Approach to assessment of heavy metals contamination in drinking water, Mandalay region, Myanmar

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Abstract. People use their drinking water sources from surface water or ground water. Contaminants including heavy metals have found their way into water supplies due to inadequate treatment and disposal of waste and industrial discharges. The present study aimed to assess the water quality parameters including heavy metals in drinking water from 120 tube wells in 6 townships (Aung-Myay-Tharzan, Chan-Aye-Tharzan, Chan-Mya-Tharzi, Mahar-Aung-Myay, Pyigyi-Tagon and Amarapura) of Mandalay region, Myanmar. Lovibond Water Testing (Photometer SpectroDirect) was used for testing turbidity, total hardness, chloride, cyanide and nitrite. Acidity (pH), electrical conductivity and total dissolved solids were tested by Pocket Pro™ Tester. Arsenic, calcium, copper, iron, magnesium, manganese, mercury, lead and zinc were analyzed by Atomic Absorption Spectrophotometer. Turbidity and pH in 5 out of 6 townships, total dissolved solids in 4 townships and electrical conductivity in 3 townships were higher than MPL in some samples but the other remaining parameters were complied with WHO limit. The levels of iron in all townships, manganese in 3 townships, arsenic and lead in 1 township respectively were detected in some samples more than the maximum permissible limit (MPL) of WHO and other metals were within MPL. Therefore, the quality of drinking water should be assessed constantly.

1. Introduction
Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking water can result in tangible benefits to health. Every effort should be made to achieve a drinking water quality as safe as practicable.1 Poor communities in developing countries of the world use their drinking water sources from either surface water (rivers, dams, etc) or ground water (tube wells, hand pumps, etc). Water tube wells are those that penetrate into aquifers in which the water is not confined by an overlying impermeable layer.2 Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have found their way into water supplies due to inadequate treatment and disposal of waste, industrial discharges, and over-use of limited water resources. Even if no sources of anthropogenic contamination exist, natural sources are also equally potential to contribute higher levels of metals and other chemicals that can harm human health.3

The Millennium Development Goals (MDG) target 7.C in relation to drinking water, as measured by the proxy indicator of access to improved drinking water sources, was met in 2010. Nevertheless, despite 2.3 billion people gaining access over the last 22 years as part of attaining the target, 748 million people...
remain unserved. The drinking water quality standards had been designated in many countries including ASEAN countries such as Cambodia, Philippines and Lao. National drinking water quality standards in Myanmar have also been developed in 2014 and it based on the series of WHO guidelines. In Myanmar, Occupational Health Division in collaboration with UNICEF and WHO had performed the activities for raising awareness on the arsenic contamination and mitigation in drinking water sources and provision of safe water option in Bago Region and Ayeyarwady Region. Mandalay is the city of upper Myanmar and increasing population and industrialization occurs. Increased industrialization makes the environmental pollution including ground water contamination. Ground water is one of the sources of drinking water and its contamination leads to human health problems. The aim of this study was to assess the level of heavy metals in drinking water from tube wells in selected townships of Mandalay region.

**Objectives**

**General objective**
To determine heavy metals from drinking water in Mandalay region, Myanmar

**Specific objectives**
1. To determine level of heavy metal contamination (As, Ca, Cu, Fe, Mg, Mn, Hg, Pb, Zn) in water samples from tube wells in 6 selected townships of Mandalay region, Myanmar
2. To detect physicochemical parameters (pH, electrical conductivity, total dissolved solids, chloride, cyanide, nitrite, total hardness, turbidity) of water samples from tube wells in 6 selected townships of Mandalay region, Myanmar

**Methodology**

**Study design**
This study was the cross-sectional analytical study.

**Study area**
This study was done in 6 selected townships (Aung-Myay-Tharzan, Chan-Aye-Tharzan, Chan-Mya-Tharzi, Mahar-Aung-Myay, Pyigyi-Tagon and Amarapura) in Mandalay region, Myanmar.

