6 - 6． Geological survey

Geological survey

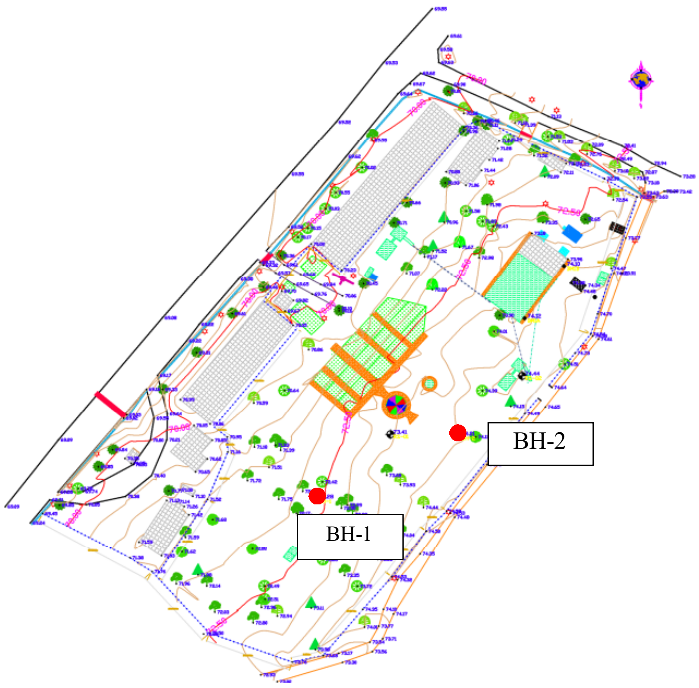


Figure 6-14　BPS No.7 survey map

BH-1
Reduced Level +72.28

BH-2
Reduced Level +74.01

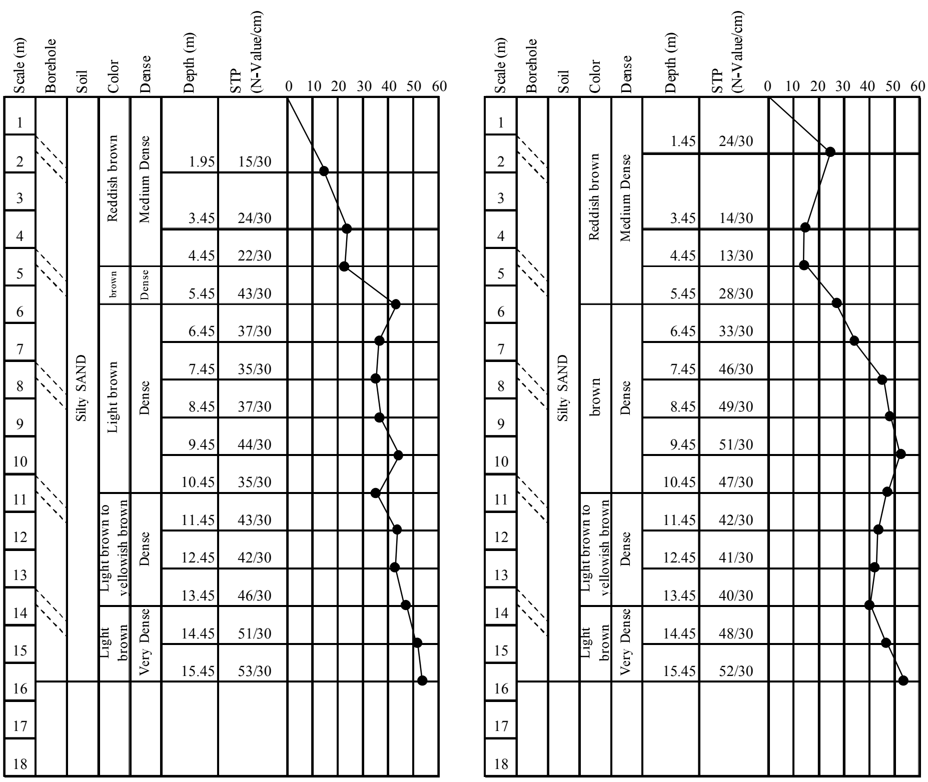


Figure 6-15　Boring log at survey site

Trial excavation survey

Survey map for trial excavation survey (at the “×”)

Table 6-1 Result of trial excavation

	Water level	Grain size analysis				Moisture	pH
		Gravel	Sand	Silt	Clay		
	m	%	%	%	%	%	%
TP-1	Nil	0.0	48.0	38.0	14.0	9.0	9.41
TP-2	Nil	0.0	61.0	26.0	13.0	9.0	9.20
TP-3	Nil	2.0	29.0	50.0	19.0	20.0	11.55
TP-4	Nil	0.0	10.0	65.0	25.0	16.0	8.95
TP-5	Nil	0.0	9.0	50.0	41.0	22.0	9.96
TP-6	Nil	0.0	8.0	49.0	43.0	27.0	9.76
TP-7	Nil	0.0	8.0	64.0	28.0	21.0	9.63
TP-8	Nil	0.0	11.0	60.0	29.0	24.0	9.58
TP-9	2.1	0.0	9.0	43.0	48.0	27.0	9.07
TP-10	Nil	6.0	8.0	76.0	10.0	16.0	10.05
TP-11	Nil	1.0	33.0	39.0	27.0	16.0	10.33
TP-12	Nil	1.0	12.0	43.0	44.0	22.0	9.48
TP-13	Nil	2.0	11.0	80.0	7.0	22.0	9.83
TP-14	Nil	1.0	17.0	44.0	38.0	17.0	11.11
TP-15	Nil	5.0	9.0	28.0	58.0	19.0	9.17
TP-16	Nil	3.0	12.0	52.0	33.0	21.0	9.44
TP-17	Nil	1.0	11.0	50.0	38.0	24.0	10.46
TP-18	Nil	1.0	12.0	73.0	14.0	22.0	8.93
TP-19	Nil	5.0	10.0	58.0	27.0	21.0	9.89

6－7．Water quality survey

6－7－1. Summary and result of water quality survey

① Purpose of this survey

The first purpose of this survey is to understand the water quality of existing water supply system of Mandalay urban area and Pyi Gyi Tagon Township (TS). Result of this survey is utilized to consider the policy of water quality improvement including the installation of chlorination facility.

In this study, test well is constructed for the new water source in Pyi Gyi Tagon area. For this test well, water quality test was conducted to obtain a baseline water quality data. Obtained water quality data is utilized to consider the policy of water quality improvement including installation of chlorination facility.

② Sampling point and water quality analysis item

Sampling point

Sampling points are listed in Table 6-2. Sampling points include newly constructed test well in Pyi Gyi Tagon TS, existing water supply facilities in Pyi Gyi Tagon TS and existing water supply facilities (water treatment plant (WTP), booster pump station (BPS), distribution reservoir (D/R) and elevated tank (ET)) in the urban area of Mandalay. For existing waterworks facility in Pyi Gyi Tagon TS, 30 water sampling points including 11 public taps, 14 private tube well (13 for private well, 1 for school), 2 hand pumps and 3 public water pot (volunteer water pot for public use) were selected. For Mandalay city urban area, 32 sampling points including WTP (2 samples: raw water and treated water), 1 D/R, 7 BPS (combined facility of water distribution pump and D/R) and 2 ET locations were selected.

Water quality test was implemented using simple water quality test kit. Laboratory test was implemented for analyzing water quality of samples collected from Test well, WTP, D/R, BPS and ET.

Table 6-2　List of sampling point

Name of sampling point		Number of sample	Test method	
			Simple test kit	Laboratory analysis
Pyi Gyi Tagon TS	Test well	1	Yes	Yes
Existing water supply facility in Pyi Gyi Tagon TS	Public tap	11	Yes	-
	Private tube well	13	Yes	-
	Tube well (School)	1	Yes	-
	Hand pump	2	Yes	-
	Public water pot	3	Yes	-
Pyi Gyi Tagon TS: Total		**31**		
Existing water supply facilities in Mandalay urban area	WTP N0.4 (Raw water and Treated water)	2	Yes	Yes
	D/R (Mandalay hill D/R)	1	Yes	Yes
	BPS	7	Yes	Yes
	ET	2	Yes	Yes
	Private tap	20	Yes	-
Mandalay Urban area: Total		**32**		

Source: JICA study team

Water quality analysis item

Water quality analysis items are listed in Table 6-3. Simple test was done using Pack Test and Coliform test paper (Kyoritsu Chemical-Check Lab.), and Merck M-Quant Test kit (Merck). Laboratory test was implemented at the laboratory in Thailand. In the laboratory test, water quality analysis was implemented in accordance with the Standard Methods (2012).

Table 6-3 Water quality analysis item

Water quality analysis item	Test method
On site measurement	
Air temperature, Water temperature , Odor	Thermometer Organoleptic examination (Odor)
pH, EC, TDS, Turbidity, Color	Water test meter (pH, EC, TDS) Turbidity and color test meter
Simple test	
Fe, Mn, Sulfide, NO_2-N, NO_3-N, NH_4-N, Al, F, Chloride	Pack test
As	Merck M-Quant test
E-coli, Fecal coli	Coliform test paper
Laboratory test	
Alkalinity, Hardness, Chloride, Sulfide, Cyanide, Ca, Mg, F, Al, As, Cu, Fe, Mn, Pb, NO_3-N, NO_2-N, NH_4-N, Zn, Cd, Cr, Hg, Se, Na, TOC, TDS, Standard plate count, E-coli	Standard Methods (2012)

③ Pyi Gyi Tagon TS: Existing water supply facility (Simple test)

MCDC public tap

Water quality of public tap is shown in Table 6-8. Water source of public tap is well water near public tap. The depth of water source well is about 30m – 90m (100ft – 300ft), and many wells have depth of about 30m (100ft).

Odor, Arsenic (As), Iron (Fe), Manganese (Mn) and Sulfide were not detected in all public tap. However, many public taps showed high concentration of total dissolved solid (TDS). The range of TDS varied from 0.29 to 0.68 ppt (290 – 680mg/L) excluding public tap No. 20 (Note: TDS of public tap No.20 was 0.11ppt (110mg/L)). WHO guidelines for drinking water quality 4th edition (hereinafter, WHO-GL) mentions that presence of more than 250mg/L of TDS will cause taste in drinking water. Therefore, many stand post except No.20 may have a problem in taste of drinking water.

Of the tested samples, 0.2-0.5mg/L of Nitrate nitrogen (NO_3-N) (1.0 -2.0 mg/L as NO_3^-) was detected in public tap No. 5, 10, 20, 7986, 7978 and 7991. Observed NO_3-N concentration is lower than the WHO drinking water quality guideline value (hereinafter, WHO-GL value) of 50mg/L as NO_3^-. However, this result shows the possibility of groundwater pollution of nitric compounds. Presumed pollution sources may be infiltration pit of domestic wastewater, pit latrine and infiltration pit of septic tank.

Fluorine (F) was detected in samples of 8 public taps (No. 2, 10, 12, 14, 15, 16, 7986 and 7978).

The range of Fluorine was 0.4-0.8 mg/L. However, the sample of tap No. 7978 showed 1.5mg/L of Fluorine. Considering the WHO-GL value (1.5 mg/L), the effects of water from public tap No. 2, 10, 12, 14, 15, 16 and 7986 on human health are assessed as not serious. However, use of water from public tap No. 7978 may cause negative impact on human health in the form of mottled enamel or skeletal fluorosis when the water is consumed for long period. Therefore, it is necessary to consider a countermeasure to reduce health risk (e.g. restriction for drinking water use or abandonment of this public tap).

E-coli were detected in the samples of all public taps. Moreover, Fecal coliform was detected in public tap No.15 and 7991. Relationship between Fecal coliform and NO_3-N concentration is not certain. However, the observation shows that the sanitary condition of public tap water is undesirable.

Tube well (private and school)

Water quality data of tube well is shown in Table 6-9. Tube wells No.1 to No.13 are private wells which were constructed by well owners mainly for private water use, and the depth of these well ranges 30 - 90m (100 - 300ft). Tube well No.14 is constructed in the school premises, and utilized mainly as source of water for the school. In the samples of all tube wells, TDS was observed in the range of 0.3 - 0.93ppt (300 - 930 mg/L). In addition, the sample of tube well No. 2, 4, and 10 indicated a high level of turbidity (>20 NTU). These observation reflect that water in these wells have problem of taste and high turbidity and are not suitable for drinking.

The elements such as As, Fe, Aluminum (Al) and Sulfide were not detected in these tube well samples. Although NO_2-N was not detected in these samples; NO_3-N and Ammoniacal nitrogen (NH_4-N) were observed. NO_3-N was detected in samples of tube well No. 5, 7, and 10 and the range of NO_3-N varied in the range of 0.2 -10mg/L (1 - 45 mg/L as NO_3^-). This range of NO_3-N is higher than the observed concentration in case of public tap water. NH_4-N (0.2 mg/L) was detected in samples of tube well No. 1, No.2, No.3, No.4 and No.13.

Fluorine (F) was detected in samples of all tube well except No.1 and No.3 and its concentration lies in the range of 0.4 or 0.8mg/L. However, the fluorine content in sample of tube well No.9 was 1.5 mg/L. Location of tube well No. 9 is close to public tap No. 7987. Therefore, it is presumed that tube well No.9 and public tap No. 7987 may be drawing water from the same aquifer

Hand pump and public water pot

Water quality data of hand pump and public water pot is shown in Table 6-10. Hand pump is installed in the same area as public tap and private tube well; however, TDS and EC in water of hand pumps are higher than those of public tap and tube well. Odor, NO_3-N and NH_4-N were detected in sample of hand pump No. 2. Therefore, it is possible that the water source (aquifer) of this hand pump (No.2) may have been polluted by the infiltration of wastewater or human waste.

