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Assessment of River Water Quality in Gold Mining Area: Case Study

Uyu and Chindwin Rivers in Homalin Township, Myanmar

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Abstract

Most of gold mines are working in Homalin Township, Sagaing region where is the catchment area of Uyu and Chindwin rivers. In gold mining process, land clearing, slucing, panning, amalgamation processes are still operating. Gold mines affects negative impacts to the environment including water, soil and air. River water quality that is still using for drinking and cooking is affected by this gold mining especially in turbidity, iron, mercury. Drinking water is one of the basic needs for human life. Streams and rivers are main sources of fresh water and also important watershed areas. Water samples are collected in seven sampling points in Uyu and Chindwin rivers. Temperature, electric conductivity, pH, total dissolved solids, dissolved oxygen and turbidity are measured by U52G water quality meter at every sampling point. Cadmium, copper, iron, lead, mercury and zinc are tested with Atomic Absorption Spectrometer in the laboratory, Environmental Conservation Department, Monywa, Sagaing Region. River water is affected in turbidity, iron and mercury. Gold mines should be controlled to work systematically for the environment especially in water quality. River water should be cleaned for local people who are using for drinking and cooking.

Keywords: Drinking Water Quality, Gold Mines, Heavy Metals, River and Stream Water, Water Pollutants

ဟုမ္မလင်းမြို့နယ် ရွှေသတ္တုတူးဖော်သည့် နေရာရှိ ဥရုမြစ်နှင့် ချင်းတွင်းမြစ်တို့၏ ရေအရည်အသွေးဆန်းစစ်ခြင်း

ဒေါက်တာမျိုးသိန်း၊ လက်ထောက်ညွှန်ကြားရေးမှူး
ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

စစ်ကိုင်းတိုင်းဒေသကြီးအတွင်း ရွှေသတ္တုတူးဖော်မှုအများဆုံးမှာ ခန္တီးခရိုင်၊ ဟုမ္မလင်းမြို့နယ်တွင်ဖြစ်ပါသည်။ ဟုမ္မလင်းမြို့နယ် အတွင်းတွင် ချင်းတွင်းမြစ်၊ ဥရုမြစ်နှင့်၎င်း၏ လက်တက်ဖြစ်သော ချောင်းကြီးချောင်းတို့၏ ရေဝေရေလဲဒေသများတွင် ရွှေတူးဖော်မှုအများဆုံးဖြစ်ပါသည်။ ရွှေတူးဖော်ခြင်းတွင် မြေပြင်ရှင်းလင်းခြင်း၊ မျောတိုက်ခြင်း၊ အင်ဝိုင်း လှည့် ခြင်း၊ ပြဒါးဖြင့်ရွှေဖမ်းခြင်းနှင့် မီးဖုတ်ခြင်းတို့ လုပ်ဆောင်လျက်ရှိပါသည်။ ရွှေတူးဖော်ခြင်း ကြောင့် ပတ်ဝန်းကျင်ရှိ ရေ၊ မြေနှင့် လေ အပေါ် ဆိုးကျိုးသက်ရောက် စေပါသည်။ နောက်ကျိ နေသော မြစ်ရေကို အနည်ထိုင်ပြီး သောက်သုံးရေအဖြစ်သုံးနေသော အိမ်ထောင်စုများစွာရှိပါ သည်။ သောက်သုံးရေသည်လူ့ဘဝအတွက် အခြေခံလိုအပ်ချက်များမှတစ်ခုအပါအဝင် ဖြစ်ပါ သည်။ မြစ်ချောင်းများသည် ရေချိုပေးသော အဓိကသယံဇာတများ ဖြစ်ပါသဖြင့် မြစ်ချောင်း များ၏ ရေအရည်အသွေးကို ထိန်းသိမ်းရန် အလွန်အရေးကြီးလှပေသည်။ ရွှေသတ္တုတူးဖော်ခြင်း လုပ်ငန်းများကြောင့် မြစ်ရေအရည်အသွေးထိခိုက်မှုများအား လေ့လာဆန်းစစ်လိုပါသောကြောင့် သုတေသနစာတမ်းရေးသားရခြင်းဖြစ်ပါသည်။

ssessment of River Water Quality in Gold Mining Area: Case Study Uyu and Chindwin Rivers in Homalin Township, Myanmar

1. Introduction

1.1. Background of the study

Although often perceived to be pretty ordinary, water is the most remarkable substance. We wash in it, fish in it, swim in it, drink it and cook with it, although probably not all at the same time. We are about two-thirds water and require water to live (Chaplin, 2001).

Water, with a deceptively simple chemical formula of H_2O, is a vitally important substance in all parts of the environment. Water covers about 70% of Earth's surface. It occurs in all spheres of the environment—in the oceans as a vast reservoir of saltwater, on land as surface water in lakes and rivers, underground as groundwater, in the atmosphere as water vapor, in the polar icecaps as solid ice, and in many segments of the anthrosphere such as in boilers or municipal water distribution systems. Water is an essential part of all living systems and is the medium from which life evolved and in which life exists. Water leaches soluble constituents from mineral matter and carries them to the ocean or leaves them as mineral deposits some distance from their sources. Water carries plant nutrients from soil into the bodies of plants by way of plant roots (Manahan, 2009).

In the current decade, fresh water has become a scarce commodity due to the over exploitation and pollution of water sources (Gupta et al., 2009). Furthermore, the rate of water quality deterioration is increasing in different regions of the world as a function of rapid demographic growth and socio-economic development (Zeilhofer, Lima, & Lima, 2006). Besides, human settlements, industries and agriculture are the major sources of water pollution (Park & Morrison, 2017).

Mining is a main economic activity in many developing countries (Ericsson & Löf, 2019). Mining operation be it small or large scale, are inherently disruptive to the environment, producing enormous quantities of waste that can have deleterious impact for decades (Haque, Hughes, Lim, & Vernon, 2014). The risk of pollution from mining sites lasts even after the cessation of mining activities. In all sites where mining activities exist, the environmental problems are present. These problems manifest as degradation of forest and loss of biodiversity, soil contamination, air pollution, surface and groundwater pollution, noise and vibrations, deterioration of natural drainage system, natural land degradation, negative impact on terrestrial and aquatic ecosystems, socio-economic and human health (Roche & Mudd, 2014). The environmental worsening caused by mining occurs mainly as a result of unsuitable and wasteful working practices and rehabilitation measures (Rytuba, 2003). Water quality protection is very important environmental challenge in mining and mineral processing sites. Therefore, this paper is intended to access the actual water quality of current situation in Uyu and Chindwin rivers around gold mining areas in Homalin Township, Sagaing Region, Myanmar.

1.2. Water in Myanmar

Myanmar is proud of offering rich natural resources such as water, land, forest, oil and gas, agricultural products, jade, ruby, gold, copper, coal and so on. In particular, people are actively involving in artisanal and small gold mines. Most small gold mines are affecting the environment. The process flow of that gold production are land clearing and vegetation removal, sluicing, panning, amalgamation, burning of the amalgamation for final product and rehabilitation of the project area. Mercury is used for these artisanal, small scale and medium scale gold production mines especially in amalgamation, panning and burning of the amalgamation. These mines are working in watershed area of Uyu river which is the main freshwater source of Chindwin river. Most of people settled around this area are using river water for their needs such as bathing, drinking, cooking, transporting and others. As water is mainly affected by these artisanal, small and medium gold mines, water quality management is needed to solve this contamination.

Gold mines which include medium scale, small scale and artisanal gold mines in Homalin Township, cause to increasing water turbidity, water contamination, mercury contamination in water, affect to the aquatic plants and animals, decrease forest and agricultural land area, migrate wildlife in that area and downstream areas. These conditions are continuously caused because there are less jobs or less income in many places of Myanmar especially in the central dry zone where there are affected less agricultural products by climate change. Therefore, most people are intending to do gold mines for their needed income.

Mining activities in Myanmar can be divided into artisanal, small-scale, medium-scale and and large-scale mining. Among them, artisanal and small-scale gold mines are mostly working in Homalin Township. The sustainability of mining operations depends on the mining and processing methods used and the scale of operation (Htun, 2014).

1.3. Problem statement

Myanmar's mining sector remains under-developed, characterized by small-scale operations. There is a lack of skills and technology needed for concentration and beneficiation. Because of weak regulation and enforcement capacity, risk of complicity in human rights violations related to land and security of the person, political uncertainty and persistent armed conflict, there are high costs and unattractive economic terms, have resulted in little formal foreign investment in the sector (Gardiner, Sykes, Trench, & Robb, 2015).

In the recent years, mining activities has been perceived negatively due to issues concerning its impact on the environment, such as deforestation, destruction of natural landscape, release of dusts, pollutants and greenhouse gases (GHGs). Therefore, the mining process mainly involves the careful extraction of large blocks or slabs of stones from the quarries, followed by the transportation to processing plants.(Borlini, 2012). As a result of environmental issues such as land degradation, water pollution, mercury release, and the destruction of farmlands posed by the mining activities, deal with the operations or to ban the mining altogether.(Bansah, Dumakor-Dupey, Stemn, & Galecki, 2018) .

Although often perceived to be pretty ordinary, water is the most remarkable substance. We wash in it, fish in it, swim in it, drink it and cook with it, although probably not all at the same time. We are about two-thirds water and require water to live(Chaplin, 2001).

Gold mines are working along both sides of Uyu river, Chindwin river and its water catchment areas. Gold mines are traditionally worked over 30 years ago and commercially worked last 20 years ago. Most of mine workers are people who stayed in the central dry zone of Myanmar and were working in agriculture sector. They transfer to mine sites to work gold mines for their needed income. Less productivity of agricultural crops causes to the migration of workers from one place to another places due to the effects climate change.

2. Objectives

The overall objective of this study is to access river water quality in gold mining areas, especially Uyu and Chindwin river water in Homalin Township, Myanmar. The specific objectives are:

- To assess the river water quality of current situation around gold mining areas in Uyu river and Chindwin river
- To identify the most polluting components by assessing the current situation results.

3. Materials and Methods

3.1. Study area

The study area, Homalin Township area is located in Khamti District, Sagaing Region which is the north-western part of Myanmar. Homalin Township area is 2,768,927 acres (1,120,545 hectares) including arable lands and forest land and population is 258,206 in 2014.

In Homalin Township, Chindwin river is one of the main rivers of fresh water sources in Myanmar and flows from North to South. It is also main tributary of Ayeyarwady river which is the longest river in Mynamar. Chaunggyi stream is one of the main turbitary of Uyu river. Most of gold mines are working in the catchment area of Chaunggyi stream, Uyu river and Chindwin river. Among them, most are working around Uyu river. There are operating many gold mines that include medium gold mines, small gold mines and artisanal gold mines. Land clearing, dredging, slucing, panning, amalgamation, burning of the amalgamation and gold refining are included in all gold mining processes.

In this study, seven sampling points are chosen to collect water samples that represent gold mining areas. Water sample is collected in Chaunggyi stream to know the quality of the water before entering the Uyu river. In Uyu river, four sampling points are collected at before coming with Chaunggyi stream, at the place after combining with Chaunggyi, at Namttaw mostly around gold mines and at the last place before combine with Chidwin river. Two sampling points are collected in Chindwin river where at Homalin and at the place below Uyu river to know downstream results.

