Research Article

Pollution of Drinking Water in Different Localities in KSA

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ABSTRACT

Drinking water quality has been greatly affected as a result of biohazards and industrialization. There are many microorganisms can initiate waterborne infections including enteric and aquatic bacteria that are strongly resistant to most of disinfectants. Beside, heavy metals can pollute drinking water either through improper industrial waste drainage systems or inadequate monitoring of the plumbing integrity, heavy metals have a great hazard on health if exceed the permissible limit. This study aimed to qualitatively screen the presence of any waterborne bacteria as well as to measure the concentrations of some heavy metals in drinking water samples from different localities in KSA. Samples were collected from industrial and suburban – non industrial – cities, as well as different sources and were analyzed for Manganese (Mn); Cupper (Cu); Cobalt (Co); Cadmium (Cd); Zinc (Zn); Mercury (Hg); Nickel (Ni); Arsenic (As) and Lead (Pb) using Inductively coupled Mass Spectrometer and their concentrations were compared to the permissible limits defined by WHO guidelines. Results showed no microbial contamination, while the variation of concentrations of heavy metals was clear among samples from different localities. Only (As) and (Hg) concentrations exceeded the permissible level and the highest levels were detected in the samples driven from the industrial provinces, indicating the improper disposal of industrial waste. On the other hand, variation in heavy metals concentration among the samples that were collected from different sources indicates the hygienic status of the commercially produced drinking water, whereas the lowest concentration of Cd, Pb, Mn and Cu were detected in bottled water samples. The aim of this study is to determine the incidence of microbial growth and/ or heavy metals in drinking water as environmental contaminants that may lead to many expected health hazards.

Keywords: Pollution, Industrial, Heavy Metals, Pathogens, Drinking Water.

INTRODUCTION

Drinking water is a major source of microbial pathogens especially in developing regions, although poor sanitation and food sources are integral to enteric pathogen exposure. Gastrointestinal disease outcomes are also more severe, due to under-nutrition and lack of intervention strategies in these regions. Poor water quality, sanitation and hygiene account for some 1.7 million deaths a year world-wide, mainly through infectious diarrhoea. Nine out of 10 such deaths are in children and virtually all of the deaths are in developing countries[1].

The better known waterborne bacteria of concern are *Salmonella typhi* causing typhoid fever, *Salmonella paratyphi* (paratyphoid fever), other Salmonella (salmonellosis), Shigella spp. (bacillary dysentery), *Vibrio cholera* (cholera), enteropathogenic *E. coli* (Gastroenteritis), *Yersinia enterocolitica* (gastroenteritis), *Campylobacter jejuni* (gastroenteritis), *Legionella pneumophila* and related bacteria (acute respiratory illness / legionellosis), thermally enriched water Leptospira spp. (leptospirosis), various mycobacteria (pulmonary illness) and many opportunistic bacteria[2]. All are easily control by chlorination of water, but recontamination of treated water is a huge problem [1].

Generally, drinking-water gastrointestinal cases are not well quantified, even in developed regions, due to the insensitivities of surveillance and specific epidemiology studies. [3, 4]

Heavy metals are considered major source of drinking water pollution after microbial contamination. Drinking water can be a significant source of exposure to substances which are harmful to health in excess quantities**.** The presence of elements such as iron (Fe) and manganese (Mn) can cause both aesthetic problems and, at higher concentrations, can have potentially harmful health effects [5]. The WHO guideline values (GV) form the basis of many national and international water quality standards, including European Union legislation (Directive 98/83/EC, Council of the European Union 1998). The GVs are periodically reviewed and revised, which generates considerable debate on the merits of those revisions [6,7,8,9]. The chemical quality of drinking water sourced from groundwater is known to vary spatially as a result of: variations in aquifer geology and chemistry; treatment works method(s); and reaction between the water and distribution and/or plumbing systems. Bottled waters similarly vary, predominantly from natural processes, but may also be influenced by leaching of the bottle itself [10]. Zinc (Zn) can be introduced into water naturally from rocks and soil. It plays a role in many body functions and necessary for making a lot of proteins in the body. Zinc deficiency in animals including humans causes stunted growth and male sexual immaturity. An excess accumulation of Zn in the human body causes harmful effects such as acceleration of anemic conditions, whereas drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. Concentration of Zinc (Zn) in water samples shouldn't exceed 5000 µg/L [5]. Lead and copper reach drinking water primarily through plumbing materials. When drinking water is exposed to lead and copper may cause health problems ranging from stomach distress to brain damage.