Public water pots are utilized by the residents who cannot purchase bottled water. However, E-coil and Fecal coliform were detected in samples of public water pots. Therefore, it can be judged that the water quality of public water pot is undesirable as drinking water.

Summary of water quality in Pyi Gyi Tagon TS

High level of TDS, EC and Turbidity is observed in most of the samples, and it is judged that water quality of Pyi Gyi Tagon TS is not suitable as drinking water.

Moreover, E-coli were detected in all water samples. Therefore, it is judged that the quality of the current drinking water in Pyi Gyi Tagon TS is not hygienic.

④ Existing water supply facility in Mandalay urban area (Simple test and Laboratory test)

The results of water quality test are shown in Tables 6-11, 6-12 and 6-13. WTP No. 4 uses irrigation water as water source. Mandalay hill D/R distributes tube well water and treated water of WTP No.8, water source of which is the Ayeyarwady River.

WTP No. 4 has a chlorination facility using electrolytic chlorine generation system; however, this disinfection facility is not operated. New electrolytic chlorination facility was installed at WTP No. 8 by MCDC; however, this new chlorination facility was not operated during the survey period. The other water supply facilities (BPS No.1, No.2, No.3, No.5, No.6, No.7 and ET No.1, No.2) use water from adjacent tube wells as source. These facilities distribute water without treatment and chlorination.

In the BPS Nos.2 and 6 water distribution areas, turbidity and color of water in house connection were observed to be higher than the samples of these BPS. In addition, in the ET No.2 water distribution area, turbidity in house connection is observed to be higher than sample of ET No.2. This increase in turbidity of water at house connection indicates the possibility of water pollution in water distribution network. Possible cause of pollution is inflow of pullulated water from wrecked pipeline or improper joint due to development of negative-pressure because of the intermittent water supply or use of suction pump at houses.

WTP No.4 has a water purification system using gravel filter and sand filter. The result of the assessment of water treatment efficiency of WTP No.4 is shown in Figure 6-16. The reduction ratios of pollution were: 62% in Turbidity, 41% in Color, and 15% in TOC. However, turbidity of treated water was observed as 7.5 NTU, which exceeds the desirable value (5 NTU) defined by the MCDC water quality standards.

Odor was not detected in the treated water of WTP No.4 (D/R at WTP No.4); however, odor was detected in tap water in area that received water from the WTP No.4. The reason for this water quality degradation is assumed to be same as in case of BPS No.2, 6 and ET No.2 (i.e. water is polluted in water distribution network). E-coli were detected both in treated water and tap water, and Fecal coliform were detected in treated water because of the lack of chlorination.

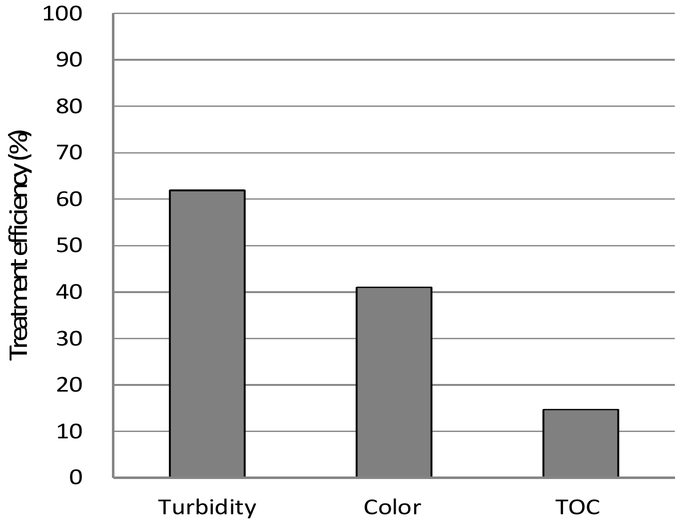


Figure 6-16 Water treatment efficiency of WTP No.4

TDS and chloride contents in water samples of Mandalay hill D/R, BPS No.1, No.2, No.3, No.5, No.6, No.7, and ET No.1, No.2 is observed to be higher than that of sample of WTP No.4. These supply facilities use groundwater as water source. TDS in these facilities were observed to lie in range of 0.22 - 0.40 ppt (220 – 400 mg/L). This range is lower than the TDS of water in Pyi Gyi Tagon TS. However, even at this level some consumers may have sensed salinity in drinking water.

Fluorine was detected in all water supply facilities which use ground water as source. The concentration was more than 0.4 mg/L in samples of all supply facilities. The Fluorine content is observed as 1.5 mg/L in the samples of BPS No.2, No.3 and No.5 in Maha Aung Mye TS and content of Fluorine in ET No. 1 (Maha Aung Mye TS) is observed as 1.9 mg/L. However, lower Fluorine concentration (0.8 mg/L) was detected in house connection in the service area of ET No.1. Therefore, continuous monitoring of Fluorine concentration is required in ET No.1 and its water service area.
According to the drinking water quality standards in Japan, the maximum allowable value of standard plate count is 100 CFU/1mL. In the WHO-GL, E-coli and Fecal coliform should not be detected (N.D./100mL) in direct drinking water, influent of water distribution system and in water distribution system. However, in existing water supply facilities in the Mandalay urban area, standard plate count was observed in the range of 2,800～330,000 CFU/1mL. Moreover, E-coli and Fecal coliform were detected in the samples of house connection. The results of water quality survey indicate that the distributed water in the water supply system in Mandalay City has a serious public health risk, and it is clear that the introduction of disinfection (chlorination) in the water supply system is required to overcome this problem.

⑤ Conclusions of water quality test of water supply facilities in Mandalay city

<u>Assessment based on the MCDC drinking water quality standards</u>

Table 6-4 shows the drinking water quality standards of Mandalay City. MCDC has prepared the drinking water quality standards based on the WHO-GL. The drinking water quality in Pyi Gyi Tagon

TS and the Mandalay urban area is assessed as follows based on the MCDC water quality standards,.

- Pyi Gyi Tagon TS

Turbidity in 3 stand posts (No.14, No.20, and No.7986) exceeded 5NTU (the maximum desirable value). Moreover, turbidity in private tube well No.2, No.4 and No.10 exceeded 20 NTU. In case of other stand posts and private wells, turbidity didn't exceed 5 NTU.

- Existing water supply facilities of MCDC (BPS, ET and WTP No.4)

Turbidity of treated water of WTP No.4 was 7.5 NTU. Turbidity of water in BPS No.1, BPS No.6 house connection (2) and ET No.2 house connection (2) ranged 6.0～6.5NTU. Other sampling points satisfied the maximum desirable value of MCDC drinking water quality standards (<5 NTU).

Table 6-4 MCDC Drinking water quality standard

Item (Unit)	(Maximum) Desirable value or range	(Maximum) Allowable value or range
pH	7.0 – 8.5	6.5 – 9.2
Color (Units)	5	50
Turbidity (NTU)	5	25
Ca (mg/L)	75	200
Mg (mg/L)	30	150
Total hardness (mg/L as $CaCO_3$)	100	500
Chloride (mg/L)	200	600
Sulfide (mg/L)	200	400
Fe (mg/L)	0.1	1.0
Mn (mg/L)	0.05	0.5

Source: MCDC (as of March 2015)

In the following paragraphs, observations of important water quality items are described.

The observation result of important water quality items other than listed in MCDC standards are described as follows.

<u>TDS</u>

Figure 6-17 shows summary of TDS results. If TDS is more than 250mg/L (0.25 ppt), taste may be felt according to the WHO-GL value. Therefore, it is judged that MCDC piped water and stand post water have some tastes except water in WTP No.4.

Private water source in Pyi Gyi Tagon (Tube well and Hand pump) shows higher level of TDS than that of MCDC water supply facilities (TDS: 0.4 – 0.6 ppt (400 – 600mg/L)). Therefore, many private water sources in Pyi Gyi Tagon TS are assessed to have insufficient quality as drinking water. In particular, tube wells and hand pumps have high TDS (0.4-0.6ppt: 400-600mg/L in most of samples), compared with samples of water supply facilities of MCDC. Therefore, water at some of these water points may be not be suitable for drinking as shown in Figure 6-17.

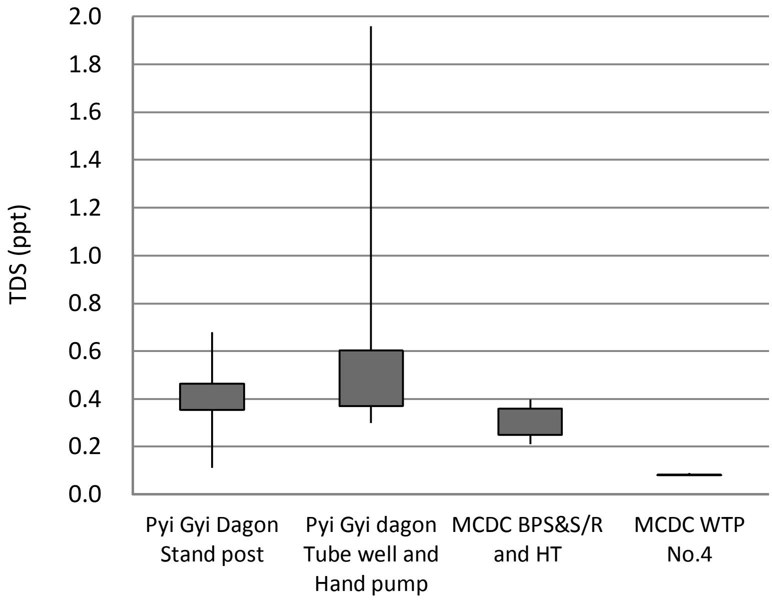


Figure 6-17 Summary of TDS measurement

Note: Water quality data is expressed using Box-whisker plot. In the Box – whisker plot, top of whisker: Maximum value, middle of Box: Median, lower end of whisker: Lowest value.

Fluorine

In MCDC water supply facilities, more than 0.4 mg/L of Fluorine was detected in the samples of facilities which use ground water as source. The range of Fluorine is shown in Figure 6-18. High concentration of Fluorine was detected in samples of Maha Aung Mye TS and Chan Mya Thar Zi TS. The highest concentration was observed as 1.9 mg/L (in case of ET No.1).

The highest Fluorine concentration in samples of Mandalay hill D/R, BPS No.1, No.2, No.3, No.5, No.6 and ET No.2 water service area was 1.5 mg/L. Therefore, measures for fluorine reduction in these facilities may be not required because the WHO-GL value of Fluorine is 1.5mg/L. In case of sample of ET No.1, the fluorine content is 1.9 mg/L. However, the fluorine content reduced to less than 0.8 mg/L in the ET No. 1 water service area. Considering this reduction of Fluorine concentration in the network, requirement of Fluorine reduction measures is lower; however, continued Fluorine monitoring in ET No.1 and its water service area is necessary.

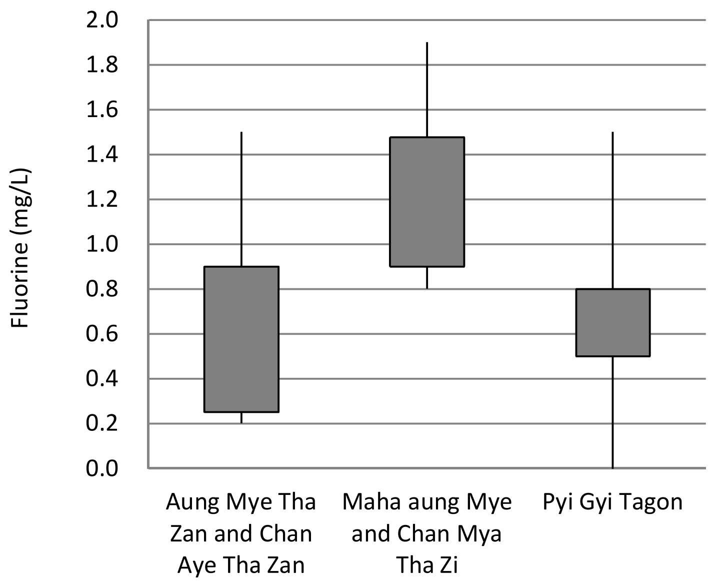


Figure 6-18 Fluorine concentration in Mandalay city water supply facilities

Note: Water quality data is expressed using Box-whisker plot. In the Box – whisker plot, top of whisker: maximum value, top of box: top 25th percentile (first quartile), middle of box: median, lower end of box: bottom 25th percentile (third quartile) and lower end of whisker: lowest value.

Biological test

Standard plate count is a simple and clear indicator of disinfection in water distribution system. Standard plate count is not included in the MCDC drinking water quality standards and WHO-GL. However, Japanese drinking water quality standards has a standard value of 100 CFU/1mL for this item. In this survey, the result of standard plate count lies in the range of 2,800～330,000CFU/1mL of samples of all sampling points of MCDC water supply facilities. In particular, the samples of facilities using groundwater source showed higher value of standard plate count.