Table 3.1. Water sampling points in the rivers

Sr	Sampling place	Point	Latitude	Longitude
1	Chaunggyi stream	WS 1	24.905142 ˚	95.338936 ˚
2	Uyu river (above Chaunggyi stream)	WS 2	24.911797 ˚	95.343475 ˚
3	Uyu river (below Chaunggyi)	WS 3	24.910372 ˚	95.323161 ˚
4	Uyu river (at Namtaw)	WS 4	24.813814 ˚	95.283903 ˚
5	Uyu river (above Chindwin river)	WS 5	24.836575 ˚	94.940575 ˚
6	Chindwin river (below Uyu)	WS 6	24.796706 ˚	94.926108 ˚
7	Chindwin river (above Uyu)	WS 7	24.862122 ˚	94.916072 ˚

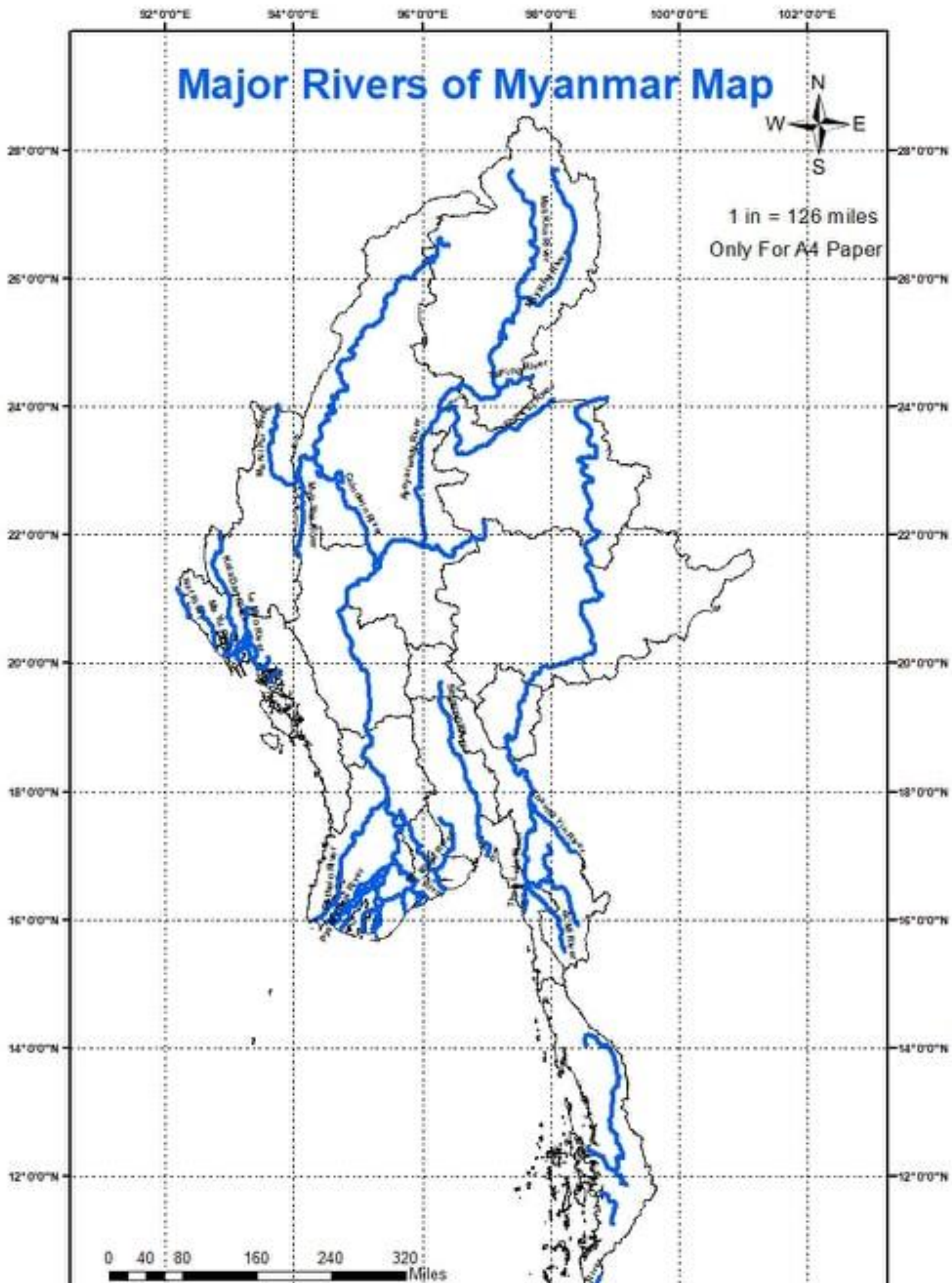

Figure.3.1. Myanmar major rivers (*Source: Myanmar Information Management Unit*)

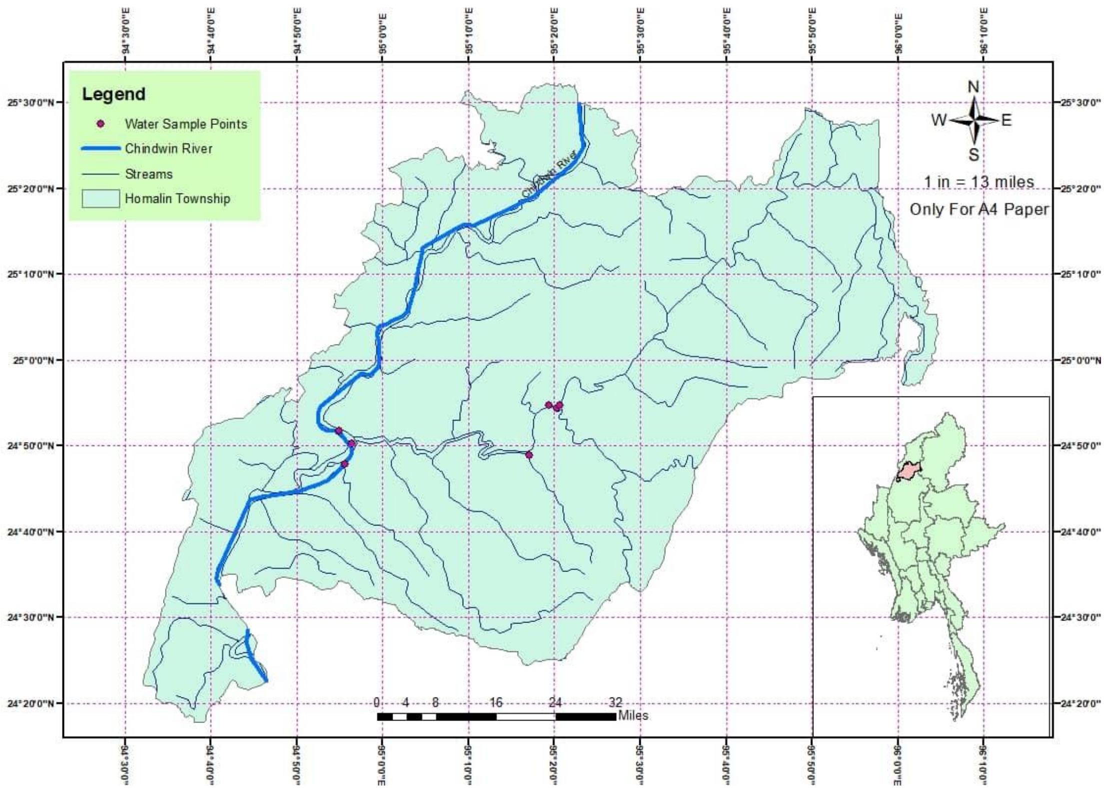

Figure.3.2. Rivers and streams in Homalin Township (*By using Arcmap 10.2.2 software*)

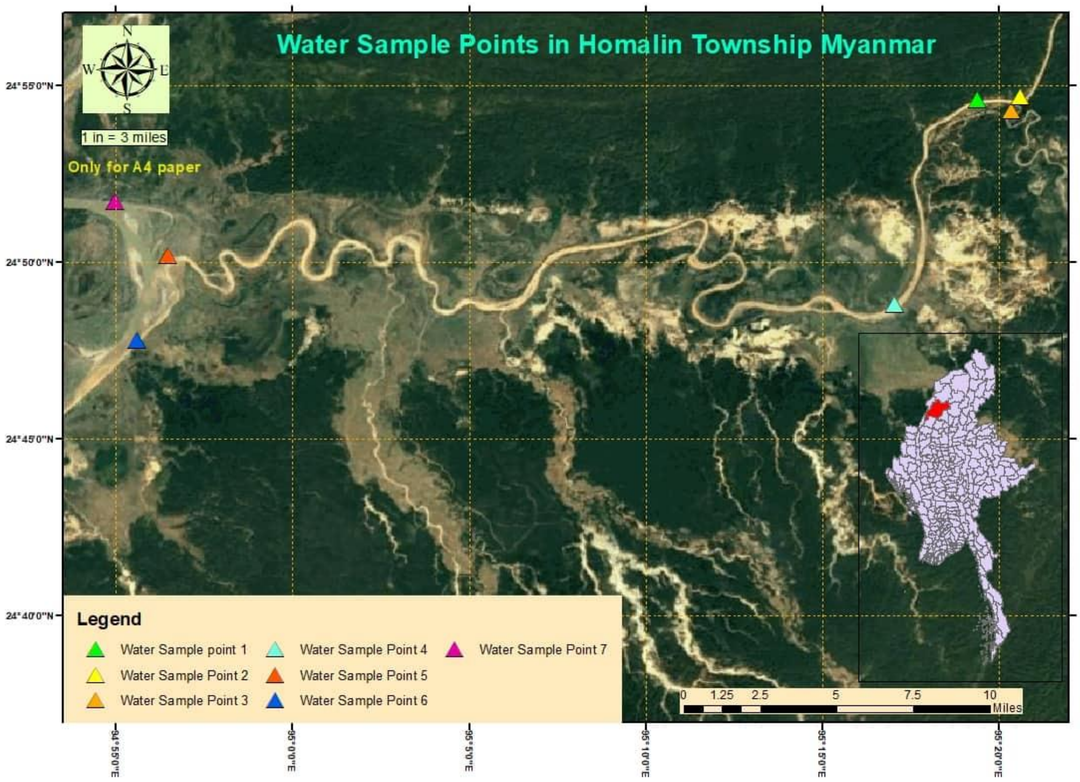

Figure.3.3. Water sampling point

3.2. Water samples collection

Primary data are obtained by collecting at seven water sampling places which are two places in Chindwin, four places in Uyu river and one place in Chaunggyi stream which is tributary of Uyu river respectively. In this paper, water samples are collected in August, October, December 2019 and February 2020. These collected water samples are tested by mobile U52G water quality meter at every sampling point and are tested by using AAS method Atomic Absorption Spectrometer SHIMADZU (Graphite) in Environmental Conservation Department's (ECD) laboratory, Monywa, Sagaing Region. Secondary data were obtained from Ministry of Transport and Communications (MOTC), Ministry of Natural Resources and Environmental Conservation (MONREC) and Chindwin River Basin Organization (CRBO).

Before collecting water samples, there was a decision to take seven sampling points that are suitable for assessment of river water quality around gold mines. Water samples are collected in the total of seven places which are two places in Chindwin river, four places in Uyu river and one place in Chaunggyi steam respectively. Water samples are collected with plastic bottles in every sampling point, write on that bottles the name of the place and location, wrapped with dark colored plastic bags and tape because the light cannot enters directly to the bottles. All water samples are collected at least, one-liter amount of water. After collecting the water samples, send them to the laboratory of Environmental Conservation Department in Monywa, Sagaing Region where is too far over 350 miles from Homalin. Heavy metals such as cadmium, copper, iron, lead, mercury and zine are tested by using AAS method which is Absorption Spectrometer SHIMADZU (Graphite) in the laboratory. Some parameters such as temperature, electric conductivity, pH, TDS, DO and turbidity are tested by using mobile U52G water quality meter at every sampling point. After testing the water samples, the results are obtained. By using these results in this paper, the assessment of river water quality in Uyu and Chindwin rivers can be done.