**Study population**
Total 120 water samples from different tube wells were collected from 6 selected townships of Mandalay region whereas 20 samples from each township were taken.

**Sampling**
Lot quality assurance sampling method was used in this study.

**Study period**
Study period was September, 2016 to August, 2017.

**Statistical analysis**
Data were analyzed by using Microsoft Excel Version 2007.

2. **Materials and Methods**

**Reagents and chemicals**
Analytical grade reagents (Merck) of arsenic (As), calcium (Ca), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg) and zinc (Zn) were used as standards for heavy metal
analysis. Acetylene gas and argon gas were used in heavy metal analysis. 69% Hydrochloric acid (HCl), 70% nitric acid (HNO₃), sulphuric acid (H₂SO₄) and double de-ionized water were used in the procedure for analysis of water. Standard kits for chloride, cyanide, hardness and nitrite were used for the measurement of physicochemical parameters of water.

**Instruments and apparatus**
Atomic Absorption Spectrophotometer (AAS) (AA 6650, Shimadzu Japan), mercury vaporizer unit (MVU 1A, Shimadzu Japan), graphite furnace atomizer (GFA-EX7, Shimadzu Japan), Lovibond Water Testing (Photometer SpectroDirect, Germany) and Pocket Pro™Tester (HACH, China) were used in this study.

**Sample collection and preservation**
One-hundred and twenty (120) water samples from different tube wells were obtained from 6 selected townships in Mandalay region. The one litre pre-washed polyethylene bottles were used for the collection of water samples. The samples were acidified to 1% with nitric acid for sample preservation.6,7

**Analysis of water samples**
According to National Drinking Water Quality Standards Myanmar (2014), the following parameters were analyzed by respective instruments and apparatus.8 The concentrations of metals (Ca, Cu, Fe, Mg, Mn and Zn) were analyzed using Atomic Absorption Spectrophotometer (AAS) by flame method and arsenic (As) and lead (Pb) by flameless method by using graphite furnace atomizer (GFA-EX7) according to the standard procedure.6 Mercury (Hg) was determined by mercury vaporizer unit (MVU 1A) according to the standard procedure.9 Lovibond Water Testing (Photometer SpectroDirect) was used for testing chloride (Cl⁻), cyanide (CN⁻), turbidity, total hardness, and nitrite (NO₂⁻). pH, electrical conductivity (EC) and total dissolved solids (TDS) of water samples were tested by using Pocket Pro™Tester.

# 3. Results and Discussion
The following tables showed the results of physicochemical parameters and heavy metals analysis of tube well water from 6 selected townships of Mandalay region according to the maximum permissible limit for drinking water set by WHO.

**Table 1.** Percentage of water samples for physicochemical parameters complied with MPL by WHO in 6 selected townships of Mandalay Region.

| Townships       | n  | pH  | EC  | TDS | Cl⁻ | CN⁻ | NO₂⁻ | Hardness | Turbidity |
|-----------------|----|-----|-----|-----|-----|-----|------|----------|-----------|
| Aung-Myay-Tharzan | 20 | 90  | 75  | 75  | 100 | 100 | 100  | 100      | 35        |
| Chan-Aye-Tharzan | 20 | 95  | 100 | 100 | 100 | 100 | 100  | 100      | 75        |
| Chan-Mya-Tharzi | 20 | 10  | 100 | 100 | 100 | 100 | 100  | 100      | 100       |
| Mahar-Aung-Myay | 20 | 70  | 100 | 95  | 100 | 100 | 100  | 100      | 5         |
| Pyi-Gyi-Tagon    | 20 | 45  | 95  | 85  | 100 | 100 | 100  | 100      | 0         |
| Amarapura       | 20 | 100 | 85  | 80  | 100 | 100 | 100  | 100      | 5         |