Figure 6-19 shows the ratio of samples in which E-coli and Fecal coliform were positively observed (i.e. detection ratio). In Pyi Gyi Tagon TS, E-coli and Fecal coliform were detected in samples of stand posts, tube wells and hand pumps, and E-coli and Fecal coliform were detected in samples of all water supply facilities in the Mandalay urban area. Considering this test results, it is judged that the water supply facilities of MCDC may pose a serious public health risk, and the result shows the necessity of introduction of disinfection (chlorination) system in water supply facilities of MCDC.

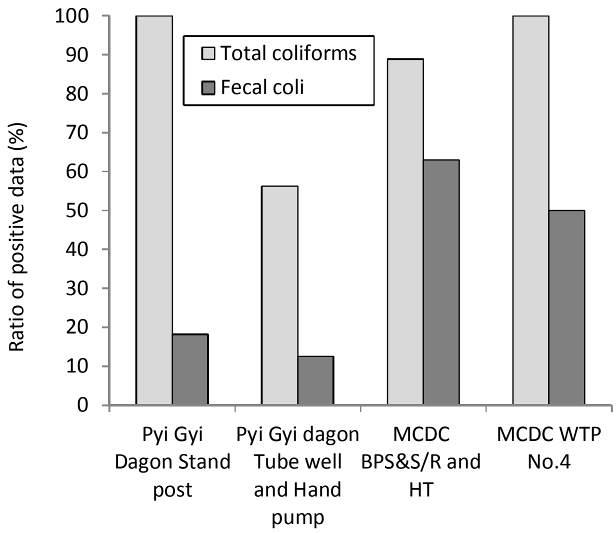


Figure 6-19 Ratio of detection (Positive) of E-coli and Fecal coliform in samples

⑥ Water quality of test wells (Simple test and laboratory test)

Water quality data of test wells is shown in Table 6-15 and Table 6-16. As for Fluorine and TDS, the result of the comparison with other water sources is shown in Figures 6-20 and 6-21.

In water quality test, As, Fe and Mn were not detected. Fluorine concentration was 1.1 mg/L. This value is relatively high in comparison to fluorine content of other water sources in Mandalay city. However, comparing with the WHO-GL value of Fluorine (1.5 mg/L), the necessity of reduction of Fluorine is assessed as low.

TDS content in sample of test well was observed as 0.28ppt (284mg/L). This TDS value is the same as TDS of existing groundwater source of MCDC, and lower than TDS of tube wells and hand pumps in Pyi Gyi Tagon TS. The parameters such as NO_2-N, NO_3-N and E-coli, Fecal coliform were not detected, however, NH_4-N and standard plate count were detected. In particular, standard plate count in case of test well sample was 120,000 CFU/1mL.

Considering these observation, following key points are recommended.

- Fluorine concentration is relatively high (1.1mg/L), but this concentration does not pose an immediate problem to human health. However, continuous monitoring of Fluorine should be considered.
- E-coli and Fecal coliform were not detected. However, standard plate count was very high (120,000 CFU/1mL). To ensure biological safety of drinking water, introduction of disinfection system is desirable.

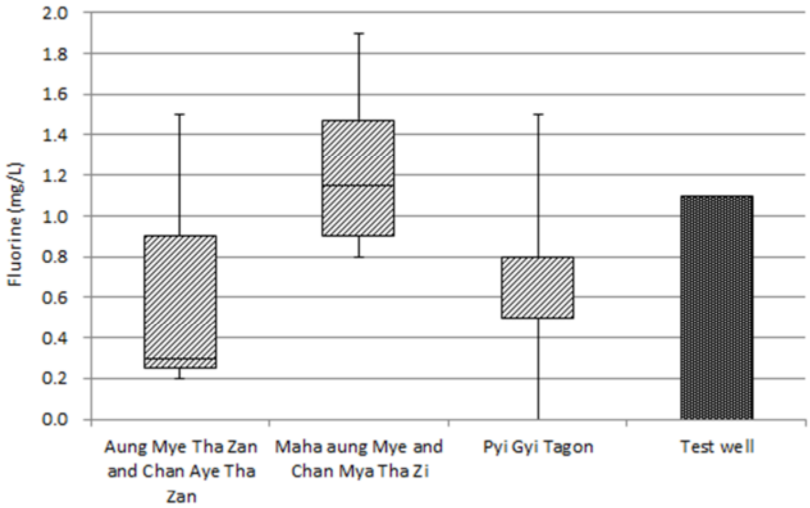


Figure 6-20 Comparison of Fluorine concentration of test well with other water sources

Note: Water quality data is expressed using Box-whisker plot. In the Box – whisker plot, top of whisker: maximum value, top of box: top 25th percentile (first quartile), middle of box: median, lower end of box: bottom 25th percentile (third quartile) and lower end of whisker: lowest value.

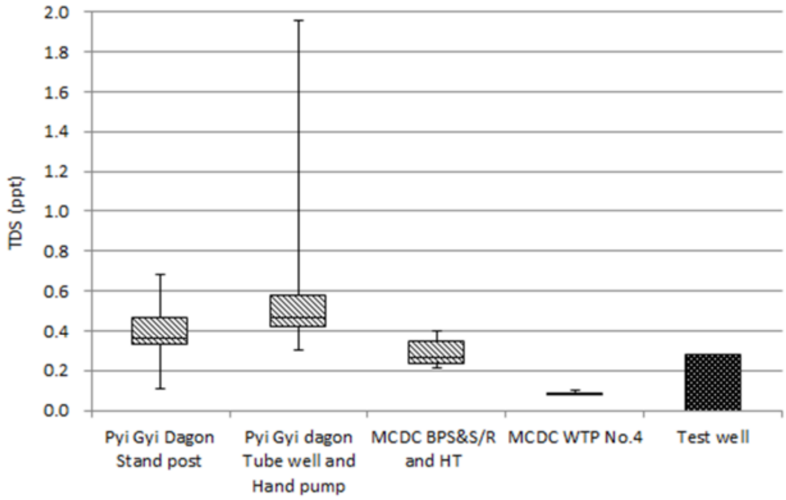


Figure 6-21 Comparison of TDS of test well with other water sources

Note: Water quality data is expressed using Box-whisker plot. In the Box – whisker plot, top of whisker: maximum value, top of box: top 25th percentile (first quartile), middle of box: median, lower end of box: bottom 25th percentile (third quartile) and lower end of whisker: lowest value.

6－7－2. Water quality data and related laws and regulations

① Water quality standard

Table 6-5 Synoptic table of Drinking water quality of MCDC, Water quality standard of Japan and WHO-GL for Drinking water quality (Part 1)

Water quality standard or WHO-GL	Odor	pH	Color (Units)	Turbidity	TDS	EC	Hardness	Ca	Mg	TOC	As	Fe	Mn	Sulfide	Chloride	NO_3^-	NO_2^-	Al	F
				(NTU) (Japan: Deg.)	(ppt)	(mS/m)	(mg/L)												
MCDC drinking water quality standard (Note:1) Desirable value	--	7.0 – 8.5	5	5	--	--	100	100	75	--	--	0.1	0.05	200	200	--	--	--	--
Allowable value	--	6.5 – 9.2	50	25	--	--	500	500	200	--	--	1.0	0.5	400	600	--	--	--	--
Japan Drinking water quality standard	Normal (Not detected) Desirable value < 3TON	5.8 - 8.6 Desirable value]7.5	5	< 2 Deg. Desirable value <1 Deg. 1Deg.＝0.6-0.8NTU	500 mg/L = 0.5 ppt Desirable value: 30 – 200mg/L	--	Ca and Mg as Hardness 300 Desirable value 10 - 100			3.0	0.01	0.3	0.05 Desirable value 0.01	--	200	NO_2-N 0.04mg/L NO_3-N＋NO_2-N Total:10mg/L		0.2 Desirable value 0.1	0.8
WHO guideline for drinking water quality 4th (Note:2)	--	--	--	--		--	--	--		--	0.01	--	--	--	--	50mg/L as NO_3-N 11mg/L	3mg/L as NO_2-N 0.9mg/L	--	1.5

Table 6-6 Synoptic table of Drinking water quality of MCDC, Water quality standard of Japan and WHO-GL for Drinking water quality (Part 2)

Water quality standard or WHO-GL	Standard plate count	Total coliforms	Fecal coliform
MCDC drinking water quality standard (Note:1) Desirable value	--	--	--
Allowable value	--	--	--
Japan Drinking water quality standard	<100CFU /1mL	--	E-Coli Not Detected
WHO guideline for drinking water quality 4th (Note:2)	--	Nil / 100mL	Nil / 100mL

CFU: Colony forming unit

Table 6-7 Synoptic table of Drinking water quality of MCDC, Water quality standard of Japan and WHO-GL for Drinking water quality (Part 3)

Water quality standard or WHO-GL	Cu	Pb	Zn	Cd	Cr	Hg	Se	Na	Cyanide
	(mg/L)								
MCDC drinking water quality standard (Note:1) Desirable value	--	--	--	--	--	--	--	--	--
Allowable value	--	--	--	--	--	--	--	--	--
Japan Drinking water quality standard	1.0	0.01	1.0	0.003	Hexavalent chromium 0.05	Mercury and Mercury compounds 0.0005	0.01	200	0.01
WHO guideline for drinking water quality 4th (Note:2)	2.0	0.01	--	0.003	Total chromium 0.05	Inorganic mercury 0.006	0.04	--	--

MCDC Drinking water quality standard: Source JICA study team

Note: 1 MCDC decides drinking water quality standards based on WHO drinking water quality standard (Latest information of MCDC, as of March 2015).

Note: 2 In WHO drinking water quality guideline (4th edition), guideline value is decided for important item related to human health.

② Result of Water quality survey

Table 6-8 Water quality of Public tap (Simple test)

MCDC Public tap	Air Temp.	Water Temp.	Odor	pH	Color	Turbidity	TDS	EC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	E-coli	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)											
Public tap No.2	29.2	29.0	N.D.	8.39	0.0	0.0	0.33	67	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	N.D	N.D.	0.8	20.0	Pos.	N.D.
Public tap No.5	32.1	29.0	N.D.	7.85	0.0	0.0	0.34	68	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	0.2	0.05	N.D.	20.0	Pos.	N.D.
Public tap No.10	36.5	30.0	N.D.	8.17	0.0	0.0	0.51	103	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	0.8	20.0	Pos.	N.D.
Public tap No.12	37.0	30.0	N.D.	7.98	0.0	1.2	0.36	73	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	20.0	Pos.	N.D.
Public tap No.14	34.7	31.0	N.D.	8.21	5.5	6.0	0.51	103	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	10.0	Pos.	N.D.
Public tap No.15	33.5	31.0	N.D.	8.12	0.0	0.0	0.29	58	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	0.4	30.0	Pos.	Pos.
Public tap No.16	37.8	30.0	N.D.	7.88	0.0	1.0	0.35	70	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	30.0	Pos.	N.D.
Public tap No.20	32.0	31.7	N.D.	8.02	20.5	9.7	0.11	22	N.D.	N.D.	N.D.	N.D.	0.5	0.02	N.D	N.D.	N.D.	20.0	Pos.	N.D.
Public tap No.7986	30.1	31.5	N.D.	8.15	2.5	5.7	0.68	136	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D	N.D.	0.8	10.0	Pos.	N.D.
Public tap No.7978	38.0	31.2	N.D.	8.52	2.0	0.0	0.42	84	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	1.5	20.0	Pos.	N.D.
Public tap No.7991	39.0	30.8	N.D.	7.99	2.5	0.0	0.36	72	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	N.D.	20.0	Pos.	Pos.

Note: TDS 1ppt = 1,000ppm ≈1,000mg/L

Table 6-9 Water quality of Tube well (Simple test)

Tube well (Private and School)	Air Temp.	Water Temp.	Odor	pH	Color	Turbidity	TDS	EC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	E-coli	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)											
Tube well 1	36.0	30.4	N.D.	7.75	0.0	0.0	0.43	87	N.D.	N.D.	N.D.	N.D.	N.D	N.D	0.2	N.D.	N.D.	>50.0	Pos.	N.D.
Tube well 2	32.2	32.0	N.D.	7.86	26.0	22.7	0.41	83	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	0.4	>50.0	Pos.	N.D.
Tube well 3	34.8	31.9	Slight septic odor	7.82	13.0	0.0	0.45	89	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	>50.0	Pos.	N.D.
Tube well 4	35.0	29.0	N.D.	8.01	7.0	20.8	0.45	89	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	0.8	>50.0	N.D.	N.D.
Tube well 5	38.5	35.0	N.D.	8.02	0.0	0.0	0.50	101	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	0.8	20.0	Pos.	N.D.
Tube well 6	35.8	30.8	N.D.	8.27	0.0	0.0	0.57	116	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	10.0	N.D.	N.D.
Tube well 7	37.3	31.8	N.D.	8.10	0.0	0.0	0.71	142	N.D.	N.D.	N.D.	N.D.	5.0	N.D.	N.D.	N.D.	0.8	20.0	Pos.	N.D.
Tube well 8	32.5	29.1	N.D.	7.99	0.5	1.6	0.93	189	N.D.	N.D.	N.D.	N.D.	10.0	N.D.	N.D.	N.D.	0.8	30.0	N.D.	N.D.
Tube well 9	32.5	33.0	N.D.	8.54	0.0	0.0	0.30	61	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	N.D.	N.D.
Tube well 10	38.7	28.5	N.D.	7.97	9.5	33	0.50	100	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	20.0	Pos.	N.D.
Tube well 11	35.0	29.8	N.D.	7.92	0.0	0.8	0.47	94	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	>50.0	N.D.	N.D.
Tube well 12	40.9	38.1	N.D.	8.22	0.0	0.0	0.47	94	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	20.0	Pos.	Pos.
Tube well 13	34.0	36.0	N.D.	8.62	0.0	0.0	0.36	72	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	1.5	>50.0	Pos.	Pos.
Tube well 14 (School)	36.1	30.0	N.D.	7.75	0.0	0.3	0.37	75	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	10.0	Pos.	N.D.