3.3. Water quality standards and guidelines

Myanmar's National Drinking Water Quality Standards (MNDWQS) have been developed in 2014. The development of ambient Water Quality Standards is ongoing under Ministry of Natural Resources and Environmental Conservation (MONREC). Therefore, in this study, MNDWQS standard is mainly used to compare with current water quality and National Environmental Quality (Emission) Guidelines (NEQG) in Myanmar is used to assess and evaluate the water in the mining sites.

Myanmar National Drinking Water Quality Standards (MNDWQS) have already declared by the Ministry of Health and Sports in 2014. This water quality standard is used for local people who are using the river water for drinking and cooking everyday. Drinking water quality parameters and units of WHO standards and MNDWQS are shown in the following table;

Table 3.2. WHO standards and MNDWQS standard values

Sr	Name	Unit	WHO standard	MNDWQS standard
1	Temperature	˚C		
2	Electric Conductivity	µS/cm		1500
3	pH		6.5 – 8.5	6.5 – 8.5
4	TDS	mg/l	1000	1000
5	DO	mg/l		
6	Turbidity	NTU	5	5
7	Cadmium	mg/l	0.003	0.003
8	Copper	mg/l	2	2
9	Iron	mg/l	0.3	1

10	Lead	mg/l	0.01	0.01
11	Mercury	mg/l	0.006	0.001
12	Zinc	mg/l		3

NTU- Nephelometric Turbidity Units

3.4. Methods

Descriptive method will be used by comparing with Myanmar's drinking water quality standards and current situation water results. And then, comparison of means and standard deviations of each parameter tested in seven sampling places will also be done for the comparison of water quality between wet and dry seasons, among Chaunggyi stream, Uyu and Chindwin rivers, and among four months.

The formula to find the sample mean μ_x, n is the number of samples.

$$\mu_x = \frac{\sum_{i=1}^{n} x_i}{n} \quad (3.1)$$

Formula to estimate sample standard deviation (*s*)

The standard deviation is a measure of the amount of variation or dispersion of a set of values. A low standard deviation indicates the values tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the values are spread out over a wider range.

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu_x)^2}{n-1}} \quad (3.2)$$

Formula to estimate standard error (SE) or mean

The standard error (SE) of a statistic (usually an estimate of a parameter) is the standard deviation of its sampling distribution or an estimate of that standard deviation. If the parameter or the statistic is the mean, it is called the standard error of the mean (SEM).

$$\mathrm{SE}_{\mu_x} = \frac{s}{\sqrt{n}} \quad (3.3)$$

The sampling distribution of a population mean is generated by repeated sampling and recording of the means obtained. This forms a distribution of different means, and this distribution has its own mean and variance. Mathematically, the variance of the sampling distribution obtained is equal to the variance of the population divided by the sample size. This is because as the sample size increases, sample means cluster more closely around the population mean.

Therefore, the relationship between the standard error of the mean and the standard deviation is such that, for a given sample size, the standard error of the mean equals the standard deviation divided by the square root of the sample size.

The following table shows that temperature, electric conductivity, pH power of hydrogen, TDS total dissolved solids, DO dissolved oxygen, turbidity are measured with mobile U52G water quality meter at all sampling points. Cadmium Cd, copper Cu, iron Fe, lead Pb, mercury Hg and zinc Zn are tested by using Atomic Absorption Spectrophotometer (AAS) method in the laboratory of Environmental Conservation Department (ECD), Monywa, Sagaing Region.

Table 3.3. Analysis methods for water samples

Sr	Quality Parameter	Unit	Method
1	Temperature	˚C	U 52G Water Quality meter
2	Electric conductivity	mS/cm	U 52G Water Quality meter
3	pH		U 52G Water Quality meter
4	TDS	mg/l	U 52G Water Quality meter
5	DO	NTU	U 52G Water Quality meter
6	Turbidity	NTU	U 52G Water Quality meter
7	Cadmium	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)
8	Copper	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)
9	Iron	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)
10	Lead	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)
11	Mercury	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)
12	Zinc	mg/l	AAS Atomic Absorption Spectrophotometer SHIMADZU (Graphite)

3.5. Statistical data analysis

In this study, the random sampling design was applied to ensure the key water situation around gold mines in Homalin Township. By using this design, water sampling places are selected in Chaunggyi stream, Uyu and Chindwin rivers.

Means of all measured water parameters were calculated for all sampling places to describe the variation in water quality parameter variables. A One-Way Analysis of Variance (ANNOVA) which is used to compare three groups variables and above, was performed to determine spatial and seasonal variation of water quality parameters among three places where Chaunggyi stream, Uyu and Chindwin rivers, among four months that are August, October, December and February and among seven sampling places. Independent samples T test which is used to compare two groups variables and below, was performed to determine variation of water quality parameters between wet and dry seasons.

Multiple comparisons were performed using a one-way ANNOVA with the post hoc test (LSD) at a significance level of ($p< 0.05$) was used to assess the significant variations in water quality existed among Chaunggyi stream, Uyu and Chindwin rivers, among four months and between wet and dry seasons. The multivariate statistical techniques were performed by using a standard statistical software package (SPSS).

4. Results and discussion

Drinking water is the suitable water for human consumption such as drinking and cooking. Water quality standard is a level for a water constituent which does not result in significant health risk and which ensures acceptability of the water to consumers. The quality of water used for many purposes such as drinking, domestic purposes, food production of recreational purposes has an important impact on health. Therefore, water quality is a measure of the suitability of water for a particular used based on selected physiochemical characteristics.

In 2014, Department of Population, Ministry of Labour, Immigration and Population, collected the population and housing census in Homalin Township. There are over 22 percentage of population who are mainly using drinking water from rivers, streams and canals and over 25 percentages are using that river and stream water for the main source of non-drinking water.

Water samples are collected at seven places and tested four times in August, October, December 2019 and February 2020. These results are compared with Myanmar National Drinking Water Quality Standards which is already declared in 2014.

Overall mean of each parameter tested in the study area, will be used to compare with MNDWQS and Korea's river water quality standards. As shown in table 4.1., overall mean of temperature and electric conductivity are 23.8429 °C and 0.14375 mS/cm. These two parameters cannot compare with MNDWQS. Maximum temperature of overall places is 29.92 °C and minimum temperature is 19.99 °C. The maximum electric conductivity is 0.304 mS/cm and minimum electric conductivity is 0.064 mS/cm.

Overall mean of pH and DO are 6.8871 and 7.825 mg/l. pH value of MNDWQS is ranged between 6.5 and 8.5. The highest pH is 7.6 and the lowest pH is 6.27. And also the highest DO is 10.96 mg/l and the lowest DO is 5.11 mg/l. Therefore, pH is within the limit of MNDWQS. DO standard value in MNDWQS is not yet defined.

Overall mean of TDS is 122.07 mg/l. The maximum TDS is 890 mg/l and minimum TDS is 41 mg/l. As the standard value of TDS in MNDWQS is 1000 mg/l, the overall mean of TDS is lower than the standard.

Overall mean of turbidity is 1582.96 NTU. The maximum turbidity is 3000 NTU and minimum turbidity is 120 NTU. As the standard value of TDS in MNDWQS is 5 NTU, the overall mean of turbidity is too much higher than the standard.

Overall mean of cadmium (Cd) is 0.00986729 mg/l. The maximum Cd is 0.041 mg/l and minimum Cd is 0.000408 mg/l. As the standard value of Cd in MNDWQS is 0.003 mg/l, the overall mean of Cd is higher than the standard.

Overall mean of copper (Cu) is 0.22435 mg/l. The maximum Cu is 1.065 mg/l and minimum Cu is 0.014 mg/l. As the standard value of Cu in MNDWQS is 2 mg/l, the overall mean of Cu is less than the standard.

Overall mean of iron (Fe) is 9.28424 mg/l. The maximum Fe is 18.105 mg/l and minimum Fe is 0.932 mg/l. As the standard value of Fe in MNDWQS is 1 mg/l, the overall mean of Fe is too much higher than the standard.

Overall mean of lead (Pb) is 0.05698 mg/l. The maximum Pb is 0.401 mg/l and minimum Pb is 0.000 mg/l. As the standard value of Pb in MNDWQS is 0.01mg/l, the overall mean of Pb is higher than the standard.

Overall mean of mercury (Hg) is 0.00566274 mg/l. The maximum Hg is 0.010567 mg/l and minimum Hg is 0.0017 mg/l. As the standard value of Hg in MNDWQS is 0.001 mg/l, the overall mean of Hg is higher than the standard.

Overall mean of zinc (Zn) is 0.06719 mg/l. The maximum Zn is 0.226 mg/l and minimum Zn is 0.000 mg/l. As the standard value of Zn in MNDWQS is 3 mg/l, the overall mean of Zn is lower than the standard.

Table 4.1. Overall mean of parameters by comparing with MNDWQS

Parameter	Overall mean	MNDWQS
Temperature (°C)	23.8429	-
Electric conductivity (mS/cm)	0.14375	-
pH	6.8871	6.5 -8.5
TDS (mg/l)	122.07	1000
DO (mg/l)	7.8250	-
Turbidity (NTU)	1582.96	5
Cd (mg/l)	0.00986729	0.003
Cu (mg/l)	0.22435	2
Fe (mg/l)	9.28424	1
Pb (mg/l)	0.05698	0.01
Hg (mg/l)	0.00566274	0.001
Zn (mg/l)	0.06719	3

Table 4.2. Summary of water quality characteristics among Chaunggyi stream, Uyu and Chindwin rivers rivers (Calculated with One-Way ANNOVA Test)

Parameter	**Spatial Measures**			**Multiple Comparison**		
	Chaunggyi	**Uyu**	**Chindwin**	**Significant value (Sig. value)**		
	Mean±Standard Error			**Chaunggyi & Uyu**	**Chaunggyi & Chindwin**	**Uyu & Chindwin**
Tem:	25.01±1.77	23.76±0.85	23.42±1.13	0.514	0.447	0.813
EC	0.21±0.04	0.14±0.01	0.11±0.01	0.034	0.007	0.216
pH	6.67±0.22	6.94±0.09	6.89±0.06	0.143	0.287	0.684
TDS	334.25±186.08	92.75±8.13	74.63±26.64	0.003	0.004	0.754
DO	7.79±0.91	7.78±0.46	7.93±0.64	0.997	0.895	0.848
Turb:	1500.00±500.00	2041.13±224.54	708.13±177.14	0.250	0.128	0.001
Cd	0.0158±0.0077	0.0090±0.0025	0.0087±0.0045	0.305	0.328	0.954
Cu	0.153±0.097	0.249±0.090	0.211±0.109	0.606	0.773	0.795
Fe	13.566±1.613	10.013±0.595	5.686±1.843	0.081	0.001	0.009
Pb	0.080±0.028	0.059±0.025	0.042±0.015	0.651	0.466	0.653
Hg	0.0068±0.0011	0.0055±0.0008	0.0054±0.0011	0.443	0.438	0.914
Zn	0.109±0.028	0.071±0.013	0.038±0.016	0.201	0.034	0.151

Note: Tem (water temperature), EC (electric conductivity), TDS (total dissolved solids), DO (dissolved oxygen), Turb (turbidity), Cd (cadmium), Cu (copper), Fe (iron), Pb (lead), Hg (mercury), Zn (zinc)

Table 4.3. Mean and standard error of parameters between wet season and dry season (calculated with T- test)

