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Short Communication

Major Inorganic Elements in Tap Water Samples in Peninsular Malaysia

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ABSTRACT

Introduction: Quality drinking water should be free from harmful levels of impurities such as heavy metals and other inorganic elements. **Methods:** Samples of tap water collected from 24 locations in Peninsular Malaysia were determined for inorganic element content. Minerals and heavy metals were analysed by spectroscopy methods, while non-metal elements were analysed using test kits. **Results:** Minerals and heavy metals determined were sodium, magnesium, potassium, calcium, chromium, manganese, iron, nickel, copper, zinc, arsenic, cadmium and lead while the non-metal elements were fluoride, chloride, nitrate and sulphate. Most of the inorganic elements found in the samples were below the maximum permitted levels recommended by inter-national drinking water standard limits, except for iron and manganese. Iron concentration of tap water from one of the locations was higher than the standard limit. **Conclusion:** In general, tap water from different parts of Peninsular Malaysia had low concentrations of heavy metals and inorganic elements.

Keywords: Heavy metals, inorganic elements, minerals, Peninsular Malaysia, tap water

INTRODUCTION

Water is the most important element for life. Water sources in Malaysia are dependent on rainfall, an average annual rainfall being between 2000 mm and 2500 mm. Total water usage is estimated to be 14 billion cubic metres by 2020 (Pillay, Hoo & Chu, 2001). Most of the water supply in Malaysia originates from rivers and streams in the country, while ground water contributes to only 1% of the water required.

In Malaysia, water supply management is not centralised but managed on a state-by-state basis. Quality control of water supply is monitored by a few agencies in the country. The Department of Environment (DOE) is the public agency that monitors the river basins to determine water quality in relation to major pollution sources (Jahi,

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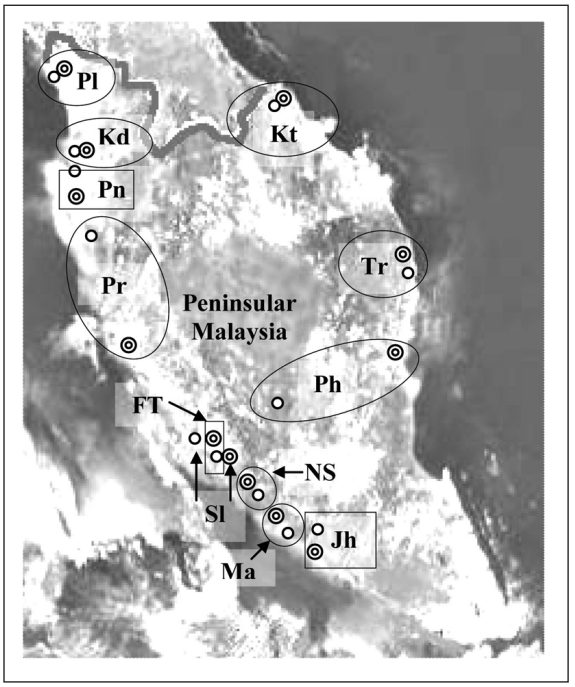

Figure 1. Sources of tap water samples in Peninsular Malaysia
Note: The map of Peninsular Malaysia was adapted from GeoPoesia (2010).
Key: Perlis (Pl); Kedah (Kd); Penang (Pn); Perak (Pr); Selangor (Sl); Federal Territory (FT); Negeri Sembilan (NS); Malacca (Ma); Johor (Jh); Pahang (Ph); Terengganu (Tr); Kelantan (Kt).

2002), while state water authorities are responsible for monitoring of raw water quality in the reservoir at the intake point of the treatment plants (Chan, 2004).

Inorganic elements in tap water are the main health concern as high levels of certain minerals or heavy metals in the drinking water may pose adverse side effects. This study was carried out to determine the major inorganic elements in tap water samples from all the 12 states of Peninsular Malaysia.

MATERIALS AND METHODS

Sample and standard preparation

Stratified sampling was applied where two locations were randomly selected from each state (Figure 1). De-mineralised 1 L plastic containers were preserved in 1:1 nitric acid solution for 2 days and rinsed with de-mineralised water for sample collection. Three replicates of tap water samples were prepared by filtering the samples through 0.45 μm pore diameter membrane filter after digestion. The pH of the filtrate was adjusted to pH 2.0 using a Toledo 320 pH meter (Mettler-Toledo Inc., Columbus, OH) with nitric acid immediately after filtration to digest the organic compounds. High purity mineral standards (Titrisol) for calibration and quality control were purchased from Merck Chemicals (Darmstadt, Germany), while certified reference materials (CRMs) were obtained from Commission of European Communities (CRM-616 and CRM-617). Ultrapure nitric and hydrochloric acids were obtained from Seastar Chemicals (Sidney, BC, Canada).