Note: TDS 1ppt =1,000ppm ≈ 1,000mg/L

Table 6-10 Water quality of Hand pump and Public water pot (Simple test)

Hand pump and Water pot on the roadside	Air Temp.	Water Temp.	Odor	pH	Color	Turbidity	TDS	EC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	E-coli	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)											
Hand pump 1	33.0	31.7	N.D.	7.40	1.5	0.0	0.61	122	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	0.05	0.8	>50.0	N.D.	N.D.
Hand pump 2	29.1	29.3	Slight septic odor	6.75	0.0	2.3	1.96	390	N.D.	N.D.	N.D.	N.D.	10.0.	N.D.	0.2	N.D.	0.4	>50.0	N.D.	N.D.
Water pot 1	38.0	29.8	N.D.	8.32	0.0	0.0	0.49	99	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	0.8	20.0	Pos.	N.D.
Water pot 2	36.5	30.0	N.D.	7.86	0.0	0.0	0.60	121	N.D.	N.D.	N.D.	N.D.	0.5	N.D.	N.D	N.D.	0.4	30.0	Pos.	Pos.
Water pot 3	37.8	28.5	N.D.	8.56	0.0	0.0	0.34	67	N.D.	0.1	N.D.	N.D.	0.2	N.D.	N.D	N.D.	1.0	20.0	Pos.	N.D.

Note: TDS 1ppt = 1,000ppm ≈ 1,000mg/L

Table 6-11 Water quality of existing water supply facility in Mandalay city: Part 1 (Simple test and Laboratory test)

MCDC Water supply facility	Air Temp.	Water Temp.	Odor	pH	Color	Turbidity	TDS	EC	Alkalinity	Hardness	TOC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	Standard plate count**	Total coliforms***	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)															
Mandalay hill D/R	35.0	34.0	N.D.	7.89	0.0	0.0	0.25	50	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	10.0	--	Pos.	N.D.
Mandalay hill D/R(Lab. test)	--	--	--	--	--	--	0.31	--	261	113	1.2	N.D.	0.12	0.05	--	N.D.	N.D.	0.02	N.D.	0.3	7.3	15,000	9	--
Mandalay hill D/R House Connection (1)	32.0	31.9	N.D.	7.93	0.0	0.0	0.23	46	--	--	--	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	N.D.
Mandalay hill D/R House Connection (2)	34.2	31.0	N.D.	7.92	0.0	0.0	0.22	45	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	N.D.
BPS No.1	34.5	32.4	N.D.	7.64	1.0	6.5	0.25	50	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D	N.D	N.D.	0.03	N.D.	5.0	--	N.D.	Pos.
BPS No.1 (Lab. test)	--	--	--	--	--	--	0.29	--	245	129	0.41	N.D.	0.04	0.07	--	N.D.	N.D.	0.02	N.D.	0.2	5.1	180,000	4	--
BPS No.1 House Connection (1)	34.7	31.9	N.D.	7.71	0.0	0.0	0.23	46	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	20.0	--	Pos.	Pos.
BPS No.1 House Connection (2)	29.7	31.9	N.D.	7.56	0.0	0.0	0.22	45	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	10.0	--	Pos.	N.D.
BPS No.2	35.0	35.0	N.D.	7.89	0.0	0.0	0.35	71	--	--		N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	10.0	--	N.D.	N.D.
BPS No.2 (Lab. test)	--	--	--	--	--	--	0.42	--	284	93	0.34	N.D.	0.10	0.07	--	N.D.	N.D.	0.02	N.D.	1.4	36.3	290,000	280	--
BPS No.2 House Connection (1)	29.2	35.0	N.D.	7.68	4.0	0.2	0.40	79	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	N.D.
BPS No.2 House Connection (2)	29.8	35.8	N.D.	7.58	6.0	0.5	0.40	81	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	Pos.
BPS No.3	31.0	37.0	N.D.	8.35	0.50	3.20	0.36	73	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	>50.0	--	Pos.	Pos.
BPS No.3 (Lab. test)	--	--	--	--	--	--	0.47	--	396	28	0.40	N.D.	0.02	0.08	--	N.D.	N.D.	0.01	N.D.	1.5	4.95	24,000	30	--
BPS No.3 House Connection (1)	35.0	35.0	N.D.	8.33	0.0	0.0	0.36	72	--	--	--	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	N.D.	0.4	>50.0	--	Pos.	Pos.
BPS No.3 House Connection (2)	34.8	37.0	N.D.	8.34	0.0	0.0	0.37	74	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	>50.0	--	Pos.	N.D.
BPS No.5	36.0	40.5	N.D.	8.47	0.0	4.8	0.36	73	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	>50.0	--	Pos.	Pos.
BPS No.5 (Lab. test)	--	--	--	--	--	--	0.45	--	368	14	0.67	N.D.	0.17	0.08	--	N.D.	N.D.	0.01	N.D.	1.4	9.25	4,000	7	--
BPS No.5 House Connection (1)	33.8	36.2	N.D.	8.49	0.0	0.0	0.32	65	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	>50.0	--	Pos.	N.D.
BPS No.5 House Connection (2)	32.0	35.0	N.D	8.43	0.5	0.0	0.32	64	--	--	--	N.D	N.D.	N.D.	N.D.	N.D	0.2	N.D.	N.D.	1.5	>50.0	--	Pos.	Pos.
BPS No.6	34.0	41.5	Slight septic odor	8.43	2.0	0.8	0.33	67	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	>50.0	--	Pos.	N.D.
BPS No.6 (Lab. test)	--	--	--	--	--	--	0.41	--	338	20	0.17	N.D.	0.04	0.08	--	N.D.	N.D.	0.01	N.D.	0.9	6.5	330,000	N.D.	--
BPS No.6 House Connection (1)	37.0	33.8	N.D	8.58	15.5	5.0	0.35	69	--	--	--	N.D	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	>50.0	--	Pos.	Pos.
BPS No.6 House Connection (2)	37.5	36.0	N.D	8.24	11.5	6.3	0.33	68	--	--	--	N.D	N.D.	N.D.	N.D.	N.D.	0.2	N.D.	N.D.	0.4	20.0	--	Pos.	Pos.
BPS No.7	34.5	34.0	N.D.	8.26	1.0	0.0	0.27	55	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	10.0	--	Pos.	Pos.
BPS No.7 (Lab. test)	--	--	--	--	--	--	0.36	--	259	34	0.44	N.D.	0.04	0.06	--	N.D.	N.D.	0.01	N.D.	1.5	9.6	89,000	3,200	--
BPS No.7 House Connection (1)	32.0	33.0	N.D.	8.15	0.0	0.0	0.27	54	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	Pos.
BPS No.7 House Connection (2)	32.9	35.0	N.D	8.19	0.0	0.0	0.27	54	--	--	--	N.D	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.5	20.0	--	Pos.	Pos.
ET No.1	38.0	36.0	N.D.	8.35	0.0	0.0	0.22	45	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	N.D.	1.5	10.0	--	N.D.	N.D.
ET No.1 (Lab. test)	--	--	--	--	--	--	0.30	--	207	14	0.49	N.D.	0.02	0.06	--	N.D.	N.D.	0.01	N.D.	1.9	4.2	170,000	N.D.	--
ET No.1 House Connection (1)	36.2	32.5	N.D.	7.74	0.0	0.0	0.22	44	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	N.D.	N.D.	20.0	--	Pos.	Pos.
ET No.1 House Connection (2)	35.4	36.0	N.D.	8.48	0.0	0.0	0.21	42	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	20.0	--	Pos.	Pos.
ET No.2	33.0	39.0	N.D.	8.38	8.5	0.2	0.25	50	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	>50.0	--	Pos.	Pos.
ET No.2 (Lab. test)	--	--	--	--	--	--	0.31	--	241	20	0.5	N.D.	0.04	0.06	--	N.D.	N.D.	N.D.	N.D.	0.6	7.9	190,000	28	--
ET No.2 House Connection (1)	32.0	39.5	N.D.	8.43	7.0	0.3	0.25	51	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	>50.0	--	Pos.	Pos.
ET No.2 House Connection (2)	33.4	39.5	N.D.	8.38	5.0	6.0	0.25	51	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	>50.0	--	Pos.	Pos.

Note

* TDS 1ppt = 1,000ppm ≈ 1,000mg/L

** Standard plate count: CFU/1mL

*** Total coliforms: CFU/100mL for lab. test.

Table 6-12 Water quality of existing water supply facilities in Mandalay city: Part 2 (Laboratory test)

MCDC Water supply facility	Ca	Mg	Cu	Pb	Zn	Cd	Cr	Hg	Se	Na	SO_4^{2-}	CN^-
	(mg/L)											
Mandalay hill D/R	26	12	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	60.7	7.16	N.D.
BPS No.1	38	8	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	54.1	3.96	N.D.
BPS No.2	21	10	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	99.8	48.9	N.D.
BPS No.3	7	2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	114	9.72	N.D.
BPS No.5	3	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	111	21.3	N.D.
BPS No.6	5	2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	113	18.6	N.D.
BPS No.7	9	3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	85.9	28.5	N.D.
ET No.1	4	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	75.6	16.3	N.D.
ET No.2	6	1	0.01	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	86.0	15.5	N.D.

Table 6-13 Water quality of WTP No.4 and water distribution area of WTP No.4: Part1 (Simple test and Laboratory test)

MCDC Water supply facility WTP No4 distribution system	Air Temp.	Water Temp.	Odor	pH	Color	Turbidity	TDS	EC	Alkalinity	Hardness	TOC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	Standard plate count**	Total coliforms***	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)															
WTP No.4 Raw water	34.0	32.1	N.D.	8.04	19.5	19.7	0.09	17	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.2	0.05	N.D.	N.D.	--	Pos.	Pos.
WTP No.4 Raw water (Lab. test)	--	--	--	--	--	--	0.10	--	93	82	1.77	N.D.	0.14	0.06	--	N.D.	N.D.	0.01	N.D.	N.D.	1.9	2,800	3	N.D.
WTP No.4 Treated water	34.0	31.9	N.D.	8.04	11.5	7.5	0.08	16	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.05	N.D.	N.D.	--	Pos.	Pos.
WTP No.4 Treated water (Lab. test)	--	--	--	--	--	--	0.10	--	101	78	1.51	N.D.	0.21	0.09	--	N.D.	N.D.	0.01	N.D.	N.D.	1.9	7,900	1	N.D.
BPS No.4 House Connection (1)	35.6	32.0	Slight septic odor	7.95	0.0	0.0	0.08	16	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	--	Pos.	N.D.
BPS No.4 House Connection (2)	36.0	32.0	Slight septic odor	7.91	0.0	0.0	0.08	16	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	--	Pos.	N.D.

Note

* TDS 1ppt = 1,000ppm ≈ 1,000mg/L

** Standard plate count: CFU/1mL

*** Total coliforms: CFU/100mL for lab. test.

Table 6-14 Water quality of WTP No.4 and water distribution area of WTP No.4: Part2 (Laboratory test)

MCDC Water supply facility WTP No.4	Ca	Mg	Cu	Pb	Zn	Cd	Cr	Hg	Se	Na	SO_4^{2-}	CN^-
	(mg/L)											
WTP No.4 Raw water	21	7	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	20.3	1.78	N.D.
WTP No.4 Treated water	20	7	0.03	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	23.2	1.44	N.D.

Table 6-15 Water quality of Test well : Part1 (Simple test and Laboratory test)

Pyi Gyi Tagon T/S Test well	Air Temp.	Water Temp.	Odor	pH	Color (deg.)	Turbidity	TDS	EC	Alkalinity	Hardness	TOC	As	Fe	Mn	Sulfide	NO_3-N	NO_2-N	NH_4-N	Al	F	Chloride	Standard plate count**	Total coliforms***	Fecal coli
	deg. C	deg. C				(NTU)	(ppt)*	(mS/m)	(mg/L)															
Test well	32.0	33.0	None	8.19	0	0	0.23	0.47	--	--	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.8	35	--	Neg.	Neg.
Test well (Lab. test)	--	--	--	--	--	--	0.28	--	207	22	0.26	N.D.	0.09	0.05	--	N.D.	N.D.	0.09	N.D.	1.1	5.4****	120,000	Neg.	--

Note

* TDS 1ppt = 1,000ppm ≈ 1,000mg/L

** Standard plate count: CFU/1mL

*** Total coliforms: CFU/100mL for lab. test.

****As for chloride, the result of laboratory is given priority.

Table 6-16 Water quality of Test well : Part2 (Laboratory test)

Pyi Gyi Tagon Test well	Ca	Mg	Cu	Pb	Zn	Cd	Cr	Hg	Se	Na	SO_4^{2-}	CN^-
	(mg/L)											
	6	1	0.01	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	79.2	9.19	N.D.