Concentration of Lead (Pb) in water samples should not exceed 190 µg/L, while the accepted concentration of copper (Cu) in drinking-water is ranged from 5 – 30.000 µg/L. [5] Most of the Earth's cobalt is in its core needed at low levels as catalysts for enzyme activities. Too high concentrations of cobalt may damage human health. Concentration of cobalt should not exceed 36 µg/L in drinking water [5]. Mercury is present in oceans, seas, rivers and lakes. It's highly toxic and accumulates in the brain where they may cause the destruction of the nervous system. Concentration of mercury should not exceed 1 µg/L in drinking water [5]. The presence of cadmium in drinking water can be the result of leaching from galvanized pipes and fittings. It is toxic metal causing both acute and chronic toxicity in humans. Concentration of Cadmium (Cd) in water samples is should not exceed 7 µg/L [5]. Cadmium (Cd) accumulates in the liver and kidney, particularly in the kidney cortex. Manifestations of cadmium toxicity such as histological changes in the kidney, liver, testes, pancreas, bowels, blood vessels, etc. has been reported in the literature [11,12,13]. Elevated levels of arsenic are more likely to be found in drilled wells than in dug wells or surface water supplies. Clinical significance of arsenic may lead to high mortalities due to liver, lung, bladder or kidney cancer if its concentration reached the ration 1/1000 in drinking water. Concentration of Arsenic in water samples should not exceed 2.5 µg/L [5]. Manganese is a trace element that occurs naturally in soil, water, and plants, and exists naturally in rivers, lakes, and underground water. We need a small amount of manganese in our diet – but not too much. Several studies have linked excessive manganese exposure and neurological disorders in children. Infants are of particular concern because they retain more manganese than adults do, probably because they absorb more and excrete less of it. Breast-fed infants tend to have a low exposure, but infant formulas contain manganese concentrations around 100-fold higher than those of breast milk. If powdered infant formulas are mixed with drinking water containing manganese equivalent to the WHO guideline value, the limit set for infant formula by the European Commission's Scientific Committee on Food can be exceeded. In 2006, the WHO lowered the guideline value for manganese in drinking water from 500 to 400 µg/L. Ljung and Vahter explain how WHO decided on that number. Although no single study is suitable for use in calculating a guideline value, the weight of evidence from actual daily intake [in humans] and from studies in laboratory animals given drinking-water in which neurotoxic and other effects were observed supports the view that a provisional health-based guideline value of 0.5 mg/litre [500 µg/L] should be adequate to protect public health. It may become noticeable in tap water at concentrations greater than 0.05 milligrams per liter of water (mg/L) by changing the color, odor, or taste of the water [6]. The primary source of nickel in drinking-water is leaching from metals in contact with drinking-water, such as pipes and fittings. Severe effects of nickel include reducing growth and development, cancer, organ damage, nervous system damage and death. Concentration of Nickel in drinking water should not exceed 10 µg/L

MATERIALS

Samples

Thirty water samples were collected and used for this study as follow:

- Three different tap water samples of three areas were collected from each city from following cities: Al Majmaah, Zulfi, Al Qassim, Riyadh and Dammam
- One water sample of the water well from Zulfi
- Bottled water from two companies, three samples from each company.
- Three samples of filtered refilled water and three samples without filter.