Sample analysis

The NovAA 400 flame AAS system (AnalytikJena, Jena, Germany) was used to determine sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), iron (Fe), copper (Cu) and zinc (Zn). The standard solution was nebulised and the absorbance was measured for calibration curve. GBC 908AA graphite furnace AAS system (GBC, Victoria, Australia) was used to determine chromium (Cr), nickel (Ni), arsenic (As), cadmium (Cd) and lead (Pb). The specific atomic absorption set and absorbance was obtained. EPA 600/4-91-0101 Method (USEPA, 1991) was applied for determination of mineral in tap water. Manganese (Mn) in the samples was analysed using ICP-OES system equipped with auto sampler, electrothermal vaporisation, laser ablation, ultrasonic nebuliser and hydrite generation system (Hewlett-Packard Co., Wilmington, DE) as reported by Rosborg*et al.* (2003).

The non-metal elements such as fluoride (Fl), chloride (Cl), nitrate (NO_3) and sulphate (SO_4) in the tap water samples were determined using test kits purchased from Merck Chemicals (Darmstadt, Germany) and measured with Spectroquant NOVA 60 photometer (Merck, Darmstadt, Germany). Quality assurance and control of data were performed by comparing the inorganic element concentrations of tap water samples with CRM values. For precision analysis, relative standard deviation (RSD) (%) was calculated based on AOAC method validation guideline (AOAC, 2002). Data are reported as mean, standard deviation, maximum and minimum values.

RESULTS AND DISCUSSION

The concentrations of inorganic elements, values of CRM detection limits, determination limits and international standard limits are presented in Table 1. The mean concentrations of Na, Mg, K, Ca, Fe, Cu, Zn and Mn in the tap water samples were 4.3, 1.1, 3.2, 6.65, 0.06, 0.09, 0.04 and 0.03 mg/L, respectively. Heavy metals determined were Ni, Ar, Cd and Pb with mean concentrations of 0.91, 0.81, 0.41 and 0.28 μg/L respectively. Non-metal elements determined were Fl (0.36 mg/L), Cl (20.19 mg/L), NO_3 (1.39 mg/L) and SO_4 (10.22 mg/L).

The relative standard deviations in percent (RSD%) of the major inorganic elements in the tap water samples are shown in Table 2. The RSD% for most of the tap water samples were low, except for Ni and As which had RSD exceeding 8% (AOAC, 2002).

The mineral concentrations varied widely among the tap water samples from the different states, ranging between 66.7 and 450.0%. The causes for the wide differences in the mineral concentrations among the tap water samples are not known. Human activities differ from place to place, change from time to time, and contamination or pollution of water sources also tend to vary from place to place. Scatena (2000) reported that factors such as land use, agricultural activities and industrialisation may influence the mineral contents present in water.

Fe concentration in one of the samples was higher than the international standard limit for iron. Fe and Zn concentrations showed wide variations among the samples. As reported by Ammann, Hoehn & Koch (2003), iron from urban roof runoff in certain areas may contribute to wide variations of Fe and Zn concentrations in the sources of tap water such as ground water and rivers. Contamination of water sources by Cr was minimal as found in the sample from Terengganu, but was not detected in the other tap water samples.

The variations of heavy metal concentrations among the tap water samples from 24 locations were between 24.4 and 307.1%. High variations (>100%) were found for As and Pb. A high concentration of As in the tap water sample from Perlis might be due to the close proximity of rice

Table 1. Inorganic elements (mg/L) in tap water samples, CRM values, detection limit and international standard limits