6－7－3. Sampling point

List of sampling point

Location	Location No.	Sampling date
Pyi Gyi Tagon TS		
Pilot well	62	12 July, 2014
MCDC No.2 Public tap	37	23 May, 2014
MCDC No.5 Public tap	36	23 May, 2014
MCDC No.10 Public tap	49	26 May, 2014
MCDC No.12 Public tap	46	26 May, 2014
MCDC No.14 Public tap	48	26 May, 2014
MCDC No.15 Public tap	38	23 May, 2014
MCDC No.16 Public tap	47	26 May, 2014
MCDC No.20 Public tap	39	23 May, 2014
MCDC No.7986 Public tap	43	23 May, 2014
MCDC No.7987 Public tap	60	28 May, 2014
MCDC No.7991 Public tap	61	28 May, 2014
Tube well 1	27	22 May, 2014
Tube well 2	28	22 May, 2014
Tube well 3	29	22 May, 2014
Tube well 4	42	23 May, 2014
Tube well 5	55	27 May, 2014
Tube well 6	56	27 May, 2014
Tube well 7	57	27 May, 2014
Tube well 8	58	27 May, 2014
Tube well 9	59	27 May, 2014
Tube well 10	44	26 May, 2014
Tube well 11	45	26 May, 2014
Tube well 12	54	27 May, 2014
Tube well 13	30	22 May, 2014
Tube well 14 (School)	50	26 May, 2014
Hand pump 1	40	23 May, 2014
Hand pump 2	41	23 May, 2014
Water pot 1	51	26 May, 2014
Water pot 2	52	27 May, 2014
Water pot 3	53	27 May, 2014
Mandalay Existing water supply facilities		
Mandalay Hill D/R	13	20 May, 2014
Mandalay Hill House Connection 1	19	21 May, 2014
Mandalay Hill House Connection 2	20	21 May, 2014
BPS No.1	1	15 May, 2014
BPS No.1 House Connection 1	21	21 May, 2014
BPS No.1 House Connection 2	22	21 May, 2014
BPS No.2	14	20 May, 2014
BPS No.2 House Connection 1	34	23 May, 2014
BPS No.2 House Connection 2	35	23 May, 2014
BPS No.3	3	19 May, 2014
BPS No.3 House Connection 1	18	21 May, 2014
BPS No.3 House Connection 2	17	21 May, 2014
BPS No.5	4	19 May, 2014
BPS No.5 House Connection 1	24	22 May, 2014
BPS No.5 House Connection 2	25	22 May, 2014

Location	Location No.	Sampling date
BPS No.6	5	19 May, 2014
BPS No.6 House connection 1	8	19 May, 2014
BPS No.6 House connection 2	9	19 May, 2014
BPS No.7	15	20 May, 2014
BPS No.7 House Connection 1	26	22 May, 2014
BPS No.7 House Connection 2	33	22 May, 2014
WTP No.4 Raw water	2	19 May, 2014
WTP No.4 Treated water	7	19 May, 2014
WTP No.4 House Connection 1	16	21 May, 2014
WTP No.4 House Connection 2	23	21 May, 2014
ET No.1	12	20 May, 2014
ET No.1 House Connection 1	31	22 May, 2014
ET No.1 House Connection 2	32	22 May, 2014
ET No.2	6	19 May, 2014
ET No.2 House Connection 1	10	19 May, 2014
ET No.2 House Connection 2	11	19 May, 2014

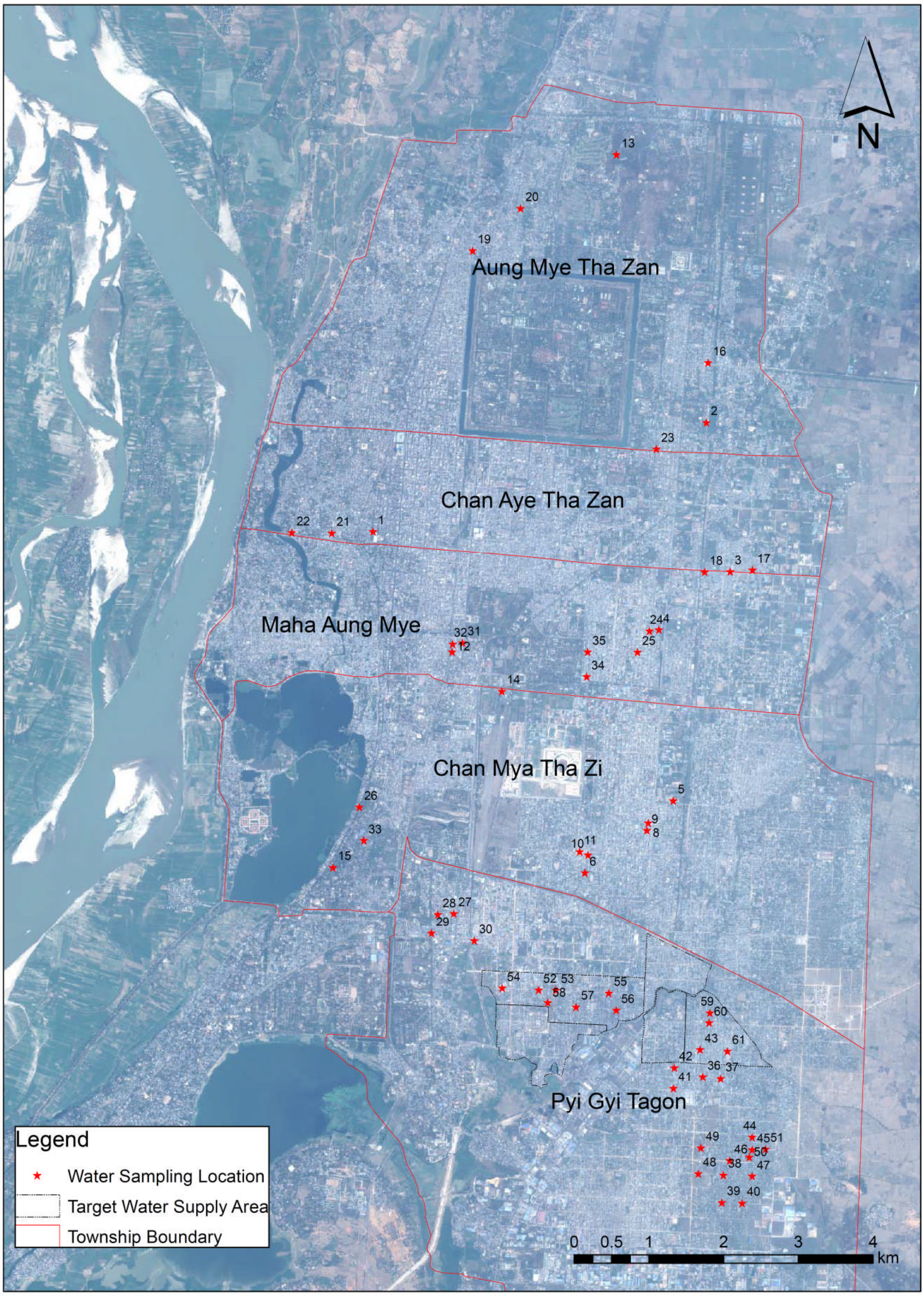


Figure 6-22 Location of Sampling point

6 - 8 . Social condition survey

6－8－1. Methodology

Social condition survey targeting overall Pyi Gyi Tagon TS was implemented. The outline of the survey is shown below.

Item	Outline
Target areas	All areas of Pyi Gyi Tagon Township (16 Wards)
Survey method	Individual interview survey of domestic households, Stratified random sampling
Surveyor	MCDC Pyi Gyi Tagon TS officers, 10 persons
Period	19 – 28 May 2014
Sampling number	300 samples (targeting domestic households) The sampling number was determined according to the ratio of population distribution in corresponding Wards
Survey items	○Information on household and its livelihoods Family member, livelihoods, income, itemized household expenses and amount, type and ownership of house and land ○Current water usage status Water sources for drinking and domestic use, main and supplementary sources, purpose for use, consumption volume, supply hours and its frequency, water fetching (distance, time frequency), expense on domestic water, ownership of meter (metered customer) ○People's awareness and level of satisfaction related to current water supply Challenges in current water supply, level of satisfaction with respect to water service and water tariff ○People's awareness for future water supply Willingness to pay for connection fee and improved water service, awareness on meter installation and beneficiary to pay water tariff, expectations related to future water service

No.	Ward	Sampling Number
1	Sa Lone	52
2	Thin Pan Kone	49
3	Ka	9
4	Ga	11
5	Ghagyi	23
6	Nga	6
7	Sa Lain	15
8	Za	15
9	Zha	21
10	Ngwe Taw Kyi Kone	23
11	Chan Mya Thar Yar	16
12	Kha	10
13	Tagon Tai	31
14	Htain Kone	8
15	Taung Myint	7
16	Yar Taw	4
	Total	300

6－8－2. Results of social condition survey

(1) General information of target households

1) Status of households and livelihoods

(a) Family number and its composition

The average number of family members is 5.8 persons per household based on the answers in survey. The average number of child under 18 years of age who live with the parent(s) is 3.0 persons.

(b) Occupation

Of all the respondents, “Self-employed” shares the largest portion with 46%, followed by “Others” with 44% and “Salaried employee” with 9%. Within the category of “Self-employed”, most of the responses were in the form of occupation like retailer, merchant and artisan.

(c) Housing ownership

Of the respondents, 95% live in the self-owned house. There are a few responses in the form of “Private-owned house for rental or borrow”, “Group-owned or religion’s house” and “State-owned house for rental” with 1% respectively.

(d) Land ownership

Similar to the above case of housing ownership, 95% of respondents live in self-owned land. About 3% of responding households live in the land of “Private-owned house for rental or borrow” and about 1% respondents live in land of “Group-owned or religion’s house”.

(2) Water usage

1) Type of water sources (plural answer applicable)

Approximately, 87% of respondents are using private wells as main and supplementary water source, followed by bottled water with 41% and public taps of non-MCDC with 8%, MCDC piped water with 3%, water vender with 2%, others with 2% and public taps of MCDC with 8%. Hence, most of the respondents use private wells as main and supplementary water sources.

2) Main water source for domestic purposes

For the domestic purposes, approximately 85% of respondents are using private wells as main water source. Of the remaining respondents, 6% of respondents use public taps of non-MCDC, 3% use bottled water, 3% use MCDC piped water, 2% use water vender, and 1% of respondents use other sources as main source of water for domestic purposes.

3) Supplementary water sources for domestic water (plural answer applicable)

For the domestic purposes, approximately 66% of respondents are using bottled water as a supplementary water source. Of the remaining respondents, 25% use private wells, and 4% use public taps. Considering the results of main water sources, approximately 63% of all respondents utilize plural water sources for domestic purposes.

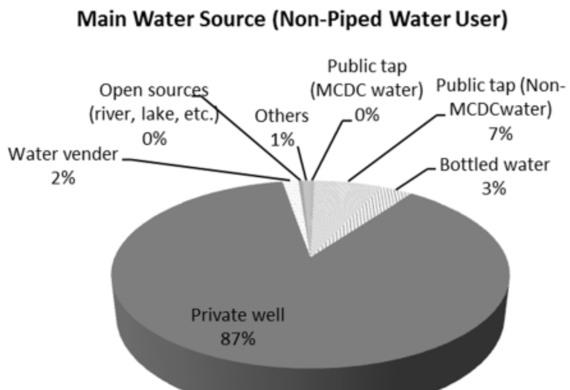
4) Water usage by purpose (plural answer applicable)

In terms of water usage by purpose, approximately 81% of respondents are using pubic wells for drinking and cooking, followed by use of bottled water by about 49% respondents. It is noteworthy that approximately half of households that own their private wells also purchase bottled water for drinking and cooking.

For other purposes, more than 85% of respondents are frequently using private wells for washing, cleaning, shower, bathing and toilet, and the percentage of respondents using other water sources remains low with less than 10%. Remarkable difference of use of water sources for washing, cleaning, shower, bathing and toilet cannot be observed.

5) Consumption volume

Water consumption per capita is estimated to be 118L in the dry season and 87L in rainy season, thereby the difference is estimated to be approximately 30L. The main reason for this may be that the consumption and the frequency of drinking and bathing in the dry season are larger than in rainy season.



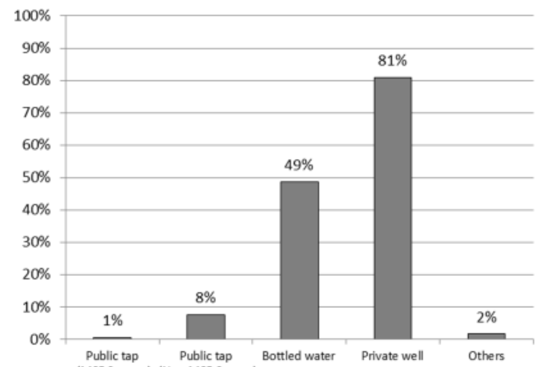


Figure 6-23 Main water sources (non-piped customer)(left) and water sources for drinking and cooking (right)

(3) Households with MCDC piped water

The number of respondents that are MCDC's piped water customers is small, as only six samples, in this Survey. Also this project targets the residents who do not have piped water supply, and it would be fair to say that the answers from piped water customer had better be used as a reference.

1) Condition of household and its livelihoods

(a) Household income

The number of all respondents is six, and the average monthly household income is in the range of 125,000 – 500,000 Kyat. The median value is estimated as 175,000 Kyat.