Parameter	Wet season	Dry season	Sig. value
Temp:	26.86±0.39	20.83±0.20	0.054
EC	0.112±0.016	0.175±0.008	0.419
pH	6.98±0.09	6.80±0.08	0.509
TDS	130.21±59.36	113.93±5.26	0.048
DO	6.60±0.31	9.05±0.37	0.086

Turb	1192.00±171.68	1973.93±303.12	0.006
Cd	0.0082±0.0028	0.0116±0.0033	0.695
Cu	0.409±0.099	0.040±0.005	0.000
Fe	10.659±1.010	7.910±1.179	0.266
Pb	0.054±0.028	0.060±0.013	0.530
Hg	0.0058±0.0010	0.0055±0.0006	0.000
Zn	0.085±0.017	0.049±0.010	0.031

Note: Tem (water temperature), EC (electric conductivity), TDS (total dissolved solids), DO (dissolved oxygen), Turb (turbidity), Cd (cadmium), Cu (copper), Fe (iron), Pb (lead), Hg (mercury), Zn (zinc)

4.1. Temperature

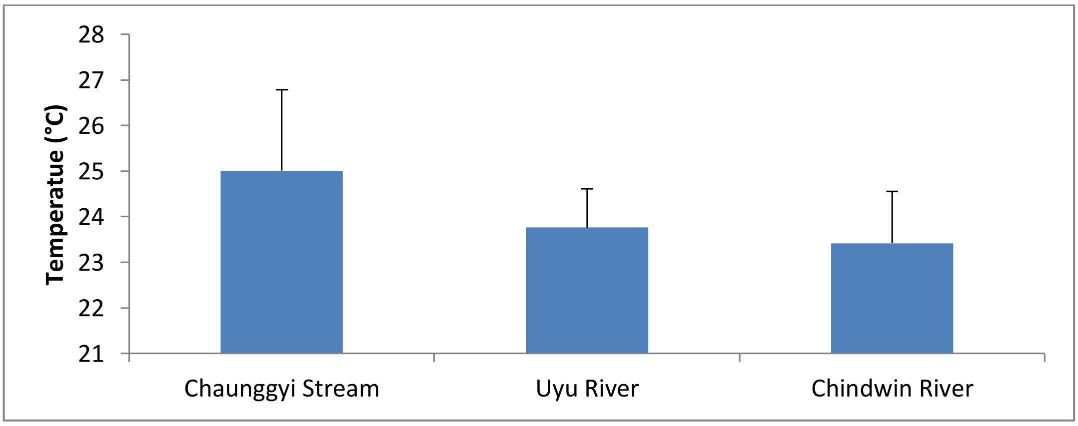

Figure 4.1. Mean± standard error values of Temperature among Chaunggyi, Uyu and Chindwin rivers

Temperature in Chaunggyi is higher than Uyu and Chindwin rivers because less amount of water in Chaunggyi and more mines are working on both sides of Chaunggyi stream.

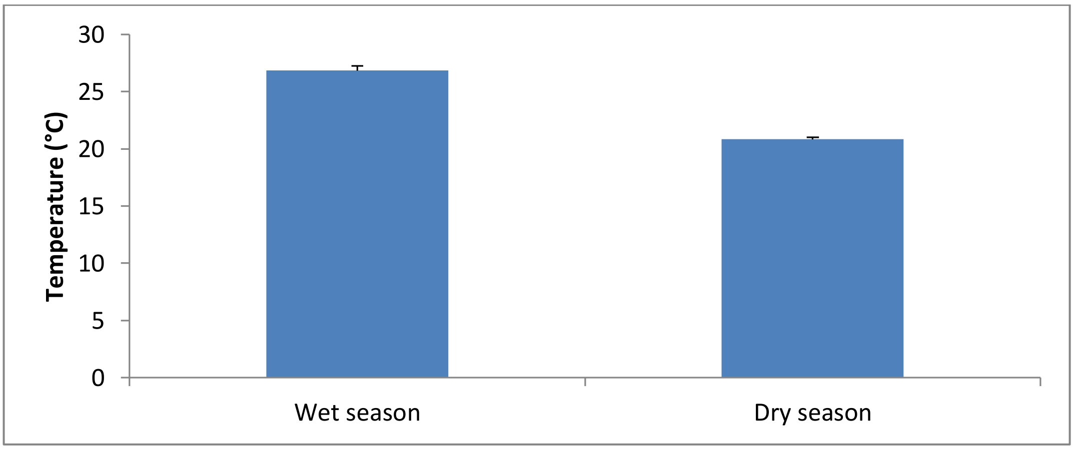

Figure 4.2. Mean± standard error values of Temperature between wet season and dry season

The mean ± standard error values of temperature is 26.86±0.39 for the wet season and 20.83±0.20 for the dry season. Temperature in the dry season is less than wet season because the weather is colder in December and February of study area than wet season.

The highest water temperature is in the wet season. Chaunggyi stream's temperature is higher than Uyu and Chindwin rivers. But there is no difference among Chaunggyi stream, Uyu and Chindwin rivers and also between wet season and dry season. Good condition of water temperature is 25 ˚C. To maintain good water temperature, physical measures can be done. Protection of forests around gold mines can maintain water temperature. Reducing directly discharged water from the gold mines sites that are using many times pumping, sucking from the ground can also affect water temperature. Therefore, systematic processing of mines should be done.

4.2. Electric conductivity

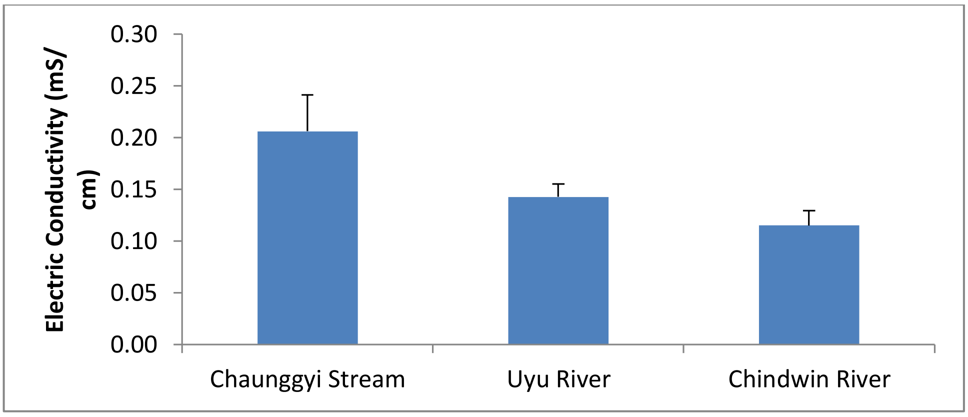

Fig: 4.3. Mean± standard error values of electric conductivity among Chaunggyi, Uyu and Chindwin rivers

The highest electric conductivity is 0.304 mS/cm in the Chaunggyi stream and the lowest electric conductivity is 0.064 mS/cm in Chindwin river. The mean ± standard error values of electric conductivity are 0.21±0.04 for Chaunggyi stream, 0.14±0.01 for Uyu river and 0.11±0.01 for Chindwin river. Electric conductivity in Chaunggyi is higher than in Uyu and Chindwin rivers.

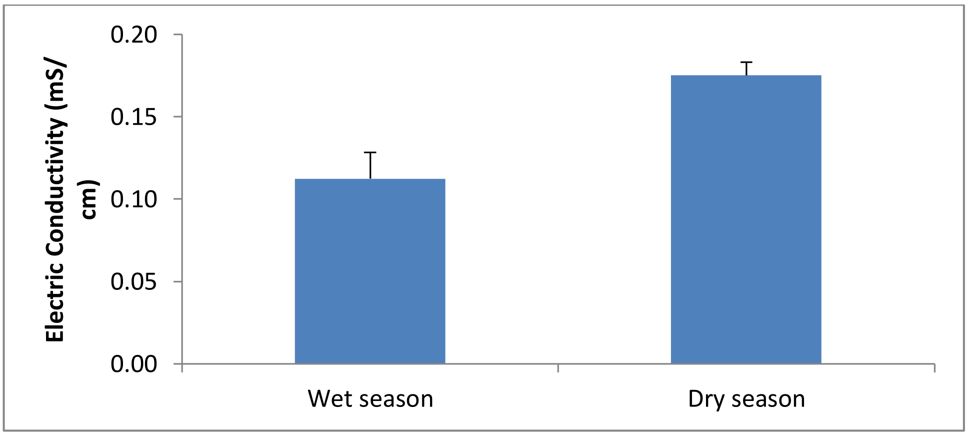

Figure 4.4. Mean± standard error values of electric conductivity between wet and dry seasons

The highest electric conductivity is 0.304 mg/l in the wet season which is hot and wet. The mean ± standard error values of electric conductivity is 0.112±0.016 for the wet season and 0.175±0.008 for the dry season. Electric conductivity in the dry season is higher than wet season because less amount of water in dry season.

The highest electric conductivity is in Chaunggyi stream. Electric conductivity is is higher in dry season. But there is no difference among Chaunggyi, Uyu and Chindwin rivers and between wet and dry seasons. EC is related with temperature. If the temperature is good condition, EC also good. Conductivity is a measure of the ability of water to pass an electrical current. Because dissolved salts and other inorganic chemicals conduct electrical current, conductivity increases as salinity increases. Conductivity is also affected by temperature, the warmer the water, the higher the conductivity. EC also depends on the iron concentration. If iron concentration and water temperature will reduce, EC will also be reduced automatically. EC should be less than 1500 µS/cm that is the value of Myanmar National Drinking Water Quality Standard.

As conductivity is measured by the electrical potential of ions in solution, it is affected by the concentration, charge and mobility of those ions. To be good water quality, there should be maintained the concentration of other related parameters.

4.3. pH

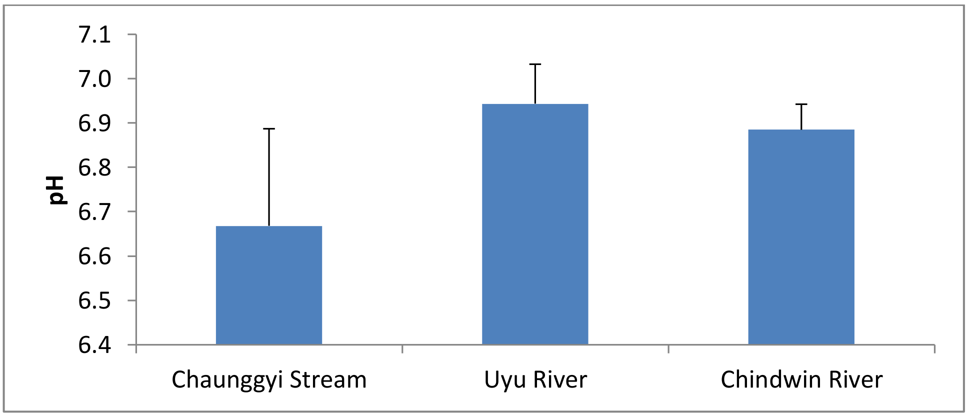

Figure 4.5. Mean± standard error values of pH among Chaunggyi stream, Uyu and Chindwin rivers

The highest pH is 7.6 in Uyu river at Namttaw and the lowest pH is 6.27 in Uyu river (downstream). The mean ± standard error values of pH are 6.67±0.22 for Chaunggyi stream, 6.94±0.09 for Uyu river and 6.89±0.0.06 for Chindwin river. pH in Chaunggyi is lower than in Uyu and Chindwin rivers.