Element	*Mean ± SD*	*Min – Max*	*CRM values*[b]	*Detection limits*[c]	*WHO Guidelines*[d]	*EU Standards*[e]	*USEPA Regulations*[f]
Sodium (Na)	4.30 ± 3.39	1.22 – 15.03	14.3 – 61.6	0.018	200.00	200.00	–
Magnesium (Mg)	1.10 ± 1.05	0.07 – 4.11	7.32 – 23.8	0.010	–	–	–
Potassium (K)	3.20 ± 1.61	0.90 – 6.61	0.5 – 9.67	0.030	–	–	–
Calcium (Ca)	6.65 ± 5.30	0.54 – 23.10	14.3 – 39.9	0.020	–	–	–
Iron (Fe)	0.06 ± 0.06	0.02 – 0.33	0.05 – 0.21	0.020	0.30	0.20	0.30
Copper (Cu)	0.09 ± 0.06	0.01 – 0.26	–	0.003	2.00	2.00	1.30
Zinc (Zn)	0.04 ± 0.07	0.002 – 0.36	–	0.001	–	–	5.00
Chromium (Cr)[a]	0.04 ± 0.18	0 – 0.88	–	–	50.00	50.0	100.00
Manganese (Mn)	0.03 ± 0.02	0 – 0.09	0.02 – 0.05	–	0.50	0.05	0.05
Nickel (Ni)[a]	0.91 ± 0.56	0.26 – 2.63	–	–	20.00	20.00	–
Arsenic (As)[a]	0.81 ± 1.26	0.16 – 6.14	–	–	10.00	10.00	10.00
Cadmium (Cd)[a]	0.41 ± 0.10	0.36 – 0.85	–	–	3.00	5.00	5.00
Lead (Pb)[a]	0.28 ± 0.86	0 – 3.80	–	–	10.00	10.00	15.00
Fluoride (Fl)	0.36 ± 0.19	0.14 – 0.71	–	–	1.50	1.50	4.00
Chloride(Cl)	20.19 ± 12.30	5.02 – 48.04	26.4 – 50.2	–	250.00	250.00	250.00
Nitrate (NO_3)	1.39 ± 2.12	0.33 – 11.00	25.8 – 50.7	–	50.00	50.00	10.00
Sulphate (SO_4)	10.22 ± 7.12	1.06 – 31.22	27.0 – 57.9	–	500.00	250.00	250.00

[a] Concentration of metal element (μg/L); [b] Detection limits are generated by AAS novAA 400 software; [c] Certified reference materials (CRM-616 and CRM-617) values are expressed in mg/L; [d] WHO (2006); [e] EU (1998); [f] USEPA (2009).

Table 2. Percentage of relative standard deviation (RSD) for selected inorganic elements in tap water samples

Sample	*Na*	*Mg*	*K*	*Ca*	*Fe*	*Cu*	*Zn*	*Cr*	*Ni*	*As*
Perlis	1.20	0.66	1.90	0.75	14.84	5.66	3.85	8.30	14.60	0.85
Kedah	0.64	1.09	0.82	0.81	4.95	4.10	1.63	5.45	13.25	18.60
Penang	0.99	0.65	0.75	0.42	8.04	4.80	1.59	3.60	19.25	23.40
Perak	0.81	0.74	0.41	0.99	5.52	4.17	1.43	15.40	17.20	20.25
Selangor	0.33	0.46	0.64	0.88	5.75	4.35	1.05	22.85	38.85	17.55
Federal Territory	0.57	0.55	1.00	0.90	2.97	2.00	5.56	9.50	10.15	16.40
Negeri Sembilan	0.41	0.72	0.99	0.34	5.34	7.39	1.49	1.55	18.40	42.55
Malacca	1.19	0.58	0.57	0.72	5.01	2.99	0.72	7.45	15.55	22.05
Johor	1.11	0.73	1.00	0.59	7.81	5.08	2.57	0.80	10.55	4.55
Pahang	0.53	0.95	1.41	0.53	5.65	2.39	2.77	9.85	10.70	22.15
Terengganu	1.29	1.31	1.08	1.93	4.38	3.46	1.39	6.5	11.50	19.1
Kelantan	2.30	0.77	1.06	0.70	1.14	1.89	2.06	2.95	11.65	16.65

[a] RSD (%) for the major inorganic elements are the average values obtained from the tap water samples in two different locations; [b] The values of mean and standard deviation were calculated based on the RSD (%) from 12 states in Peninsular Malaysia

Note: Na: sodium, Mg: magnesium, K: potassium, Ca: calcium, Fe: iron, Cu: copper, Zn: zinc, Mn: manganese, Cr: chromium, As: arsenic, Pb: lead, Fl: fluorine, Cl: chlorine, NO_3: nitrate, and SO_4: sulphate

cultivation near to the water source. Meharg *et al.* (2009) reported that the use of chemical fertilisers in rice fields may increase the level of As in the rice grain and the soil. Both tap water samples from Kelantan showed elevated levels of Pb, which could be due to corrosion of household plumbing systems and erosion of natural deposits (Scatena, 2000).