2) Water supply status

(a) Regular/ irregular water supply

Two-thirds of respondents with MCDC piped water supply replied that they are able to receive regular water supply.

(b) Frequency of water supply

All four respondents, even as a limited sampling number, answered to receive water every day. The daily supply hours ranges 4-6 hours.

3) People's awareness and level of satisfaction for water service

(a) Level of satisfaction for water service

The overall average satisfaction rate for water supply remains at a medium level, not at a high level. The lowest points of evaluation aspects are "Accountability/ Customer relation" with 2.0 points, followed by water supply volume with 2.6 points, and stable and continuous supply with 2.8 points. The highest points are given to "Regular delivery/ accuracy of water bill" with 3.5 points.

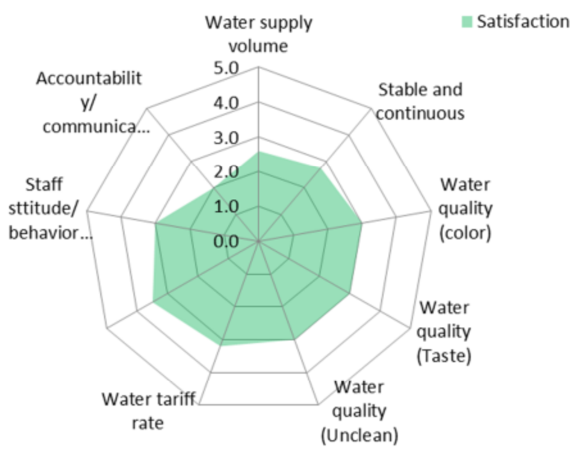


Figure 6-24 Level of satisfaction on MCDC piped water supply (households with piped water)

(b) Willingness-to-Pay

The question related to Willingness to pay (WTP) for current and improved services are asked to households using piped water supply of MCDC. The amount of WTP for existing services, as a medium value, is estimated as 1,156 Kyat/month. Meanwhile, the amount of WTP for future improved water supply service, as a medium value, is estimated as 2,083 Kyat/month.

The average water expenditure per month is 1,950 Kyat, as mentioned in the following section. Since the amount of WTP for current service remains at approximately 60% of the current water expenditure, it can be interpreted that households is not satisfied with the current water supply status. The amount of WTP for the future improved service is similar to the actual current expenditure on water.

(c) Payment for domestic water use

Monthly average expenditure is 13,900 Kyat for "Bottled water", 12,000 Kyat for "Public taps by non-MCDC", 2,333 Kyat for "Private wells" and 1,950 Kyat for "MCDC piped water".

Approximately, 60% of respondents answered to purchase bottled water everyday even though they are connected to MCDC piped water supply.

(d) Awareness on water expense for domestic water use

All respondents replied that water expenditure for domestic use is a moderate level, not expensive and not cheap.

(e) Level of water tariff

All respondents replied that water tariff level is "Moderate"

(f) Ownership of water meter

All respondents mention that the ownership of water meter rests with the households.

(g) Level of satisfaction for piped water supply

The level of satisfaction for piped water supply service remains at middle or relatively low level. The lowest satisfaction is given to "accountability/ customer relation" with 2.0 points, followed by "Insufficient water supply volume" with 2.6 points and "Water quality color, taste, odor" with 3.0 points respectively. In contrast, the largest points is given to "Regular delivery/ accuracy of water bill" with 3.5 points. The sample number is limited; hence this survey result should be indicated as a reference.

(4) Households without MCDC piped water

Of the selected sample, the number of respondents in the category of customers without MCDC piped water supply is 294 households.

1) Condition of household and livelihoods

(a) Household income

The monthly household income of majority of the respondents falls in the range of "Less than 25,000 Kyat" and "More than 1,000,000 Kyat". Looking at the distribution, 40% of the total respondents affirmed their monthly income in the range of "200,001-300,000 Kyat" as a major class. The results are distributed evenly over the major class between the highest class and lowest class.

The monthly household income is estimated to be 250,000 Kyats for overall respondents as a median value and 310,500 Kyats as an average value. Also the monthly household income of lower income class whose income is among the bottom 20% is estimated to be 112,500 Kyats as a median value and 114,300 Kyats as an average value.

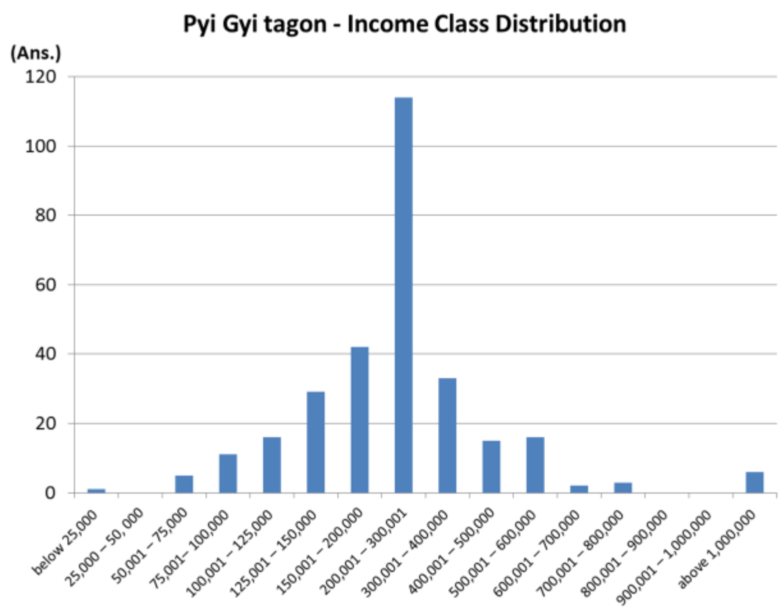


Figure 6-25 Distribution of monthly household income (households without piped water supply)

(b) Monthly household expenditure and amount

Within the number of respondents from non-piped water customers as 293 households, 203 households, nearly 70% of the total, responded that they purchase water for drinking/ domestic use. On average, monthly household's expenses on water is estimated to be 12,180 Kyats as an average value and 10,500 Kyats as a median value.

Annual average expense on water per household is estimated to be 15,120 Kyats. This amount is equivalent to ten times of the estimated expenses considering water tariff[1]. The estimated water tariff is equivalent to 0.5% of overall household's income and 1.1% of lower income class of the bottom 20%, thus the burden of paying for water uses could be below the affordable amounts of both groups. If current tariff level is applied for this calculation, household's expenses on water will be reduced by new connection to the MCDC's water supply services. Hence the conversion to piped water supply

[1] In here, a median value is adopted for the estimation, because usage of an average value may not sufficiently reflect the reality by having an influence of extremely high value.

service is assumed to be enhanced by the Project. Also approximately 30% of household does not spend their money for water presently. Even for these people, 1% of their income on water could be sufficiently affordable for receiving safe water.

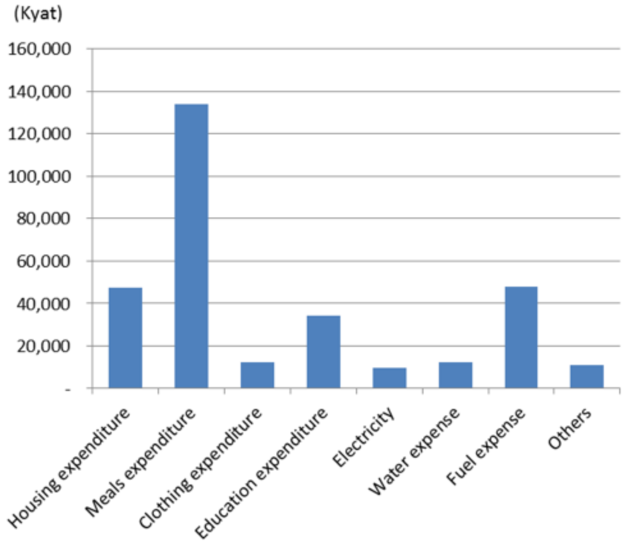


Figure 6-26 Monthly household expenditure (households without piped water supply)

(c) Payment for domestic water use

With regard to monthly average expense on water for domestic uses per household, the largest expense is for buying water from "water vender" as 17,000 Kyat, followed by purchase of "bottled water" as 12,383 Kyat, and water from "Non-MCDC public tap" as 10,946 Kyat and water expenses on "Others" as 9,750 Kyat.

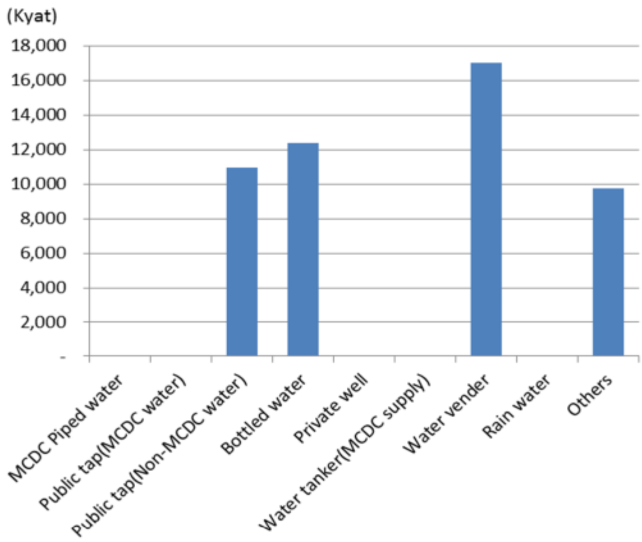


Figure 6-27 Payment for domestic water use (households without piped water supply)

2) Water supply status

(a) Time for fetching/drawing water

About 7% of all respondents answered that the time for fetching water is less than 5 minutes. The largest answer in terms of frequency is 2-3 times per day, which shares 66% of the total respondents.

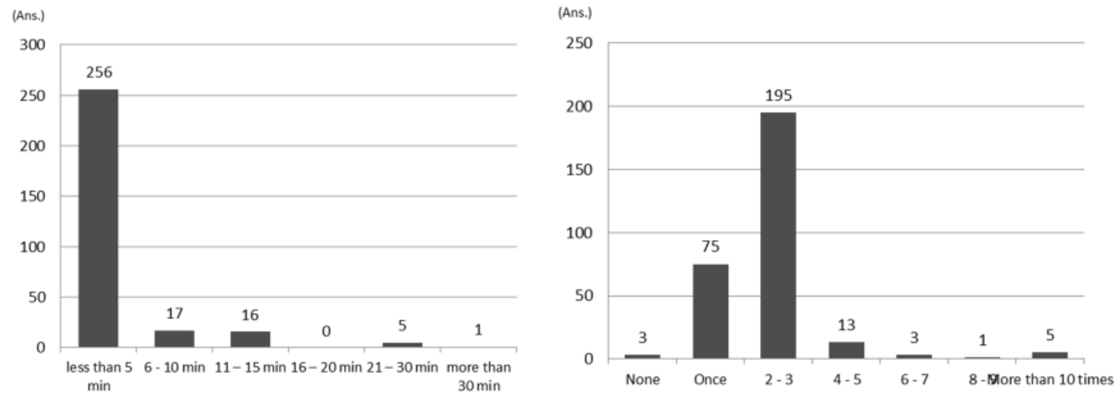


Figure 6-28 Time for fetching water (left) and frequency (right)

(b) Water consumption from main water sources

With regard to the obtained water volume one time, the most frequent answer of the total is "More than 50 Gallons" with 46% of respondents. This reason is because water is largely taken from private wells within their territory. However there is no significant difference among other answers, such as "1-5 Gallon(s)" with 14% and "21-30 Gallons" with 11 %.

(c) Responsibility of water drawing (including fetching)

In overall, adult/grownup man and woman have responsibility of water drawing with man in 93% cases and woman in 85% cases, respectively. The case of drawing water by child (children) is limited to only 6% of responses.

3) People's awareness and level of satisfaction on water supply

(a) Willingness-to -Pay

To the non-piped households, the question was asked on their willingness-to-pay for piped water supply under satisfactory water service condition, having sufficient quantity and quality of water, when in future they will be connected to piped water supply. The answer varied in the range of "less than 1,000 Kyat" and "more than 10,000 Kyat". The largest share of the answer is "2,001-3,000 Kyat" by 32% respondents, followed by "1,001-2,000 Kyat" by 28%, and "less than 1,000 Kyat" by 20% of respondents. These three answers account for approximately 80% of the total. The medium value is estimated as 2,500 Kyat.

When this amount of willingness to pay[2] is compared with the estimated water tariff, monthly

[2] Monthly water tariff is assumed to be 1,144 Kyat. (Domestic unit price 55 Kyat/m^3 x Monthly water consumption in rainy season 20.8m^3 (Social Condition Survey))

water tariff is estimated to be 1,144 Kyats, which is less than half of the amount of willingness to pay. Thus it is assumed that the estimated water tariff is sufficiently below the level of willingness to pay. According to the MCDC, current connection fee usually amounts to for more than 100,000 Kyats, hence it is clear that the amount of willingness-to-pay is smaller than the current fee. Only 1% of the total respondents indicate the willingness-to-pay higher than 100,000 Kyats.