MPL = maximum permissible limit

According to table 1, chloride (Cl⁻), cyanide (CN⁻), nitrite (NO₂⁻) and hardness were complied with the maximum permissible limit (MPL) of drinking water by WHO (Cl⁻ = 250 mg/L, CN⁻ = 0.07 mg/L, NO₂⁻ = 3 mg/L and hardness = 500 mg/L).10 Concerning with pH values, most of the water samples in all townships except Amarapura were higher than MPL of WHO (6.5-8.5). The pH is a measure of the
acidity or alkalinity of the water. Although pH usually has no direct impact on the health status of consumers, it is one of the most important water quality parameters for household water treatment.10

Electrical conductivity was higher than MPL of WHO (1400 µS/cm) in some of the water samples taken from Aung-Myay-Tharzan, Pyi-Gyi-Tagon and Amarapura townships while the remaining 3 townships were complied with the MPL. Conductivity is the ability of water to carry an electric charge and it can also be considered as a proxy indicator of total dissolved solids (TDS). It is generally considered that drinking-water becomes significantly and increasingly unpalatable at levels greater than 1400 µS/cm. Although this parameter does not provide information about specific chemicals in water, it can act as a good indicator of water quality problems. As the conductivity can change with time, high conductivity values can indicate the contamination of water.11

Although total dissolved solids in water samples were complied with MPL (1000 mg/L) in Chan-Aye-Tharzan and Chan-Mya-Tharzi townships, some of the samples in other 4 townships were higher than MPL. Total dissolved solids (TDS) are composed of not only inorganic salts (mainly sodium chloride, calcium, magnesium, and potassium) but also small amounts of organic matter dissolved in water. TDS in drinking water comes from natural sources, sewage, urban runoff and industrial wastewater.12 The palatability of water with TDS level of less than about 600 mg/L is generally considered to be good while the drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/L.10

Turbidity in most of the water samples were higher than MPL (5 NTU) in 5 out of 6 townships (except Chan-Mya-Tharzi). Turbidity in water can be caused by suspended particles or colloidal matter that obstructs light transmission through the water. Turbidity in some groundwater sources is a consequence of inert clay or chalk particles or the precipitation of non-soluble reduced iron and other oxides. As microorganisms (bacteria, viruses and protozoa) can be typically attached to particulates, filtration will significantly reduce microbial contamination and also can remove the turbidity of water. Occasionally, turbidity can be caused by minute air bubbles released when water has the high dissolved oxygen. Drinking water should not exceed 5 NTU. If it is greater than 5 NTU, sedimentation and/or filtration should be undertaken to reduce the level of turbidity.10

Table 2. Percentage of water samples for heavy metals complied with MPL by WHO in 6 selected townships of Mandalay Region.

| Townships               | n  | Percentage (%) of water samples complied with MPL by WHO |
|-------------------------|----|---------------------------------------------------------|
|                         |    | As  | Ca  | Cu  | Fe  | Pb  | Mg  | Mn  | Hg  | Zn  |
| Aung-Myay-Tharzan       | 20 | 100 | 100 | 100 | 85  | 100 | 90  | 100 | 100 | 100 |
| Chan-Aye-Tharzan        | 20 | 100 | 100 | 100 | 85  | 95  | 100 | 90  | 100 | 100 |
| Chan-Mya-Tharzi         | 20 | 100 | 100 | 100 | 95  | 100 | 100 | 100 | 100 | 100 |
| Mahar-Aung-Myay         | 20 | 95  | 100 | 100 | 75  | 100 | 100 | 100 | 100 | 100 |
| Pyi-Gyi-Tagon           | 20 | 100 | 100 | 100 | 70  | 100 | 100 | 100 | 100 | 100 |
| Amarapura               | 20 | 100 | 100 | 100 | 55  | 100 | 85  | 100 | 100 | 100 |

MPL = maximum permissible limit

According to table 2, calcium (Ca), copper (Cu), magnesium (Mg), mercury (Hg) and zinc (Zn) levels in the water samples of all 6 townships were complied with the maximum permissible limit (MPL) of drinking water set by WHO (Ca = 200 mg/L, Cu = 2 mg/L, Mg = 150 mg/L, Hg = 0.001 mg/L and Zn = 3 mg/L).10