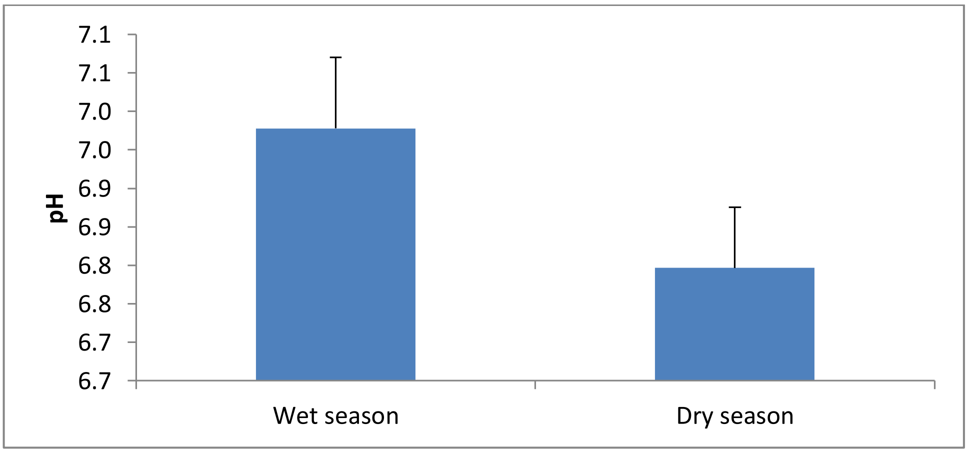

Figure 4.6. Mean± standard error values of pH between wet and dry seasons

The mean ± standard error values of pH is 6.98±0.09 for the wet season and 6.80±0.08 for the dry season. pH in the wet season is better than dry season because the heavy rain always fall in the wet season and drought in the dry season.

pH is good condition in Uyu and Chindwin rivers than Chaunggyi stream. There is no difference among Chaunggyi, Uyu and Chindwin rivers and between wet and dry seasons. The current situation of pH is neither acid nor base. pH value should be between 6.5 and 8.5 that is WHO drinking water quality standard and MNDQWS standard.

4.4. Total Dissolved Solids

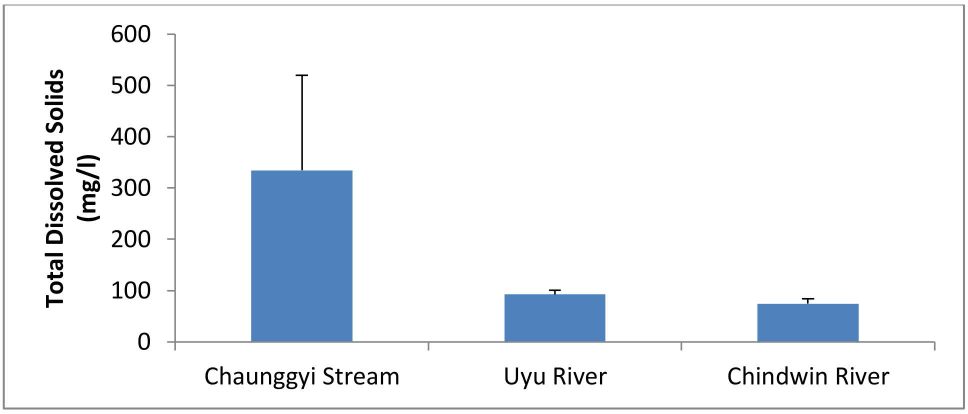

Figure 4.7. Mean± standard error values of TDS among Chaunggyi stream, Uyu and Chindwin rivers

The highest TDS is 890 mg/l in Chaunggyi stream and the lowest TDS is 41 mg/l in Chindwin river at Homalin. The mean ± standard error values of TDS are 334.25±186.08 for Chaunggyi stream, 92.75±8.13 for Uyu river and 74.63±26.64 for Chindwin river. TDS in Chaunggyi is higher than in Uyu and Chindwin rivers because of many mines on both sides of that stream.

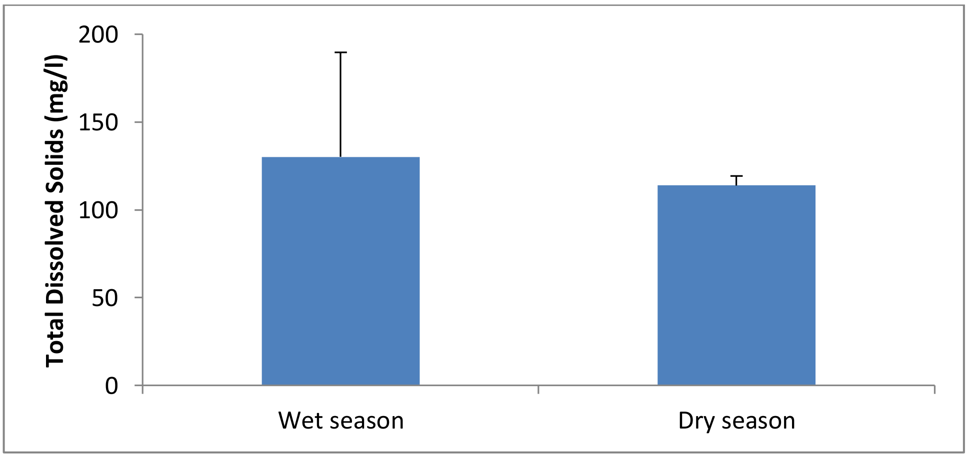

Figure 4.8. Mean± standard error values of TDS between wet and dry seasons

The mean ± standard error values of TDS is 130.21±59.36 for the wet season and 113.93±5.26 for the dry season. TDS in the dry season is much more than wet season because there is more concentration in the dry season due to the less amount of water.

TDS is in Chaunggyi stream than Uyu and Chindwin rivers. TDS is higher in wet season than dry season. But TDS value of drinking water quality standard is 1000 mg/l. Most of the results are over 100 mg/l. There will be no harmful effects. Ways to reduce or remove TDS in water are Reverse Osmosis (R.O.) that removes TDS by forcing the water, under pressure, through a synthetic membrane. Distillation process involves boiling water to produce water vapor and Deionisation (DI). RO *water* purifier can be used to *reduce* the *TDS* levels of *water*. RO reduces *TDS* by forcing *water* through a fine membrane with microscopic pores which eliminates even the smallest of particles. It is allowed to pass through atoms smaller than 0.0001 microns.

In streams and rivers, conductivity levels come normally from the surrounding geology. Clay soils will contribute to conductivity. The minerals in clay will ionize due to dissolving. Inflows of groundwater contribute to the conductivity of the stream or river depending on the geology. Groundwater that is heavily ionized from dissolved minerals will increase the conductivity of the water into which it flows.

4.5. Dissolved Oxygen

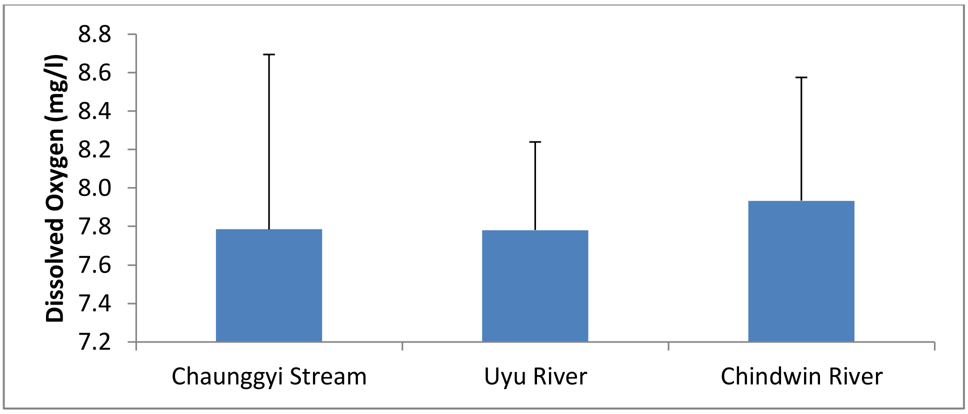

Fig. 4.9. Mean± standard error of DO among Chaunggyi steam, Uyu and Chindwin rivers

The highest DO is 10.96 mg/l in Uyu river downstream and the lowest DO is 5.11 mg/l in Uyu river upstream. The mean ± standard error values of DO are 7.79±0.91 for Chaunggyi stream, 7.78±0.46 for Uyu river and 7.93±0.64 for Chindwin river. DO in Chaunggyi is a little higher than in Uyu and Chindwin rivers but all are good condition.

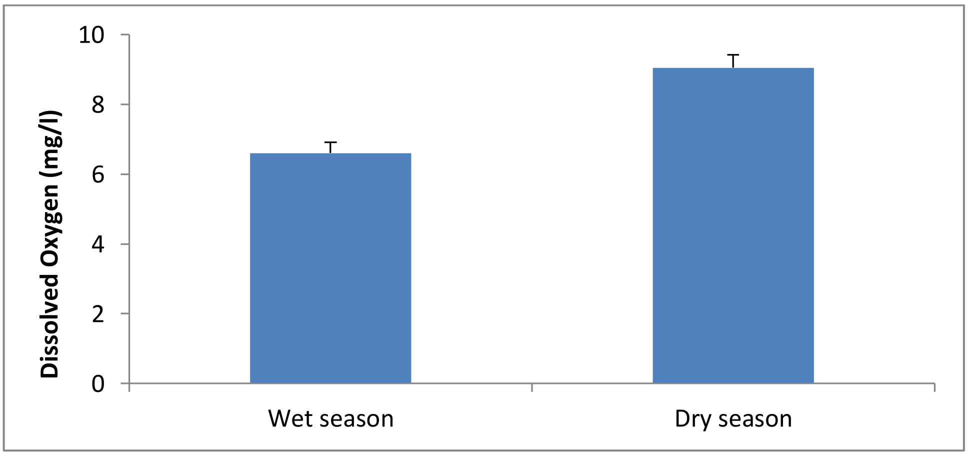

Figure 4.10. Mean± standard error values of DO between wet and dry seasons

The mean ± standard error values of DO is 6.60±0.31 for the wet season and 9.05±0.37 for the dry season. DO in the dry season is much more than wet season because there is more oxidation in the dry season due to the less amount of released water from gold mines sites.

As the significant value of DO is greater than significant level 0.05, there is no difference among Chaunggyi, Uyu and Chindwin and also between wet season and dry season. DO is a little higher in Chindwin than Uyu and Chaunggyi. DO is also higher in the dry season than wet season. DO condition is greater than 7.5 mg/l, there is very good condition for aquatic life and environment. To be much more DO, creating waterfalls can cause. Cold water can hold more dissolved oxygen than warm water. In winter and early spring, when the water temperature is low, the dissolved oxygen concentration is high. In summer and fall, when the water temperature is high, the dissolved-oxygen concentration is often lower. By protecting forests around gold mines and along the rivers, DO can be obtained more.

Changing in wind velocity, water temperature, convection currents, numbers of decomposers, intensity of light, rate of photosynthetic activity, respiration by other animals and plants, the presence of oxidizable ions, atmospheric pressure, and humidity can affect DO.