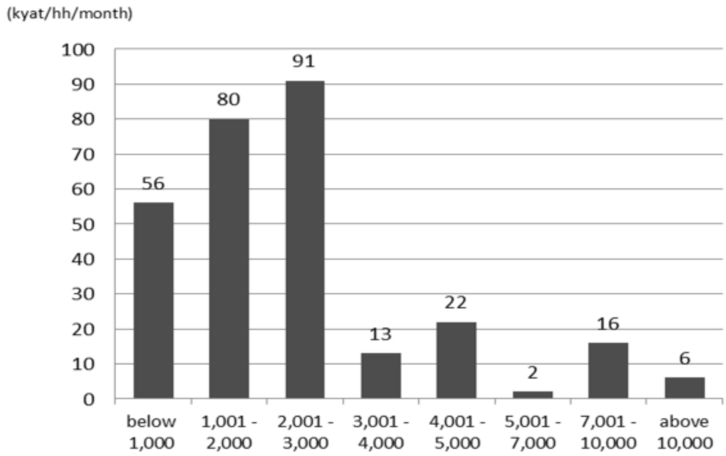


Figure 6-29 Willingness-to-Pay for piped water (under satisfactory water service condition)

(b) Awareness on water expense for domestic use

About 63% of respondents replied that water expenditure for domestic use is a moderate level. While, one-fourths of the respondents mentioned that the current level of water expense is expensive.

(c) Awareness on new connection and metered tariff rates

About 99% (280 households) of non-piped households answered that they wish to have new house connection of MCDC piped water supply. Also 95% (255 households) of the respondents replied to agree on the application of metered tariff rates.

(d) Willingness-to-Pay for new connection

About 77% of the respondents selected the lowest choice as “less than 50,000 Kyat”. It is followed by “50,001 – 75,000 Kyat” selected by 14% respondents, and “75,001 – 100,000 Kyat” selected by 8% of the respondents. According to the MCDC, the current connection fee usually amounts to more than 100,000 Kyat, hence it is assumed that the amount of willingness-to-pay is smaller than the current fee. Only 1% of the total respondents responded their willingness-to-pay of more than 100,000 Kyat.

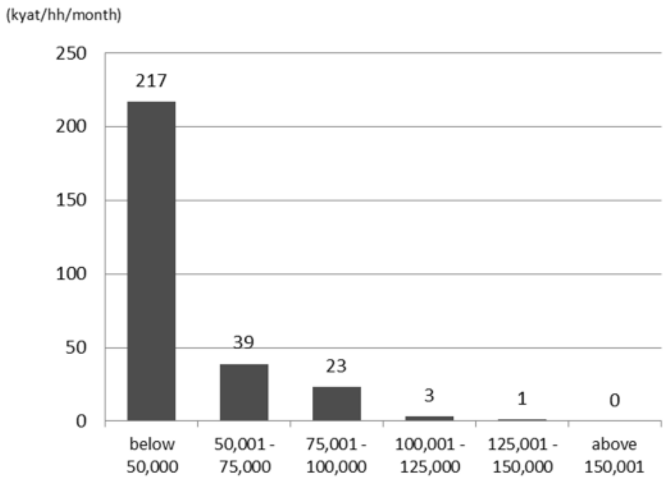


Figure 6-30 New connection and willingness-to-pay

(e) Level of satisfaction for main water sources

The surveyors asked households to rate their satisfaction for main water sources in the key seven aspects of “water volume”, “service hours/ access”, “distance/ time for drawing/fetching water”, “water quality (color, taste, cleanness)” and “water price”. The answer indicates that all evaluation points remain in the range 3.0 points, as a middle level, so that it can be said that the evaluation does not indicate the high level of satisfaction. The detail points are: “water volume (3.4)”, “service hours/ access (3.6)”, “distance/ time for drawing/fetching water (3.9)”, “water quality (color, taste, cleanness)(3.5, 3.4, 3.5)” and “water price (3.6)”. More than 98% of respondents answered the question related to evaluation of water quality level, hence it can be judged that people are concerned about the issue of water quality very much.

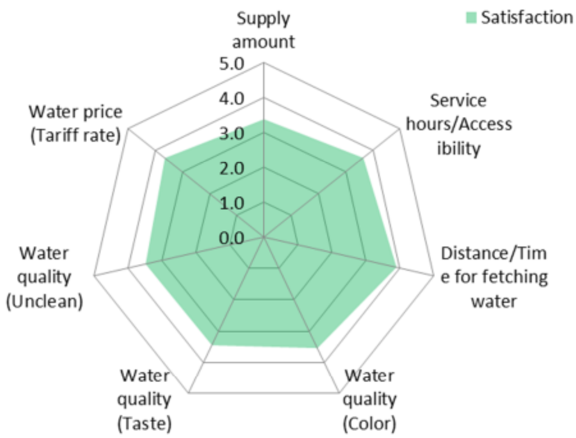


Figure 6-31 Level of satisfaction for main water sources

(f) Expectation from piped water supply

The people’s expectation from piped water supply services indicates high points with more than 4.1 points in every evaluation aspects. The highest expectation is given to “safe water supply” with 4.9

points, followed by “continuous supply” with 4.7 points and “publicness with equitable water supply” with 4.7 points. In overall, it can be concluded that the expectation from piped water supply is significantly high.

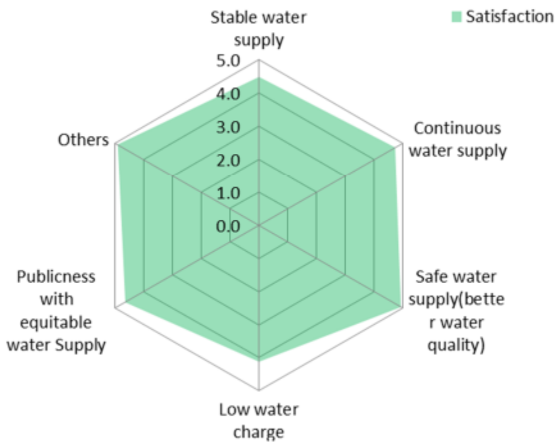


Figure 6-32 Expectation for piped water supply service (households without piped water supply)

6－9． Calculation result of population served

1. Population data from 2008 to 2013 and Population forecast result in 5 Townships in Mandalay city

		2008	2009	2010	2011	2012	2013	2020	2025
1	Aung Myay Thargan	255,659	259,277	262,066	248,746	251,100	254,910	282,897	304,761
2	Chan Aye Targan	243,341	246,784	249,440	224,300	226,500	229,900	255,094	274,809
3	Ma Ha Aung Myay	222,519	224,500	227,096	227,920	230,105	233,560	259,212	279,244
4	Chan Mya Thargi	172,267	174,692	178,561	194,703	196,570	199,530	221,435	238,548
5	Pyi Gyi Tagon	136,220	138,578	140,977	153,272	154,741	157,062	174,315	187,786

Souce: Department of Water and Sanitation, MCDC

2. Population growth rate in 5 Townships in Mandalay city

	year	2009	2010	2011	2012	2013	Average per year	Pacentage
1	Aung Myay Thargan	0.0142	0.0108	-0.0508	0.0095	0.0152	0.0124	1.2%
2	Chan Aye Targan	0.0141	0.0108	-0.1008	0.0098	0.0150	0.0124	1.2%
3	Ma Ha Aung Myay	0.0089	0.0116	0.0036	0.0096	0.0150	0.0113	1.1%
4	Chan Mya Thargi	0.0141	0.0221	0.0904	0.0096	0.0151	0.0152	1.5%
5	Pyi Gyi Tagon	0.0173	0.0173	0.0872	0.0096	0.0150	0.0148	1.5%

Souce: Department of Water and Sanitation, MCDC

3. Population served in the target water supply area

No.	Ward	Area (km^2)	Existing data in 2013				Water supply plan in 2013		Planned Population Served in 2015	Planned Population Served in 2020	Planned Population Served in 2025
			No. of Blocks	No. of Households	Population	Exixting Population Served	Rate of population served	Population Served			
1	Sa lone	2.36	59	3,197	20,030	2,800					
2	Thin Pan Kone	2.87	78	4,547	25,780	250	52%	13,152	13,549	14,597	15,725
3	Ka	0.86	23	828	4,472	704					
4	Ga	0.88	23	1,098	5,654	0	100%	5,654	5,825	6,276	6,761
5	Ghagyi	0.42	18	2,068	12,057	0	100%	12,057	12,422	13,382	14,416
6	Nga	0.56	11	631	3,393	0	100%	3,393	3,495	3,765	4,056
7	Sa Lain	1.08	83	2,965	15,146						
8	Za	0.60	45	1,619	8,095						
9	Zha	10.18	422	2,152	10,810						
10	Ngwe Taw Kyi Kone	2.52	31	2,155	12,524	0	100%	12,524	12,903	13,900	14,975
11	Chan Mya Thar Yar	1.61	11	1,713	8,372	2700					
12	Kha	0.10	24	1,009	5,085	704					
13	Tagon Tai	3.40	12	2,980	15,649						
14	Htain Kone	0.96	3	903	4,220						
15	Taung Myint	1.40	10	793	3,656						
16	Yar Taw	0.52	4	486	2,116						
	Population served	30.31	857	29,145	157,062	7,158		46,781	48,195	51,919	55,932
	Total Population							157,062	161,809	174,314	187,786

Souce: Department of Water and Sanitation, MCDC

6 - 10 . Examination of sustainability of the water source

1) Estimation of optimal yield

The optimal yield for individual wells is examined using a theoretical formula and so on.

In Japan, various methods are proposed for the estimation of optimal yield (critical pumpage) as follows;

① The transition point (break point) is recognized when values of pumping rate and water level change obtained from the step-drawdown test are plotted on double logarithmic chart. The pumping rate corresponding to this point is regarded as critical pumpage.

② The point that the angle of inclination exceeds 45° is recognized when pumping rate (X-axis) and water level change (Y-axis) obtained from the step-drawdown test are plotted on double logarithmic chart. The pumping rate corresponding to this point is regarded as critical pumpage.

③ The drawdown is estimated from the aquifer loss and well loss. The pump discharge when pumping water level is decreased to the pump position is defined as the possible maximum pumpage. Sustainable amount of pumping rate of an individual well is estimated as less than or equal to this value.

④ The following pumping rate calculated in order to prevent clogging due to turbulence is regarded as the optimal yield; "effective intake area × laminar velocity (1.0 cm/s) × effective porosity"

Recently, Tohoku Regional Agricultural Administration Office of the Ministry of Agriculture, Forestry and Fisheries (2008) [3] conducted a review of the pumping test result of the past and recommended method of ③ above[4]. In addition, well loss is important in the analysis of pumping test outside of Japan. So the optimum yield is estimated using method of ③ above in this analysis.

The drawdown of the pumping well is the combination of the aquifer loss and the well loss and is indicated by the following equation described above.

$$s = BQ + CQ^{n}$$

Where: s = drawdown, Q = pump discharge rate, B = aquifer loss coefficient, C = well loss coefficient, and the value of the well loss exponent (n) is often taken as 2.

$B = 3.88\times10^{-3}$ day/m^2 and $C = 6.68\times10\text{-}^{7}$ day^2/m^5 are gained through step-drawdown pumping tests that were conducted in the test well. The drawdown using these values is estimated as shown in the Table and Figures below. The optimal yield for an individual well is examined using the following method (Tohoku Regional Agricultural Administration Office of the Ministry of Agriculture, Forestry and

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[3] www.maff.go.jp/j/nousin/noukan/tyotei/t_seika/pdf/h20seika_10.pdf

[4] Generally in Japan, when the optimum yield is estimated, pump discharge and water level change obtained from the step drawdown test are plotted on the graph and a rate accounting for 60 to 80 % of the pump discharge (critical pumpage of above-mentioned ①) corresponding to the transition point is defined as the optimal yield. However, Tohoku Regional Agricultural Administration Office (2008) pointed out that this method is not used outside of Japan and there are some literatures that questioned in Japan, and conducted arrangement and reanalysis of the existing 178 cases. The result is as follows;

- In many cases, the relationship between the pump discharge and the drawdown can be approximated by a quadratic curve "$s = BQ + CQ^2$" that is a theoretical formula containing the term well loss.
- In the above case, the transition point does not exist.
- It is only 9 cases that the transition is clear. These transition points can be explained by well structure and heterogeneous aquifer (such as multi-aquifer).

Fisheries, 2008);

① The dry season ends in April and the rainy season ends in November in the vicinity of Mandalay City. In the M/P survey, simultaneous water level measurement was conducted in November 2001 and March 2002. In this result, the groundwater level in March was about 5 m lower than that of November around the target area. While the current static water level of test well is 11 to 12 m, the groundwater level at the end of the dry season is assumed to be 17 m on the safe side.

② When the pumping of 50 liters per second is conducted by a submersible motor pump (nearly equal to the pumping rate of the existing production well on BPS No.7 property), the limit of total head is about 75 m, even if the largest scale pump is used. Considering this, the deepest depth of the pump top is planned to be 70 m.

③ It is necessary that the space between the screen of the pump and the top of the well screen should be 3 m or more. If the length of the submersible motor pump is 2 m, the top of the pump must be located about 5m above the top of the well screen. Because the top of the screen of the test well is 90 m, the above-mentioned deepest depth of pump top (70 m) satisfies this requirement.

④ It is necessary that the clearance between the pump top and deepest pumping water level should be at least 2.75 m (about 3 m). Due to the above reasons, the deepest water level is planned to be 67 m and the drawdown is acceptable to be 50 m.

⑤ As shown in the table below, the pumping rate (possible maximum pumpage) corresponding to the drawdown 50 m is 6,220 m^3 per day.

