ± 2.7	0.06 ± 0	6.27 ± 0.15	6.47 ± 0.04	6.19 ± 0.18	0.28 ± 0.01	1.50± 0.03	784.53±7.30
40	273.45 ± 2.49	48.5 ± 1.44	372.89 ± 4.26	6.51 ± 0.04	461.78 ± 4.25	28.68 ± 0.29	2246.33 ± 22.78	43.97 ± 0.18	9.15 ± 0.14	20.07 ± 0.72	8.13 ± 0.13	0.74 ± 0.06	1.68± 0.04	1650.29± 7.45
41	168.37 ± 2.02	57.46 ± 0.45	146.24 ± 2.18	4.66 ± 0.05	242.34 ± 2.34	53.32 ± 0.68	2276.66 ± 17.8	10.74 ± 0.09	17.19 ± 0.33	11.43 ± 0.2	4.4 ± 0.15	0.55 ± 0.04	0.45± 0.01	309.93±1.51
42	531.16 ± 4.02	188.89 ± 3.92	1703.67 ± 13.9	8.56 ± 0.06	647.94 ± 6.8	42.09 ± 0.35	8807.74 ± 59.72	309.83 ± 2.51	31.32 ± 0.83	29.39 ± 0.81	10.64 ± 0.23	1.36 ± 0.03	2.16± 0.02	7390.62± 3.10
43	615.36 ± 1.82	7.99 ± 0.26	16.25 ± 0.17	3.07 ± 0.01	139.96 ± 0.37	14.98 ± 0.07	512.74 ± 23.1	0.87 ± 0.01	4.45 ± 0.14	7.53 ± 0.47	0.79 ± 0.04	0.18 ± 0.04	1.15± 0.02	57.63±2.32
Range	142.2-3483.6	2.87-672.4	0.3-1703.7	1.3-125.2	54.9-13148.6	4.0-155.1	40.9-50840.4	0.05-450.7	0.67-112.2	2.3-133.0	0.43-25.0	0.06-12.61	0.04-6.95	50.25-20166.1
Average	546.1	54.6	335.4	12.74	1014.6	25.8	4659.2	43.4	16.7	21.8	5.5	1.6	1.20	1620.6
Median	368.9	25.7	268.5	3.78	230.8	17.9	2276.7	10.9	7.1	11.6	4.6	0.8	0.68	690.6

Results expressed as average ± SD for three samples (SD: standard deviation).

From table 1, it was found that the highest concentration of seven metals (Cu, V, Al, Pb, Cr, As, and Cd) were found in sample number 12. Additionally, the other metals also present in high concentrations in this sample, and the total concentration of trace metals and phosphorous is 60417 ppb which is the highest compared to other samples. Samples number 3 and 11 were also highly contaminated with trace metals and phosphorous with total concentration of 40815 and 57666, respectively. Actually sample number 11 and 12 have the highest total concentration followed by sample number 3, and 13. These samples are highly contaminated with trace metals as they are located in an area directly bombed; sample number 3 was obtained from Rain water pool next to house that has been hit by one rocket, while samples number 11, 12, and 13 were collected from different rain water pools where the area was hit by eight missiles.
In this regard, bombings and explosions in Gaza which occurred in November 2012 is considered as the main cause of these heavy metals that were found in harvested water that is used for drinking and agriculture use in this area of Gaza strip.

Conclusions

Harvested rainwater from bombed area of Gaza strip contains different trace metals with eight heavy metals (Ba, Mn, Al, Pb, Cr, Ni, As, Cd) exceeding the WHO limits in drinking water. pH of the waters samples is within the WHO limits, while some water samples exceed the limits for total dissolve solids and electrical conductivity. Based on the results of this study, it is believed that the bombing of Gaza in November 2012 may present one source of heavy metal and phosphorous contamination in the harvested rain water samples analyzed in this study.

However, pre-existing sources of heavy metal and phosphorus contamination resulting from agricultural or industrial practices must be taken into consideration as possible causes apart from bombing (UNEP, 2006). However other sources of waste contamination in this high populated region have not been controlled for. Uncontrolled consumption of harvested rainwater used for drinking in this region of Gaza may be dangerous for human health. We recommend additional studies to monitor the trace metals in water (surface, ground, etc.) and soil of Gaza strip.

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