4.6. Turbidity

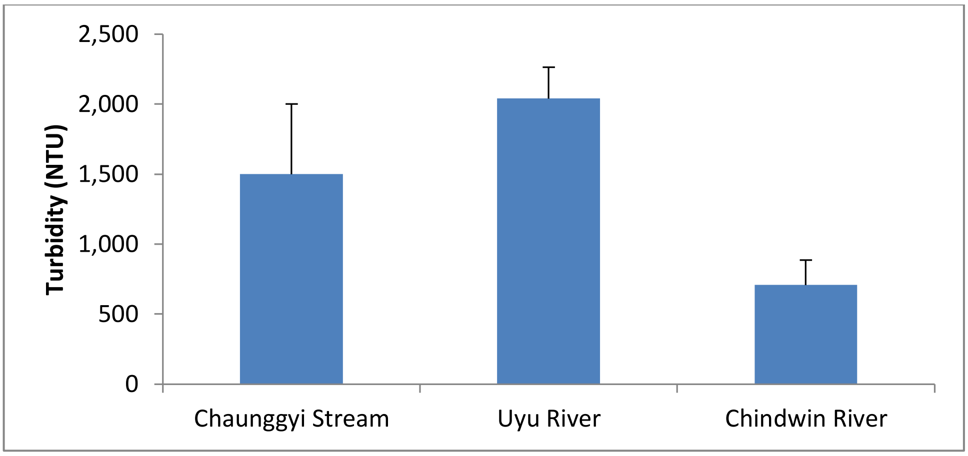

Figure 4.11. Mean± standard error values of Turbidity among Chaunggyi stream, Uyu and Chindwin river

The highest turbidity is 3000 NTU in Uyu river and the lowest turbidity is 120 NTU in Chindwin river upstream. The mean ± standard error values of turbidity are 1500.00±500.00 for Chaunggyi stream, 2041.13±224.54 for Uyu river and 708.13±177.14 for Chindwin river. Turbidity in Chaunggyi stream and Uyu river are higher than in Chindwin river because there are many gold mines on both sides of Chaunggyi and Uyu river than Chindwin river.

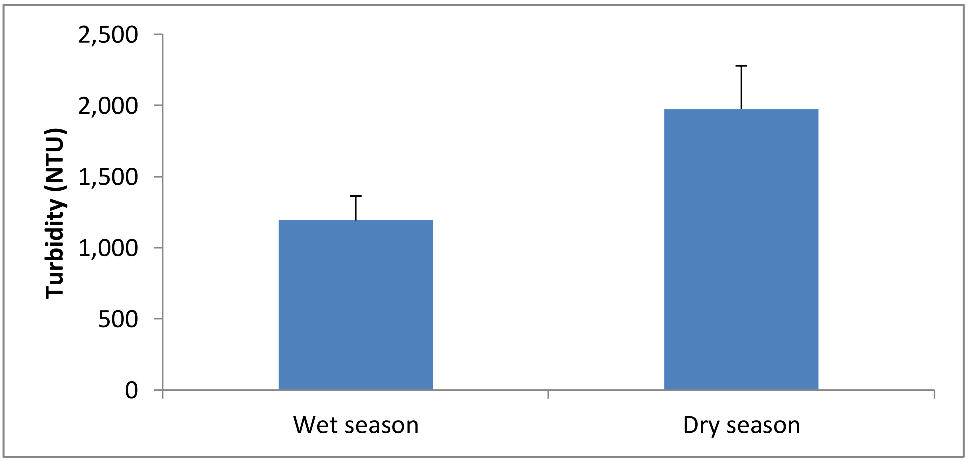

Fig. 4.12. Mean± standard error values of Turbidity among seven sampling places

The mean ± standard error values of turbidity is 1192.00±171.68 for the wet season and 1973.93±303.12 for the dry season. Turbidity in the dry season is much more than wet season because the less amount of water in the river and directly discharged from the gold mines. Thus too much concentration of turbidity will form in the dry season.

In drinking water, turbidity indicates the presence of high bacteria levels, pathogens, or particles that can be harmful organisms from disinfection processes. Therefore water treatment plants should constantly monitor the turbidity levels to ensure not exceed the safe levels.

There is a difference among Chaunggyi, Uyu and Chindwin and also between wet season and dry season. Turbidity is higher in Uyu river than Chaunggyi and Chindwin river. Turbidity is higher in dry season than wet season. Turbid water are directly released from all of gold mining sites. Gold mines make much more erosion of soil by sucking-dredging of high horse power engines almost every day. To reduce turbidity, there must be tailing ponds that can make sedimentation before flowing to the outsides of mines area. If there is less turbidity, the rivers will be clean and can also be seen as good in esthetic points of view.

In a household using for cooking, turbidity can be treated by using sand filters and cartridge filters. A sand filter should include a tank with fine sand on top of gravel. The sand effectively removes all but the finest suspended particles. These filters must be backwashed periodically to remove the accumulated sediment from the filter.

4.7. Cadmium

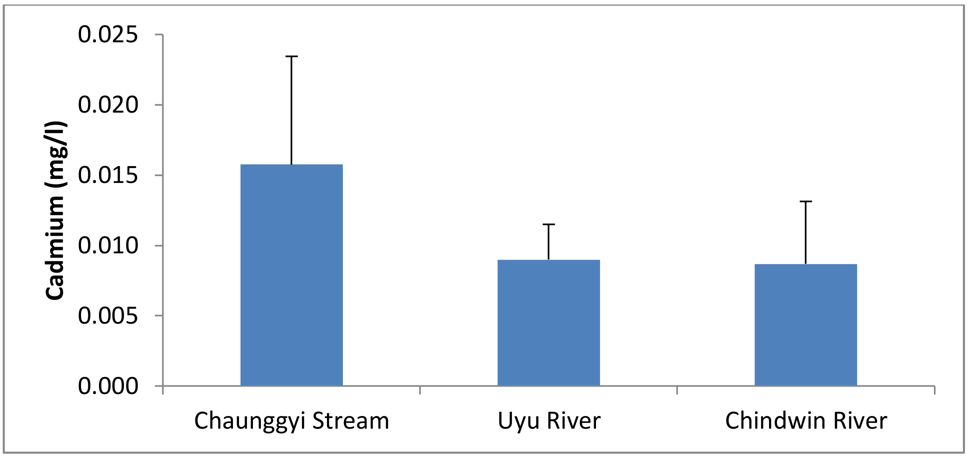

Fig. 4.13. Mean± standard error values of Cadmium among Chaunggyi, Uyu and Chindwin rivers

The highest cadmium is 0.401 mg/l in Uyu river at Namttaw and the lowest cadmium is 0.0004 mg/l in Uyu river upstream. The mean ± standard error values of cadmium are 0.0158±0.0077 for Chaunggyi stream, 0.0090±0.0025 for Uyu river and 0.0087±0.0045 for Chindwin river. Cadmium in Chaunggyi is higher than in Uyu and Chindwin rivers because of much more working mines on both sides of Chaunggyi.

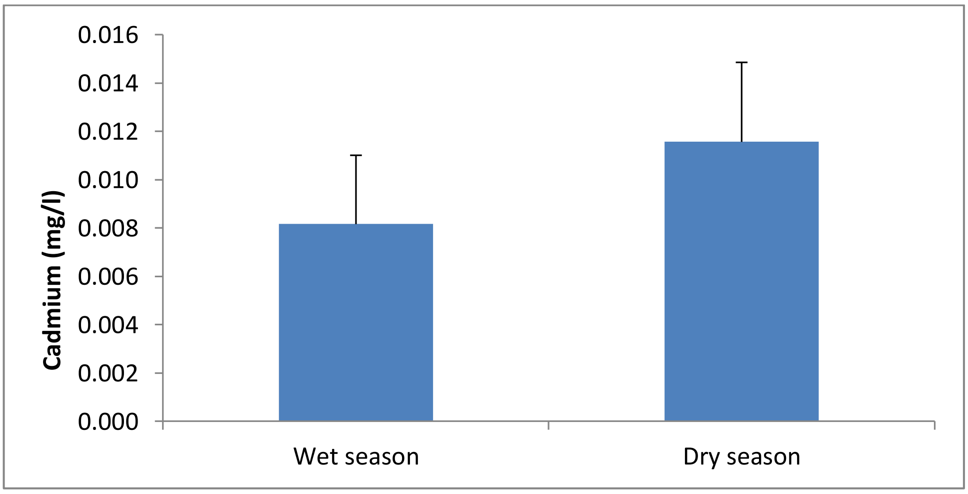

Fig. 4.14. Mean ±standard error values of Cadmium between wet and dry seasons

Cadmium is not significantly varied between wet season and dry season. The highest cadmium is 0.041 mg/l in the dry season. The mean ± standard error values of cadmium is 0.0082±0.0028 for the wet season and 0.0116±0.0033 for the dry season.

There is no difference of cadmium among Chaunggyi, Uyu and Chindwin rivers and between wet and dry seasons. There is a little higher in Chaunggyi stream than Uyu and Chindwin. Cd is higher in dry season than wet season.

Cadmium can be removed by coagulation, precipitation and filtration treatment when pH is raised. It can also be removed as a part of a lime softening process. Reverse osmosis systems can effectively reduce all ionic species of cadmium by 92-98 percent of the influent concentration for influent water concentrations when operated at pressures greater than 50 psig and at temperatures between 40° and 85° F. S types of membrane materials are used. Acceptable operating conditions for each type are different. Care is needed to insure that operating conditions for the specific membrane material are adhered to especially feed water pH, particulates and oxidants, to maintain effectiveness. Distillation is also effective means to reduce cadmium. Precipitated and insoluble species of cadmium that may exist in some waters can be reduced with filtration that effectively removes particles of 0.5 microns in size.

Cadmium, a heavy metal, is produced by refining zinc ores. Cadmium metal is practically insoluble in water but some cadmium salts are water soluble. Powdered cadmium will burn and can release corrosive fumes.

Mining activities may release cadmium ions in waste water. Natural decontamination can be introduced using some medicinal plants. The seeds of *Moringa oleifera*, peanuts (*Arachis hypogaea*), cowpeas (*Vigna unguiculata*), urad (*Vigna mungo*) and corn (*Zea mays*) were used for water purification. These seeds can absorb and neutralize colloidal positive charges. This action causes to absorb the negative charged impurities and metals in waste water.

4.8. Copper

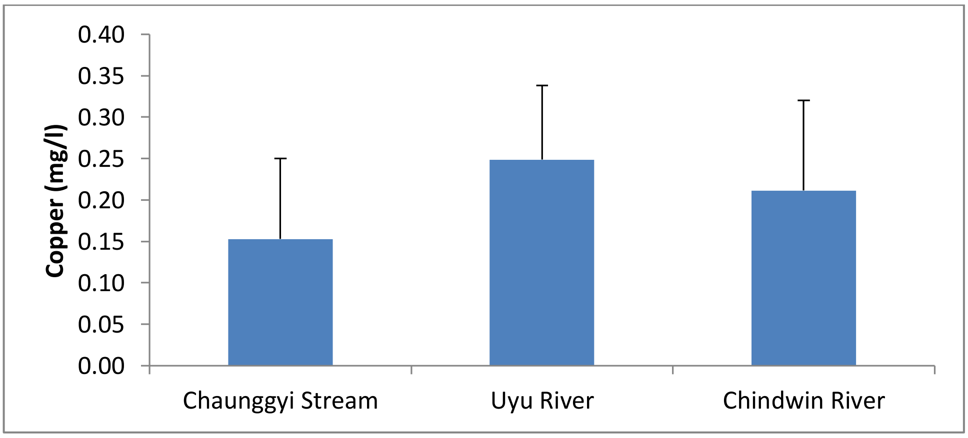

Fig. 4.15. Mean± standard error values of Copper among Chaunggyi, Uyu and Chindwin rivers

The highest copper is 1.065 mg/l in Uyu river upstream and the lowest copper is 0.014 mg/l in Chaunggyi stream. The mean ± standard error values of copper are 0.153±0.097 for Chaunggyi stream, 0.249±0.090 for Uyu river and 0.211±0.109 for Chindwin river. Copper in Chaunggyi is less than in Uyu and Chindwin rivers because Chaunggyi flows from clay and sandy mountains.