As described above, the possible maximum pumpage is estimated to be 6,220m^3 per day. Daily pumping rate based on the design water supply is 3,000 m^3 per day (estimated drawdown is 17.65 m) and it can be said that this value (3,000 m^3 per day) is a water amount that can be sufficiently pumped.

Table 6-17 Relationship of the pump discharge and the estimated drawdown of the test well

Pump Discharge* (Q: m^3/day)		Aquifer Loss (BQ: m)	Well Loss (CQ^2: m)	Drawdown (s: m)
1,000	(50 L/sec × 5.6 hours) (13.9 L/sec × 20 hours)	3.88	0.67	4.55
1,500	(50 L/sec × 8.4 hours) (20.8 L/sec × 20 hours)	5.82	1.50	7.32
1,818	(50 L/sec × 10 hours) (25.3 L/sec × 20 hours)	7.05	2.21	9.26
2,000	(50 L/sec × 11.2 hours) (27.8 L/sec × 20 hours)	7.76	2.67	10.43
2,500	(50 L/sec × 13.9 hours) (34.7 L/sec × 20 hours)	9.70	4.18	13.88
3,000	(50 L/sec × 16.7 hours) (41.7 L/sec × 20 hours)	11.64	6.01	17.65
3,600	(50 L/sec × 20 hours)	13.97	8.66	22.63
6,220	(86.4 L/sec × 20 hours)	24.13	25.84	49.97

* Upper: Pumping rate is fixed (nearly equal to the pumping of the existing production well on BPS No.7 property).
Lower: Operation time is fixed (continuous operation is assumed to be 20 hours).

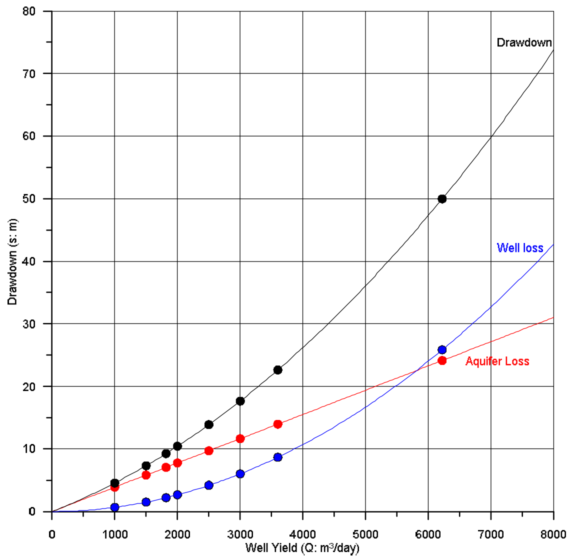

Figure 6-33 Relationship of the pumping rate and the estimated drawdown of the test well

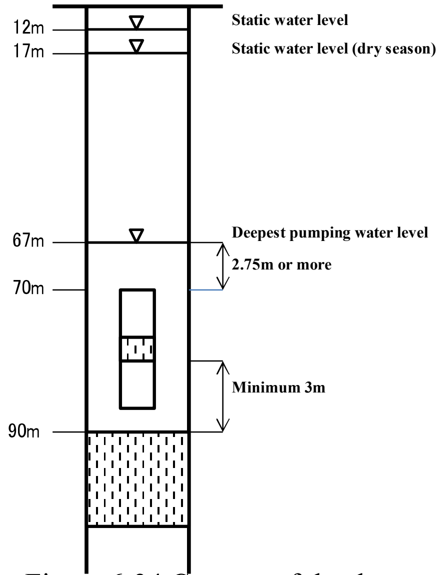

Figure 6-34 Concept of the deepest pumping water level

(2) Influence on the surrounding wells

The possible maximum pumpage of an individual well is estimated as above. In addition, it is necessary to consider the influence on the surrounding environment as a result of the pumping.

Though Tohoku Regional Agricultural Administration Office (2008) proposed the consideration of the water budget of the entire groundwater basin, this target area does not have sufficient data for performing the calculation of the water budget. Therefore, using a theoretical formula, predictions of two types ("Influence area of a single well" and "Drawdown volume around the new well development area") are conducted as follows.

1) Influence area of a single well

Influence area of a single well is estimated using the Theis equation below.

$$s = \frac{Q}{4\pi T} W(u)$$

where: s = drawdown, Q = pumping rate, T = transmissivity, $W(u)$ = well function

A guideline for the design of water supply facilities, provided by Japan Water Works Association (2012), describes "within 10 – 20 cm" as the amount whereby there is almost no impact on the surrounding environment from actual use of the well. Therefore, the area of the drawdown amount s > 20 cm is defined as the influence area "R" and R is estimated using the following values.

- Daily pumping amount: 3,000m^3 per day
- Unit pumping rate (Q): 50 L/s (= 4,320m^3 per day)
- Operation time of well (t): 16.67 hours (= 0.694 day), (50 L/s × 16.67 hours = 3,000m^3 per day)
- Transmissivity (T): 1,138m^2 per day as a result of pumping test

- Storage coefficient (S): 0.0001 (common value of confined aquifer)

s = 0.20 = (4320/(4π×1138))×W(u)

W(u) = ((4π×1138)/4320)×0.20 = 0.66173

W(u) is a well function tabulated by Wenzel (1942) and when value of W(u) is 0.66173, value of u is 0.42553.

non-equilibrium equation

$$u = \frac{R^2 S}{4tT}$$

When this equation is expanded, $R = 2\sqrt{\frac{utT}{S}}$

Therefore, R = 2×((0.42533×0.694×1138) / 0.0001)$^{0.5}$ = 3655m

Thus, because the transmissivity is large, the horizontal groundwater flow amount, due to pumping is large and the influence area by calculation using the theoretical formula is wider. In this calculation, a concentric drawdown is estimated due to limitations of the equation. However, the amount of horizontal groundwater flow from the direction of Irrawaddy River is large and drawdown of the other direction area is estimated to be smaller.

2) Prediction of the drawdown volume around the new well development area in future

Prediction of the drawdown of the 3rd aquifer around the new well development area is conducted using the following equation (deformation of the Cooper-Jacob equation).

$$s = \frac{2.30Q}{4\pi T}\log_{10}\left(\frac{2.25Tt}{r^2 S}\right)$$

where: s = drawdown, Q = pumping rate, T = transmissivity, S = storage coefficient, t = elapsed time, r = distance from the pumping wells

When the analysis conditions are as follows, the predicted drawdown of the 3rd aquifer in the surrounding area of the BPS No.7 after 20 years after the start of the pumping is shown in figure 6-25.

- Target aquifer: 3rd aquifer
- Transmissivity: 1,138 m^2 per day as a result of pumping test
- Storage coefficient: 0.0001 (common value of confined aquifer)
- Pumping well: New drilled wells that abstract groundwater according to the scenario[5] shown in the table below, and PTW35 and PTW36

[5] From among the eleven points (at eight sites), five points were narrowed down as candidate points for the new well development. At the time of selection, difficult level of land-use approval into the future and the consent of the residents were the basis of this selection.
Among the above five points, test drilling was performed at the point No.1 where the permission of the land-use has been obtained in the shortest time.
Four scenarios in consideration of the following were prepared, i) Point No.5-3 is a leading development candidate point, because this point has a good hydrogeological capacity since it is located near the river. ii) A drawdown caused by the multiple-well interference is reduced (consideration of the distance between wells).

- Total amount of new pumping: 9,000 m^3 per day, which is based on the planned daily maximum water supply amount

Table 6-18 New well development plan (○: Development candidate sites)

No.	New well candidate sites	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	Next to Martyr memorial (Test drilling point)	○ 3,000m^3/day	○ 3,000m^3/day	○ 3,000m^3/day	○ 2,250m^3/day
2	Play ground Next to transformer station	○ 3,000m^3/day	–	–	○ 2,250m^3/day
3	In front of Yinn Taw, Su Taung Pyae Pagoda, Aung Myay Bon San Ka Toe Kyaung, side by KOICA well	–	○ 3,000m^3/day	–	–
5-3	Behind the New Day gas station, near Sanda Mon Pagoda	○ 3,000m^3/day	○ 3,000m^3/day	○ 3,000m^3/day	○ 2,250m^3/day
8	Park in front of BEHS (7)	–	–	○ 3,000m^3/day	○ 2,250m^3/day

Note: For scenario, refer to Figure 6-25 below

In any scenario from 1 to 4, the occurrence of the drawdown of about 10 – 11 m is estimated around pumping wells after 20 years of the start of pumping. In addition, in the east side of the BPS No.7, the drawdown of about 8 m (about 9 m in some areas, in a scenario pumped in the park in front of BEHS (7)) is predicted around the railway line running in north-south direction.

A comparatively large drawdown as above is predicted because recharge from the vertical direction (i.e. from above) and from the adjacent river is not considered in this estimation. However, because the various recharges are received naturally, it is estimated that such over-evaluated drawdown will not occur. Estimated value is intended to be treated as the possible maximum value (no one can affirm probability of occurrence of 0%) of the drawdown.

For reference, even when increased pumping amounts of 36,000 m^3 per day in the northwest well field and 24,000m^3 per day in south industrial area are assumed, the maximum drawdown after 18 years of the pumping is estimated at about 0.7 m in the former and about 2.1 m in the latter case by the “M/P” survey. As final vertical recharge value, 0.84 - 1.05 mm was input to the groundwater model constructed at that time (it is not possible to consider this parameter in the calculation using a theoretical formula).

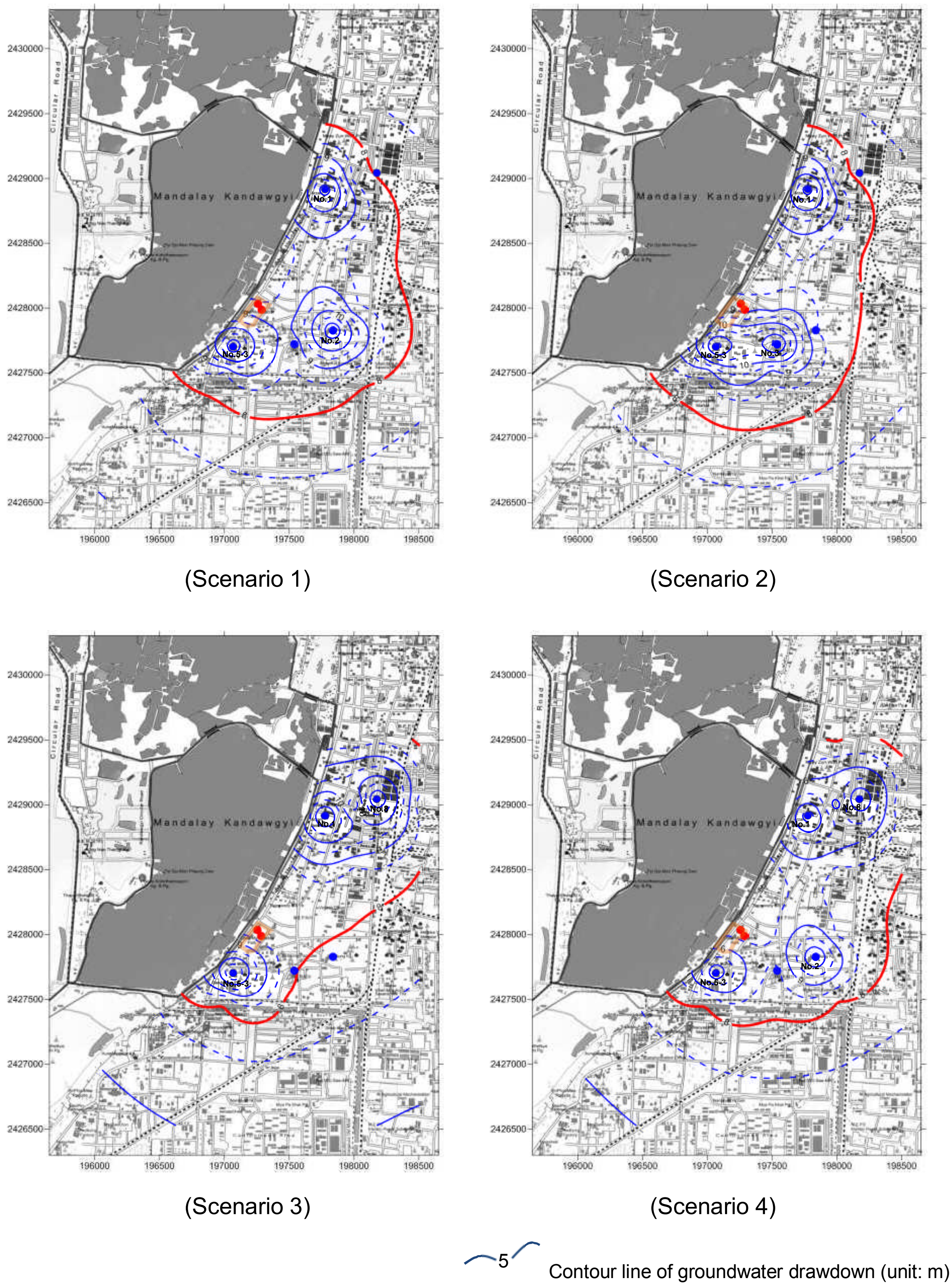

Figure 6-35 Comparison of predicted drawdown volume due to new well development (20 years after the start of pumping)

(Refer to Table 6-18 for details of numbers in the figure. ●: Existing production wells managed by MCDC)

(Contour line of groundwater drawdown of 8 m is shown as a red line for comparison)