Reagents for quantitative measurement

Conc. Nitric acid

Equipment

Laminar air flow, Autoclave, Incubator and Inductively coupled mass spectrometry: NexION 300D (Perkin Elmer, USA)

METHOD

Microbiological examination

All the samples were streaked on Nutrient agar and Muller Hinton plates and incubated at 37° C for 24 hours

Measuring the concentrations of heavy metals in water samples

The assessment of manganese, cupper, cobalt, cadmium, zinc, mercury, nickel, arsenic and lead concentration levels was carried out by Inductively Coupled Plasma Spectrometry (ICP-MS; Hitachi, Ltd, Tokyo, Japan): NexIon 300D (Perkin Elmer, Waltham, MA). The operating conditions of the instruments were as the following: nebulizer gas flow was 0.65 L/min, lens voltage was 9.55 V, analog stage voltage was – 1745, pulse stage voltage was 950 V, scan mode was peak hopping, dwell time was 40 ms, and integration was 1200ms. Results were recorded and analyzed statistically in College of Science, King Saud University, Riyadh, KSA.

RESULTS AND DISCUSSION

Results of microbiological examination

Four samples only showed positive bacterial growth. Identification of the grown strains indicated the presence of bacterial colonies due to sample's containers contamination, the colonies count was less than 10 CFU. No pathogenic microorganisms were isolated. The absence of pathogenic bacteria may be either due to accepted hygienic measures applied on water supply systems in KSA or may be due to elevated concentrations of certain heavy metals. It is well known that addition of trace amounts of heavy metals to the environment of microbial cells often stimulates microbial growth [14]. However, higher concentrations result in severe reduction of microbial activity, which is reflected by reduction of the apparent growth rate and increase in lag time. Heavy metal toxicity on microorganisms has been discussed previously [15]. Heavy metals-induced delay in the increased in metabolic activity in response to substrate arrival, as well as oxygen mass transfer limitation during active aeration [16]. Previous studies explained the strong probabilities behind the inhibition of microbial growth examined in the current study.