Concentrations of non-organic elements in drinking water from the different locations were not at critical levels. All the water samples had low Fl, Cl, NO_3 and SO_4 concentrations. Generally, high chloride concentration in tap water samples may be related to flooding of the river (main source of tap water) as previously reported by Naidu & Morrison (1994). The concentration of nitrate in most of the tap water samples was low, below 1 mg/L. High levels of nitrate would indicate contamination of water sources (Juneau, 2007). The common sources of NO_3 include fertilisers, animal wastes, municipal sewage treatment systems and decaying plant debris (Ricker, Peters & Golling, 2001). The tap water samples had low SO_4 concentration (1.06–31.22 mg/L), except for one sample each from Selangor and Johor, where SO_4 concentrations exceeded 20 mg/L.

CONCLUSION

Human activities and environmental pollution are the main factors for the increase in heavy metal levels in some of the tap water samples. Most of the tap water samples had low concentrations of inorganic elements, at below the international standard limits, except for Fe in the sample from Kelantan. The results indicate that regular determination of inorganic elements in tap water is essential in order to ensure that the tap water is not contaminated with toxic metals.

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REFERENCES

Ammann AA, Hoehn E & Koch S (2003). Ground water pollution by roof runoff infiltration evidenced with multi-tracer experiments. *Water Res* 37: 1143–1153.

Association of Official Analytical Chemists (AOAC) (2002). AOAC Requirements for Single Laboratory Validation of Chemical Methods, DRAFT 2002-11-07, Association of Official Analytical Chemists International, USA.

Chan NW (2004). Managing Water Resources in the 21st Century: Involving All Stakeholders Towards Sustainable Water Resources Management in Malaysia. Centre for Graduate Studies, Universiti Kebangsaan Malaysia, Selangor, Malaysia.

European Union (EU) Standards (1998). Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. *Official J Eur Commun* L330: 32–54.

GeoPoesia(2010). Malaysia Map. *http://www.geopoesia.ru/gp/map/malaysia-map.jpg* [Accessed 8 May 2010].

Jahi JM (2002). Issues and challenges in environmental management in Malaysia. *Mal J Environ Manage* 3: 143–163.

Juneau AK (2007). 2006 Drinking Water Quality. Juneau Drinking Water Quality Continues to Exceed Federal and State Standards during 2006. *http://www.juneau.org/* [Accessed 8 May 2010].

Meharg AA, Williams PN, Adomako E, Lawgali YY, Deacon C, Villada A, Cambell RCJ, Sun GX, Zhu Y-G, Feldmann J, Raab A, Zhao F-J, Islam R, Hossain S & Yanai J (2009). Geographical variation in total and inorganic arsenic content of polished (white) rice. *Environ Sci Technol* 43: 1612–1617.

Naidu SD & Morrison RJ (1994) Contamination of Suva Harbour, Fiji. *Mar Polllut Bull* 29: 126–130.

Pillay M, Hoo T & Chu KK (2001). Drinking Water Quality Surveillance and Safety in Malaysia for WHO Workshop on Drinking Water Quality, Surveillance and Safety. In: *Country Report*. Engineering Services Division, Ministry of Health, Kuala Lumpur, Malaysia.

Rosborg I, Nihlgård B, Gerhardsson L & Sverdrup H (2003). Inorganic chemistry of well water in one acid and one alkaline area of South Sweden. *Water Air Soil Pollut* 142: 261–277.

Ricker J, Peters S & Golling R (2001). Evaluation of Urban Water Quality In: *Task 4 Report*. San Lorenzo River Watershed Management Plan Update.

Scatena FN (2000). Drinking Water Quality. In: *Drinking Water from Forests and Grasslands: A Synthesis of the Scientific Literature*. Dissmeyer GE (ed). General Technical Report SRS-39, Southern Research Station, Department of Agriculture Asheville, NC. 246 p.

United States Environmental Protection Agency (USEPA) (1991). Methods for the Determination of Metals in Environmental Samples, EPA 600/4-91-0101, supplemented by EPA 600/R-94-111. Office of Water Regulation and Standards, Washington, DC.

United States Environmental Protection Agency (USEPA) (2009). Drinking Water Contaminants. Office of Water Regulation and Standards, Washington, DC.

World Health Organization (WHO) (2006). WHO Guidelines for Drinking-Water Quality. World Health Organization, Geneva. *http://www.who.int/* [Accessed 10 May 2010].