In this study, among 6 townships, arsenic was detected more than MPL (0.01 mg/L) in only one water sample of Mahar-Aung-Myay Township. Arsenic can naturally occur in ground water. In Myanmar, arsenic can be found in the ground water in delta region.5 It is one of the greatest chemical problems in developing countries. The WHO suggests that drinking water should have less than 0.01 mg/L. Many Southeast Asian countries with an arsenic problem have adopted a temporary standard of 0.05 mg/L because it is difficult to test accurately to 0.01 mg/L and to treat water to meet that standard.
Arsenic is poisonous, and when people drink water or eat food contaminated with arsenic for long term, they can develop the chronic health problems such as arsenicosis and various cancers. Arsenic may also cause vascular diseases, neurological effects, and infant developmental defects. There is no effective cure for arsenic poisoning until now. Therefore, the only one way of prevention is to drink the water with safe level of arsenic.12

The content of iron in some water samples was higher than MPL (1 mg/L) in all 6 selected townships. Iron can be naturally found in groundwater and it is the fourth most abundant element in the earth’s crust.10 In this study, the water samples were taken from tube wells which came from the groundwater and the iron may be dissolved and not visible. Iron is an essential element in human nutrition. The shortage of iron causes disease called anemia and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haemosiderosis.3,10

Lead level in only one sample was higher than MPL (0.01 mg/L) in Chan-Aye-Tharzan Township among 6 selected townships. Although lead may be transmitted via other environmental routes such as air and food, drinking water can be a significant reservoir of lead. This can be also derived from lead water pipes used in some old household plumbing systems. There are also natural sources of lead in groundwater and some industrial discharges may contain lead as well.11 Long-term exposure to low lead levels can cause adverse neurological effects, especially in infants, young children and pregnant women. Lead exposure is most serious for infants and young children because they absorb lead more easily than adults and are more susceptible to its harmful effects.12

Manganese level was higher than MPL (0.4 mg/L) in 3 townships (Aung-Myay-Tharzan, Chan-Aye-Tharzan, Amarapura) whereas the rest of the townships were complied with MPL. Manganese can be naturally found in groundwater and surface water, and it usually occurs with iron. The presence of manganese together with iron in water may lead to the accumulation of microbial growths in the water distribution system. Human activities may also be responsible for manganese contamination in water. People need small amounts of manganese to keep healthy.12 Exposure to high concentrations of manganese over the course of years has been associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism. This type of effect may be more likely to occur in the elderly.13

Conclusion
This study aimed to assess the status of the quality of drinking water taken from the different tube wells in 6 selected townships in Mandalay city, Myanmar. In this study, 9 kinds of heavy metals (arsenic, calcium, copper, iron, lead, magnesium, manganese, mercury and zinc) and 8 kinds of physicochemical parameters (pH, electrical conductivity, total dissolves solids, chloride, cyanide, hardness, turbidity and nitrite) were determined. Among 9 metals determined, although the iron in all townships, manganese in 3 townships, arsenic and lead in each 1 township were detected in some water samples more than the maximum permissible limit of WHO, most of the samples were complied with MPL. Concerning with physicochemical parameters, pH and turbidity in most of the samples were higher than the maximum permissible limit of WHO in 5 out of 6 townships. And hence, total dissolved solids in 4 townships and electrical conductivity in 3 townships were higher than MPL in some samples. In spite of the higher level of the above parameters than MPL, the other remaining parameters (Ca, Cu, Mg, Hg, Zn, Cl−, CN−, NO2− and total hardness) were complied with the limit of WHO. Therefore, it can be suggested that most of the water sources in Mandalay City are appropriate for drinking purpose. However, the water sources are needed the constant monitoring and the people should be given the health education about the safe drinking water because people may be suffered from various diseases on drinking the water with the high concentration of heavy metals.

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