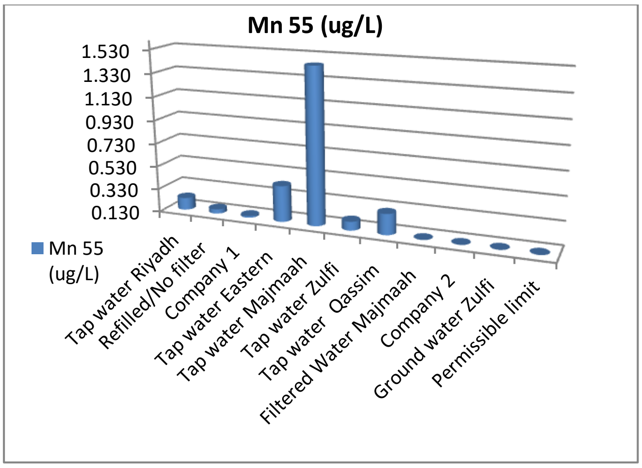

Figure 1: Level of Mn among the examined samples

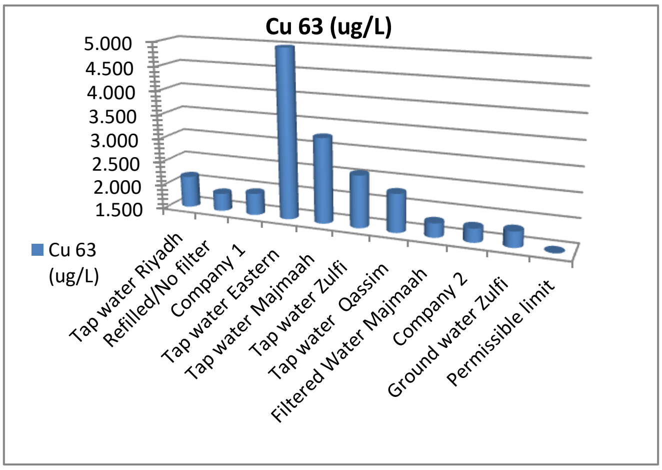

Figure 2: Level of (CU) among the examined samples

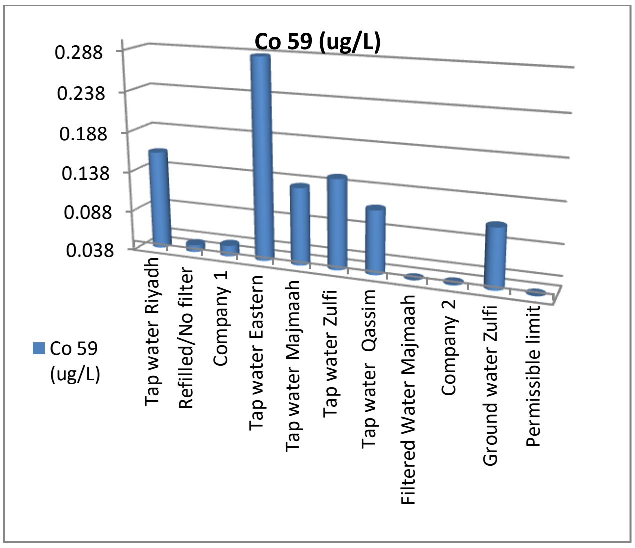

Figure 3: Level of (CO) among the examined samples

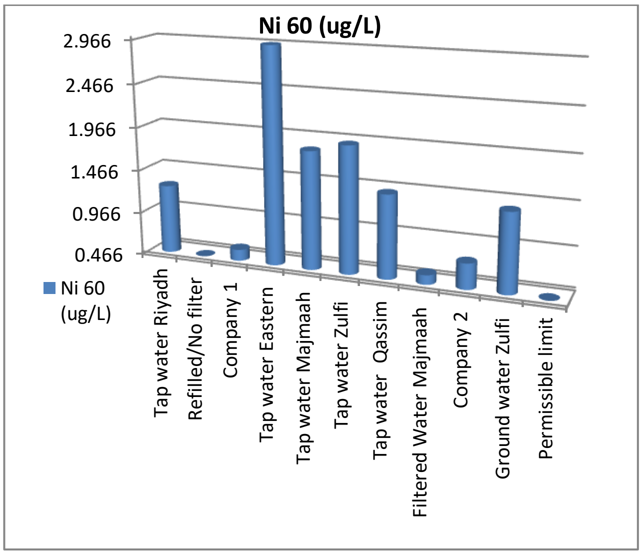

Figure 4: Level of (Ni) among the examined samples

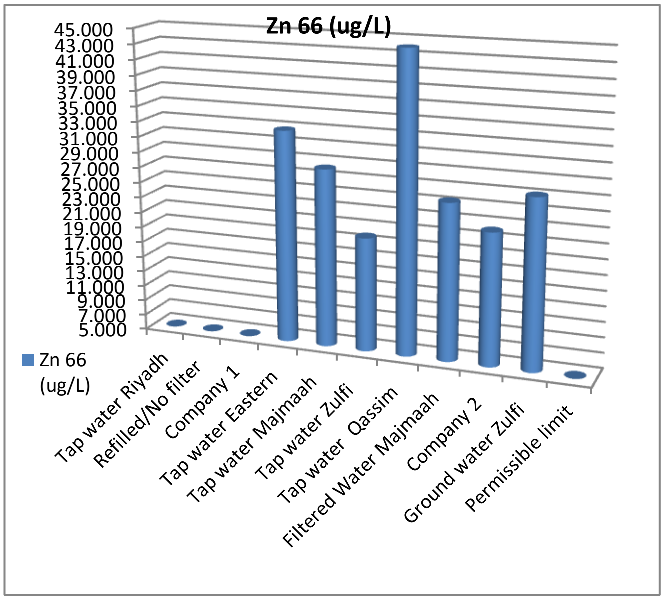

Figure 5: Level of (Zn) among the examined samples

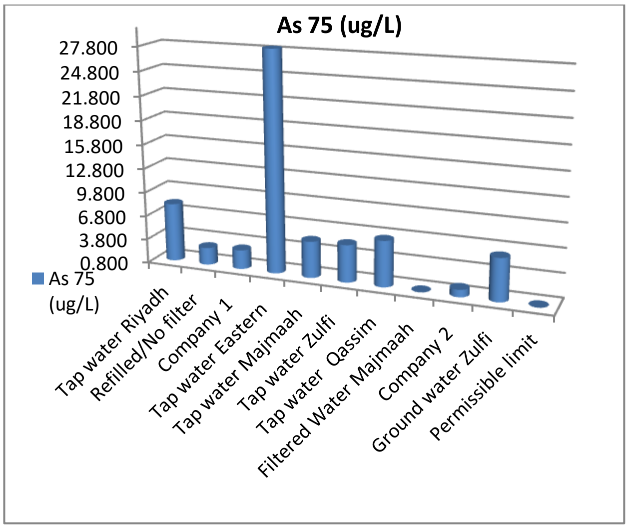

Figure 6: Level of (As) among the examined samples

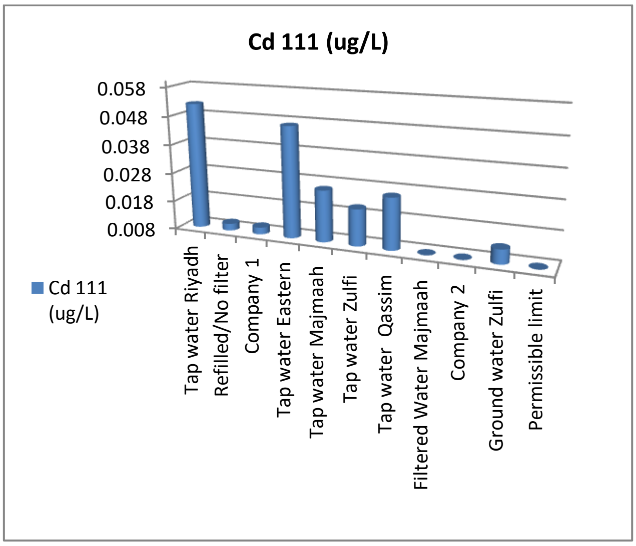

Figure 7: Level of (Cd) among the examined samples

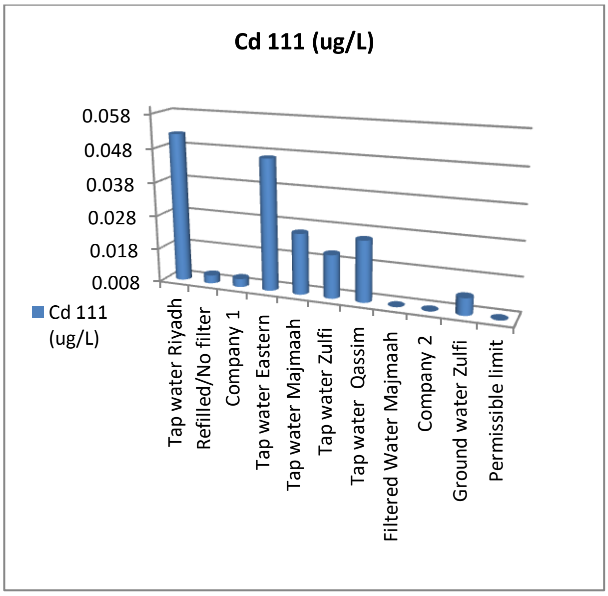

Figure 8: Level of (Hg) among the examined samples

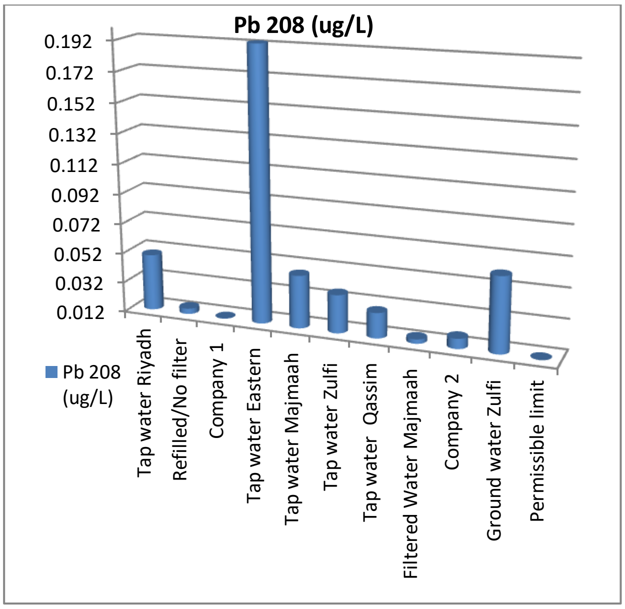

Figure 9: Level of (Pb) among the examined samples

Results depicted in table (1) showed that the concentration level recorded of (Mn) from water samples collected from different localities ranged from 0.109 µg/ L to 1.459 µg/ L (Fig. 1). Manganese level was below the permissible level in tap water samples collected from Majmaah city (1.459 µg/L) but it was the highest recorded level among the surveyed provinces as shown in Fig (1).In spite of the recent claim that Mn in drinking water is not found above 400 µg/L and is not a threat to human health, the WHO (1996) previously stated that Mn in drinking water from Greece and Japan greatly exceeded 400 µg/L and caused significant