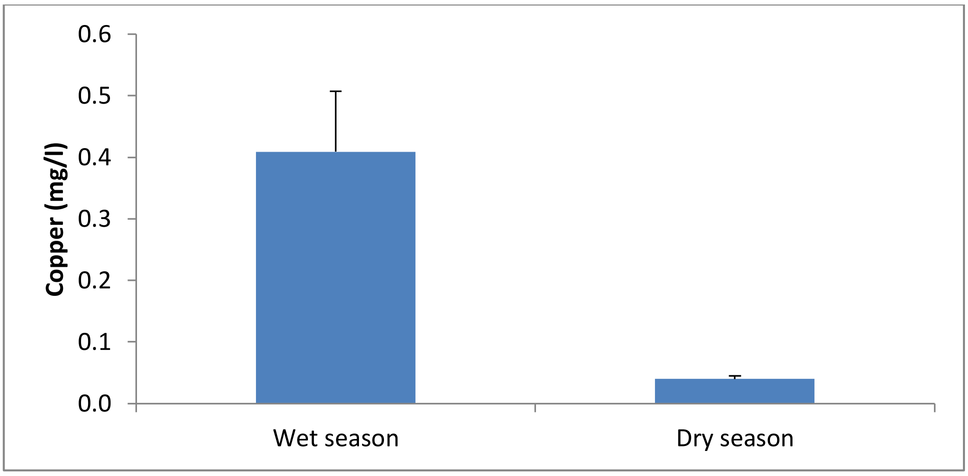

Fig. 4.16. Mean± standard error values of Copper between wet and dry seasons

The mean ± standard error values of copper is 0.409±0.099 for the wet season and 0.040±0.005 for the dry season. Copper in the wet season is much more than dry season because the less amount of water in the river, directly discharged from the gold mines and drainage from the Rocky Mountains in the raining season. Thus too much concentration of copper will form in the wet season.

There is no difference among Chaunggyi, Uyu and Chindwin rivers. But there is difference between wet and dry seasons. There is a little higher in Uyu than Chaunggyi stream and Chindwin. Copper is higher in wet season than dry season.

Copper can be removed from drinking water by one of several different methods, including reverse osmosis, distillation, and ion exchange filtering. Reverse osmosis works by forcing water through a membrane that allows water to pass through but blocks ions such as copper.

4.9. Iron

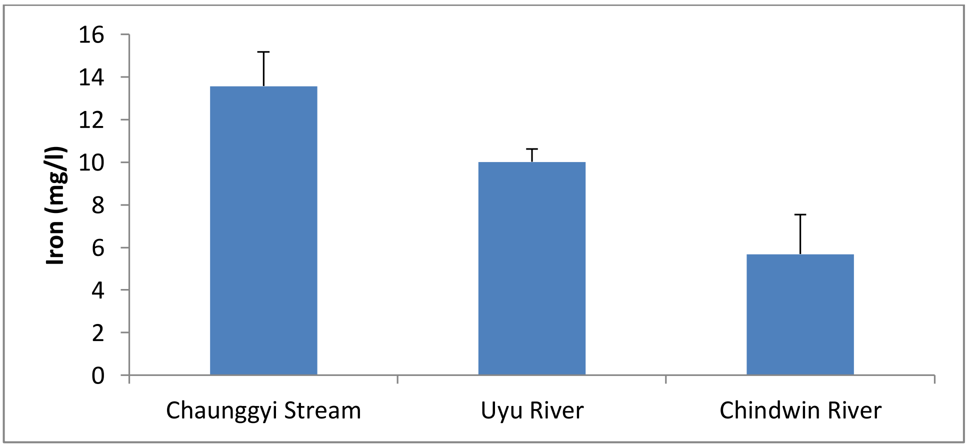

Fig. 4.17. Mean± standard error values of Iron among Chaunggyi, Uyu and Chindwin rivers

The highest iron is 18.105 mg/l in Chaunggyi stream and the lowest iron is 0.932 mg/l in Chindwin river at Homalin. The mean ± standard error values of iron are 13.566±1.613 for Chaunggyi stream, 10.013±0.595 for Uyu river and 5.686±1.843 for Chindwin river. Iron in Chaunggyi is greater than in Uyu and Chindwin rivers.

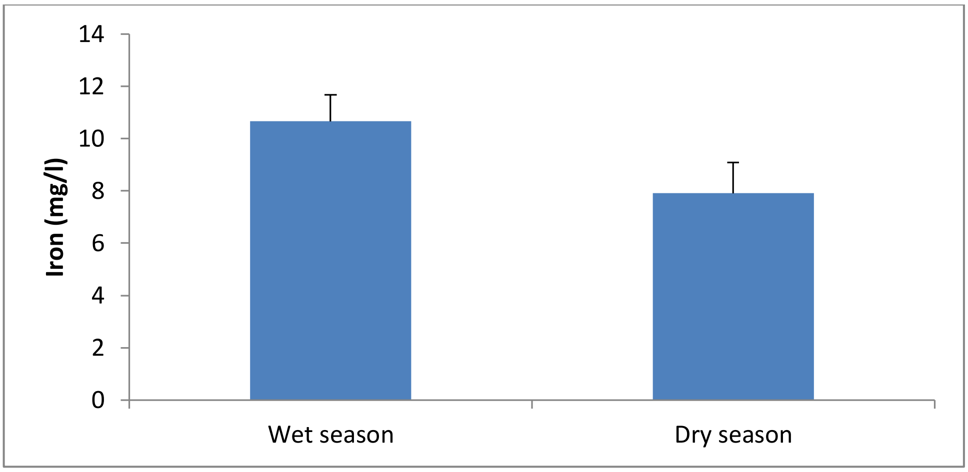

Fig. 4.18. Mean± standard error values of Iron between wet and dry seasons

The mean ± standard error values of iron is 10.659±1.010 for the wet season and 7.910±1.179 for the dry season. Iron in the wet season is a little more than dry season because directly discharged from the gold mines.

There is a difference among Chaunggyi, Uyu and Chindwin rivers. But there is no difference between wet and dry seasons. Chaunggyi stream is higher iron concentration than Uyu and Chindwin. Iron is a little higher in wet season. Iron concentration is directly related with turbidity. If higher turbidity, higher concentration of iron will be. Gold mines are still using ironic pipes in sucking-dredging process. The contaminated water from the mining sites will be the one of the main sources of iron concentration.

4.10. Lead

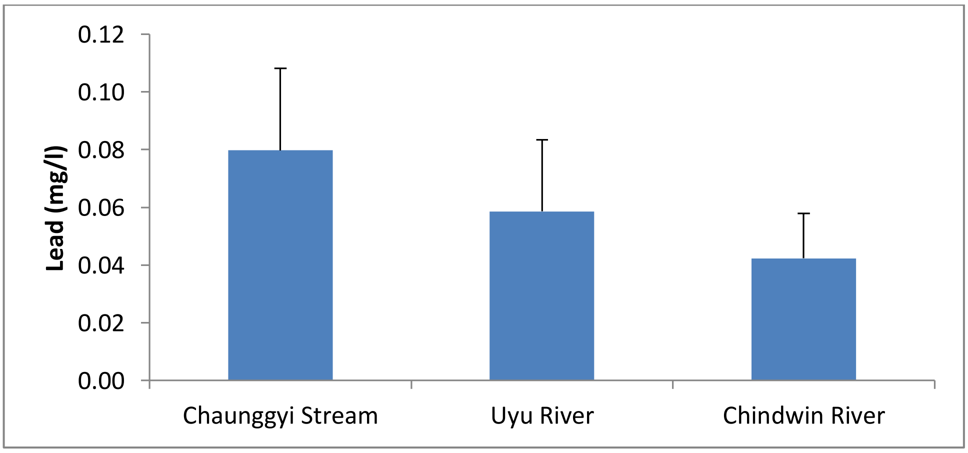

Fig. 4.19. Mean± standard error values of lead among Chaunggyi, Uyu and Chindwin rivers

The highest lead is 0.401 mg/l in Uyu river at Namttaw and the lowest lead is 0.00 mg/l in Uyu river and Chanuggyi stream. The mean ± standard error values of lead are 0.080±0.028 for Chaunggyi stream, 0.059±0.025 for Uyu river and 0.042±0.015 for Chindwin river. Lead in Chaunggyi is greater than in Uyu and Chindwin rivers.

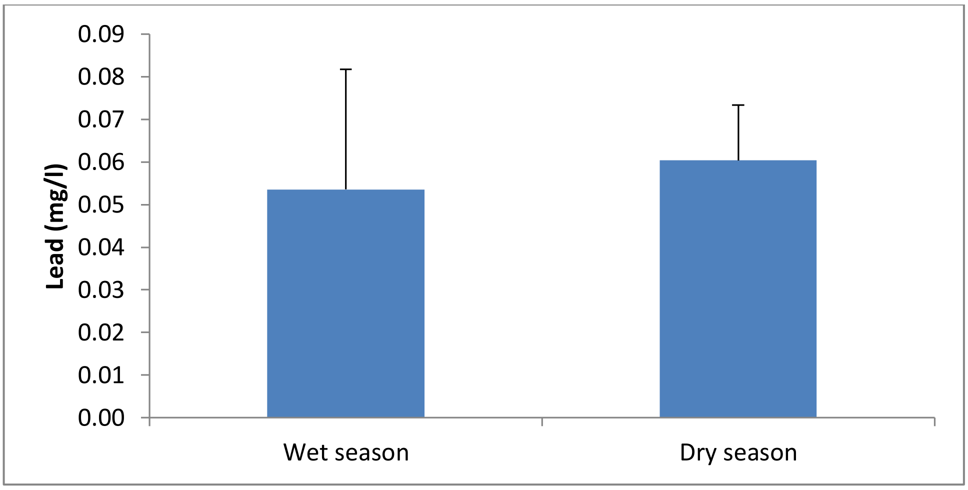

Fig. 4.20. Mean± standard error values of lead between wet and dry seasons

The mean ± standard error values of iron is 0.054±0.028 for the wet season and 0.060±0.013 for the dry season. Lead in the dry season is a little more than wet season because the less amount of water in the river and directly discharged from the gold mines.

There is not difference among Chaunggyi, Uyu and Chindwin rivers and between wet and dry seasons. Lead is higher in Chaunggyi stream than Uyu and Chindwin rivers. Lead is a little higher in dry season.

The water has not been used for several hours, may contain lead from the pipes. Lead can be reduced in water levels up to 90%. It is not suitable to cook with or drink water from the hot water tap because lead dissolves more easily into hot. Boiling water will not reduce lead. The right filtration methods to remove lead from water reverse osmosis, activated carbon filtration and distillation.

4.11. Mercury

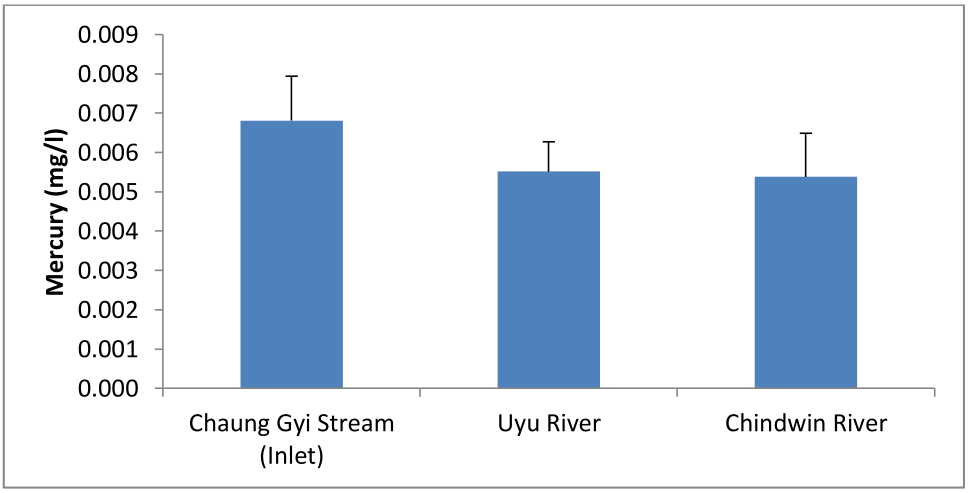

Fig. 4.21. Mean± standard error values of mercury among Chaunggyi, Uyu and Chindwin rivers

The highest mercury is 0.0106 mg/l in Chaunggyi stream and the lowest mercury is 0.0017 mg/l in Chindwin river at Homalin. The mean ± standard error values of mercury are 0.0068±0.0011 for Chaunggyi stream, 0.0055±0.0008 for Uyu river and 0.0054±0.0011 for Chindwin river. Mercury in Chaunggyi is a little higher than in Uyu and Chindwin rivers.