neurological damage in humans [5]. On the other hand, In 2011 the 400 µg/L drinking-water guideline for manganese was withdrawn with the assertion that since "this health-based value is well above concentrations of manganese normally found in drinking-water, it is not considered necessary to derive a formal guideline value" [5] .Another study mentioned that there were 16 cases of poisoning were reported, the symptoms including lethargy, increased muscle tone, tremor, and mental disturbances. However, over 50 countries have drinking-water or potential drinking-water supplies with manganese concentrations above 400 µg/L[6]. In other words, since manganese might affect the taste of drinking-water and stain laundry and plumbing fixtures at less than 400 µg/L, the WHO assumes that a person will not drink such water, so a 400 µg/L guideline is not needed and according to this report, our study can confirm that only monitoring of the level of manganese is sufficient to make sure it is less than the permissible level.

Table 1: Heavy metals concentrations mean± (SD)

Sample	Mn 55 (µg/L)	Cu 63 (µg/L)	Co 59 (µg/L)	Ni 60 (µg/L)	Zn 66 (µg/L)	As 75 (µg/L)	Cd 111 (µg/L)	Hg 202 (µg/L)	Pb 208 (µg/L)
Tap water Riyadh	0.235±(0.014)	2.155±(0.071)	0.161±(0.005)	1.266±(0.062)	4.837±(0.183)	8.105±(0.324)	**0.052±(0.002)**	**3.780±(0.083)**	0.050±(0.002)
Refilled/No filter	0.167±(0.005)	1.867±(0.028)	0.047±(0.001)	0.466±(0.013)	2.122±(0.106)	2.944±(0.123)	0.010±(0.0002)	2.692±(0.053)	0.016±(0.0002)
Company 1	0.144±(0.017)	1.953±(0.017)	0.051±(0.001)	0.596±(0.029)	2.370±(0.080)	3.176±(0.117)	0.010±(0.0001)	2.184±(0.041)	0.012±(0.00003)
Tap water Eastern	0.440±(0.002)	**4.989±(0.284)**	**0.287±(0.006)**	**2.968±(0.109)**	32.825±(1.378)	**28.164±(0.929)**	0.047±(0.001)	**3.051±(0.061)**	**0.194±(0.013)**
Tap water Majmaah	**1.459±(0.052)**	3.262±(0.185)	0.134±(0.004)	1.833±(0.117)	28.316±(0.849)	5.344±(0.261)	0.026±(0.001)	2.213±(0.152)	0.047±(0.001)
Tap water Zulfi	0.206±(0.013)	2.580±(0.109)	0.150±(0.003)	1.935±(0.085)	19.931±(0.677)	5.457±(0.190)	0.021±(0.001)	1.818±(0.085)	0.037±(0.002)
Tap water Qassim	0.309±(0.020)	2.294±(0.080)	0.117±(0.004)	1.433±(0.041)	**44.084±(2.292)**	6.521±(0.110)	0.026±(0.001)	1.621±(0.056)	0.029±(0.001)
Filtered Water Majmaah	0.131±(0.005)	1.791±(0.102)	0.037±(0.001)	0.575±(0.014)	25.513±(0.408)	0.768±(0.051)	0.008±(0.0005)	1.434±(0.077)	0.015±(0.001)
Company 2	0.109±(0.006)	1.783±(0.065)	0.039±(0.002)	0.764±(0.052)	22.310±(0.713)	1.704±(0.040)	0.008±(0.0003)	1.518±(0.068)	0.019±(0.0002)
Ground water Zulfi	0.123±(0.007)	1.822±(0.069)	0.112±(0.006)	1.382±(0.053)	27.203±(0.761)	6.105±(0.354)	0.013±(0.001)	1.363±(0.043)	0.062±(0.003)
Permissible limit	**< 20.000 µg/L**	**5-30000 µg/L**	**8-36 µg/L**	**< 10 µg/L**	**5000 µg/L**	**< 2.5 µg/L**	**< 1 µg/L**	**< 1 µg/L**	**< 190 µg/L**
Max	1.459	4.989	0.287	2.968	44.084	28.164	0.052	3.780	0.194
Min	0.109	1.783	0.037	0.466	2.122	0.768	0.008	1.363	0.012