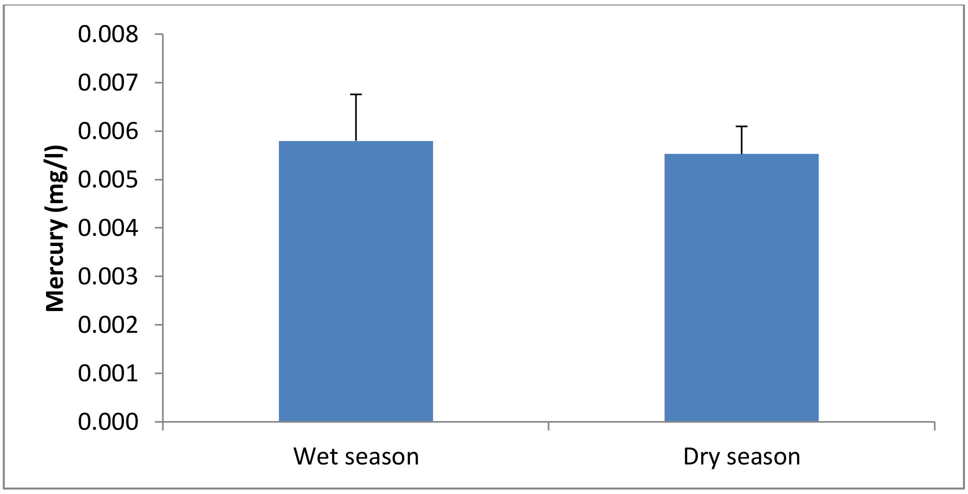

Fig. 4.22. Mean± standard error values of mercury between wet and dry seasons

The highest mercury is 0.011 mg/l in the wet season. The mean ± standard error values of mercury is 0.0058±0.0010 for the wet season and 0.0055±0.0006 for the dry season. Mercury is always using in the amalgamation of gold mining processes.

There is no difference mercury level among Chaunggyi stream, Uyu and Chindwin rivers. Chaunggyi stream is a little more concentration than Uyu and Chindwin. But there is a difference between wet season and dry season. Mercury contamination is higher in the wet season.

Mercury contamination is mainly caused by the gold mines which are used mercury for amalgamation for many years ago. If mercury is systematically used in gold mines, there may be less contaminated in water. The best way to reduce mercury usage is to upgrade the mining processes without using mercury. On the other hands, if Myanmar is one of membership countries of Minamata Convention, there will be to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. And then gold mines will be working systemaically. If there is less gold mines, these negative impacts will be reduced.

The specific methods for controlling mercury releases from these sources vary widely, depending upon local circumstances, but fall generally under the following four groups:

a) Reducing mercury mining and consumption of raw materials and products that generate mercury releases;
b) Substitution (or elimination) of products, processes and practices containing or using mercury with non-mercury alternatives;
c) Controlling mercury releases through end-of-pipe techniques;
d) Mercury waste management.

According to the World Health Organisation (WHO), mercury is one the most harmful substances for human health because that can influence the nervous system, the development of the brain, and more. There is particularly harmful for children and can also be transmitted from a mother to a child during pregnancy. Furthermore, mercury spreads very easily through nature, and can enter the food chain. Freshwater fish, for example, often contain high levels of mercury.

4.12. Zinc

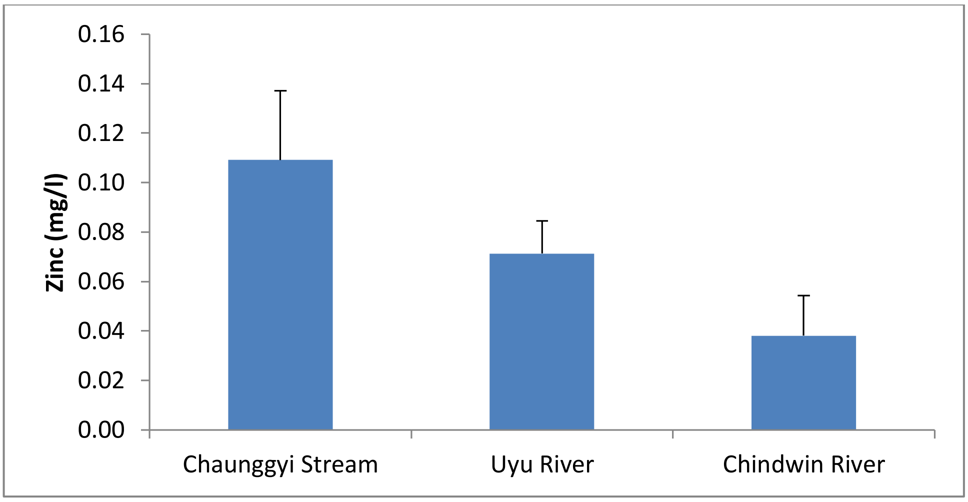

Fig. 4.23. Mean± standard error values of zinc among Chaunggyi, Uyu and Chindwin rivers

The highest zinc is 0.226 mg/l in Uyu river downstream and the lowest zinc is 0.00 mg/l in Uyu river upsteam. The mean ± standard error values of zinc are 0.109±0.028 for Chaunggyi stream, 0.071±0.013 for Uyu river and 0.038±0.016 for Chindwin river. Zinc in Chaunggyi is higher than in Uyu and Chindwin rivers.

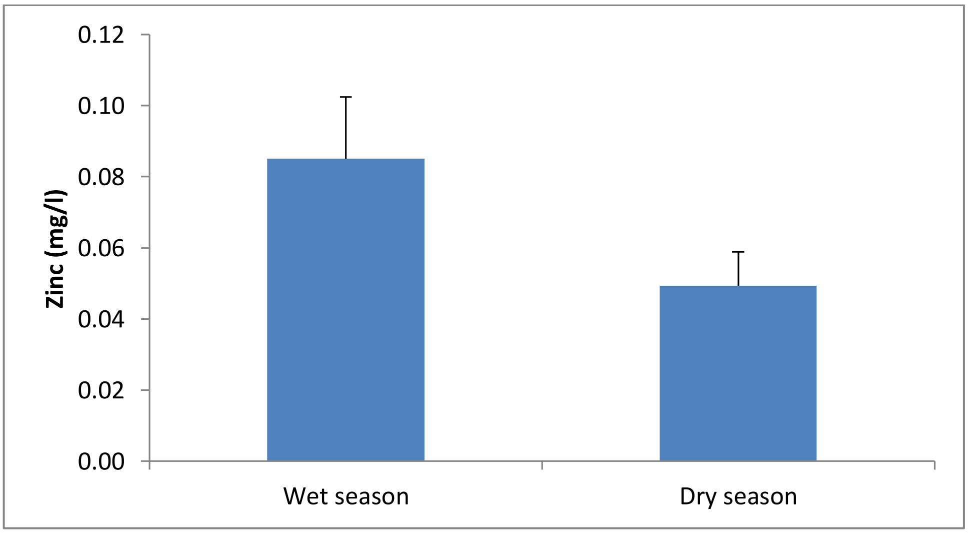

Fig. 4.24. Mean± standard error values of zinc between wet and dry seasons

The highest zinc is 0.226 mg/l in the wet season. The mean ± standard error values of zinc is 0.085±0.017 for the wet season and 0.049±0.009 for the dry season.

There is difference in zinc contamination level among Chaunggyi stream, Uyu and Chindwin rivers. Zinc is higher in Chaunggyi stream than Uyu and Chindwin. And also zinc is higher in wet season than dry season.

Zinc can be removed from water by different methods. To achieve a level that meets legal standards, coagulation, ion exchange and active carbon, and sand filtration may be applied.

Coagulation is the destabilization of colloidal particles brought about by the addition of a chemical reagent called as coagulant. Flocculation is the agglomeration of destabilized particles into microfloc and after into bulky floccules which can be settled called floc. The addition of another reagent called flocculant or a flocculant aid may promote the formation of the floc.

Zinc can be removed from drinking water by carrying out through ion exchange softening method. Many softening agents are used in order to reduce the hardening caused by the presence of magnesium and calcium. The replacement of ions is done with sodium in a particular resin. Saline is used to wash away or remove the ions and resin is then regenerated to check its affectivity.

5. Conclusion

River water management for Homalin Township is a very important role as its main fresh water sources, transportation values, cultural, ecological and ecosystem services. Chindwin and Uyu river watershed is crucial for monitoring of drinking water that is used by people who lived along the river from upstream to downstream. These two rivers are facing serious problem in water quality, degradation of water storage and water sources due to gold mines. It is important to provide environmental information for Homalin Township watershed at improving water quality and protection of water resources. Therefore, the results of the study investigate the assessment of river water quality in gold mining areas especially in Uyu and Chinwin rivers by collecting 7 water sampling places for four times during seven months.

The results have been demonstrated by using multivariate statistical technique including analysis of variance with multiple comparison, principal component analysis that could provide an overview of the spatial and seasonal variation of river water quality and also the relationship between gold mines and water quality. The results show that gold mines was negatively associated with water pollutants especially in turbidity, iron and mercury.

The results show that TDS, turbidity, Cu, Hg and Zn are difference between wet season and dry season. Among them turbidity is higher level in the dry season because there is less amount of river water in the dry season and high concentration of contaminated water discharged from the gold mine sites. TDS, Cu, Hg and Zn concentrations are higher in the wet season.

TDS, turbidity, iron and zinc are difference among Chaunggyi stream, Uyu and Chindwin rivers. Turbidity concentration is higher in Uyu river than Chindwin and Chaunggyi. TDS, iron and zinc concentrations are higher in Chaunggyi stream than Uyu and Chindwin rivers.

Although higher income is getting from the gold mining sites, there are still environmental degradation problems including water pollution, air pollution and soil pollution. As a consequence, negative impact, current situation stream and river water should not directly be used for drinking and cooking. This is the huge loss of fresh water resources to people and aquatic lives as well as esthetic point of view. Therefore, mines working should be systematically worked to reduce negative impacts on river and stream water quality.

Rural people should not directly use the river water for drinking and cooking because of Turbidity, Cd, Fe, Pb and Hg. Gold mines should be operated systematically for sustainable deveopment. Proponents should participate in all gold mines processes to be systematically. Myanmar should do river water quality guidelines or standards to maintain water quality and also should be a member of minamata convention to be a better solution. Government organizations should participate in the rehabilitation processes. Research and Development should do in agriculture crop, soil, aquatic life, water quality, gold miners that will be negative impacts from the gold mine processes. Job opportunities should be creating for income such as factory, small farm enterprises to reduce mining activities. Monitoring and evaluation of river water quality should be done for the next generation and for further gold mines.

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