Copper (Cu), cobalt (Co), nickel (Ni), arsenic (As) and lead (Pb) levels were the highest levels in all water samples collected from Alsharqeyah province in comparison to the other cities subjected to our study as revealed in figures (2,3,4,6 and 9) respectively. Variation between provinces was a strong factor revealed by the current study, the increment of the mentioned trace elements levels may be resulted from considering this province the most famous industrial locality in KSA. Large number of industrial factories along with improper waste's disposal may lead to contamination of drinking water with released trace elements, while low hygienic measures is an excluded reason but it may occur. The similar results obtained from Riyadh's samples supported our hypothesis.

For arsenic (As) and mercury (Hg) were the only trace elements exceeded the permissible limits in most of the surveyed cities for arsenic and in all these cities for mercury, on the other hand, those elements were the highest records in samples collected from Alsharqeyah province again as revealed in figures (6&8). Elevated arsenic element level above the permissible limit leads to destruction of nervous system and brain damage [5], while the increment of concentration of Hg leads to high mortalities due to hepatic, pulmonary, renal and bladder's cancer when its ratio reaches 1:1000 in drinking water [5]. Tap water sample from Riyadh showed the highest level of Hg (3.780 µg/L) as shown in figure (8). While filtered water was taken from Majmaah was the lowest level of arsenic followed by water sample driven from water –producing company (Hayah) and both of them were below the permissible limit (Fig. 6).

On the other hand, all the remaining trace elements were below the permissible limits mentioned by WHO standards but we have to concern the cumulative effect of these elements in the body.

Comparing the recorded values of tap water with treated water samples indicated the low hygienic status of tap water among all the surveyed provinces, as filtered tap water samples showed little improvement of hygienic status and this fact strongly recommending strict hygienic measures applied on the tap water supplies either on the material, manufacturing of the pipes or the continuous routine evaluation of the integrity of these pipes, beside the periodical evaluation and monitoring of water filters. While the comparison between water samples collected from two companies (randomly selected) and the raw drinking water (tap water, filtered and refilled water samples) confirmed the improvement of hygienic standards applied by those companies somewhat. Results depicted in table (1) revealed the lowest levels of Cd, Pb, Mn and Cu (Table 1).

Ground – water samples had the lowest level of Hg (1.363 µg/L), promising the future investigations to use this type of water as a source of water treating.

Recommendations

1. Strict measures should be applied and observed beginning from the design of water supplies, materials used for manufacturing, routine observation of their integrity and continuous maintenance.
2. Strict surveillance should be applied on the companies producing drinking water and periodical evaluation of the hygienic standards they are following.
3. Legalizing of new rules to be applied on the industrial factories regards the disposal strategies of wastes and toxic substances.
4. Further studies should be applied to more drinking water samples and more localities to collect more precise data and wider overview.

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