Arsenic, Drinking Water and Environmental Health in Myanmar

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Abstract

The quality of drinking water is a powerful environmental determinant of health. Every stream, lake, river and aquifer can be used as a drinking water source. Protecting these sources from contaminants is a major national priority in protecting public health. Arsenic is one of the most important inorganic contaminants found in drinking water. Drinking water rich in arsenic over a long period leads to arsenic poisoning (arsenicosis). The most effective preventive measure is supply of drinking water with permissible arsenic concentration. In 2002, from 25 villages in Ayeyarwady Division, 66.6% of well water has high arsenic levels. In 2013, 123,962 drinking water samples in 17 townships were tested for arsenic contamination in Ayeyarwady Division and 6.22 % was 51 µg/l – 100 µg/l and 1.98 % was > 100 µg/l. Among a variety of technologies for the treatment of arsenic in water, Schwertmannite is a natural mechanism to remove arsenic. In Aung Thapyay village, Zalun Township, Ayeyarwady Division, water samples from 12 arsenic contaminated tube wells were filtered by Schwertmannite and the concentrations of 89.15 – 293.49 ppb were reduced to 12.32 – 30.87 ppb.
Now the project for promoting environmental health in arsenic contaminated area in Myanmar has been started in Thabaung Township, Ayeyarwady Region and project period is 2015 to 2018.

Keywords: Arsenic, environmental, Schwertmannite, Ayeyarwady Division

1. History of Department of Medical Research (DMR)

The Department of Medical Research (DMR) was first established as the Burma Medical Research Institute (BMRI) in June, 1963 and went into actual operation on 10 June 1963 at No. 5, Zafar Shah Road (now called Ziwaka Road, Yangon). It was renamed the Department of Medical Research in 1972. After the establishment of another Medical Research Institution in Pyin Oo Lwin, Upper Myanmar, DMR was named as the Department of Medical Research (Lower Myanmar) in 1999. In 2015 April, two Departments of Medical Research were merged into one Department of Medical Research. The Director-General is the head of the institution supported by the three Deputy Directors-General. The Board of Directors includes twelve Directors, five working for Administration-related jobs, and one each for Socio-medical Research, Clinical Research, Biomedical Research, Poison Control, Blood Research, Vaccine Research and Advanced Molecular Research.

Vision

Achieving a healthier nation through application of

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research findings

Aims

- To undertake research that contributes to the improvement of the health of the people of Myanmar
- To promote research on accidental, occupational, environmental and climatic factors affecting human health
- To carry out research on traditional medicine for safe and effective utilization within the existing health-care system
- To promote research culture at medical and related health institutions and to provide academic and technical training for postgraduate students
- To enhance technology development and analytical services applicable in the diagnosis, management and control of common diseases or conditions

Research Centres (7)

- Biomedical Research Centre
- Clinical Research Centre
- Sociomedical Research Centre
- National Poison Control Centre
- National Blood Research Centre
- Vaccine Research Centre
- Advanced Molecular Research Centre

- Research Divisions (27)
- Clinical Research Units (12)
- Supporting Divisions (4)
- Administrative Divisions (5)

National Poison Control Centre

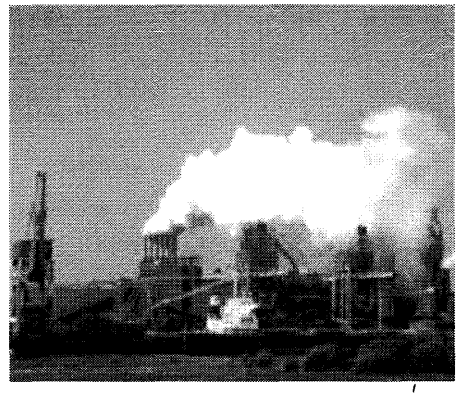
National Poison Control Centre was established at the Department of Medical Research in October 2003. It includes four main Divisions; Pharmaceutical Toxicology Research Division, Biological Toxicology Research Division, Chemical Toxicology Research Division and Radiation Toxicology Research Division. The main function of NPCC is to provide substantial information on diagnosis, treatment, prevention and control of acute and chronic poisoning cases. Each Division is carrying out research on their respective area which gives valuable and essential information on different kinds of poisoning cases for applicability in the field.

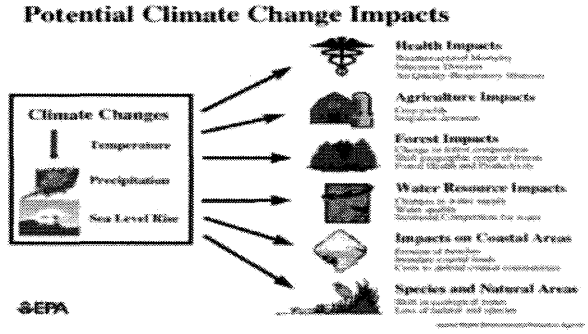
Myanmar Traditional Medicine

The Department of Medical Research has undertaken the research on safety and efficacy of reputed medicinal plants and locally available traditional medicines for the treatment of vireous diseases. The technology on the production of six herbal drugs was transferred to the Department of Traditional Medicine and Myanmar Pharmaceutical Factory (Ministry of Industry 1) for mass production. Moreover, studies on quality control and identification of active compounds from medicinal plants are performed by using Densitometer, High Performance Liquid Chromatography (HPLC), Gas Liquid Chromatography Mass Spectrophotometer (GCMS) and Liquid Chromatography Mass Spectrophotometer (LC MS/ MS).

2. Environmental Impact

Possible adverse effects caused by a developmental, industrial, or infrastructural project or by the release of a substance into the environment, where Dam construction, biodiversity, fishery resilience, forests, and natural water flows exist. In addition, renewable energy sources such as wind, solar, geothermal and the effect that the activities of people and businesses have on the environment.





3. Environmental Health

Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors influencing behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behaviour not related to environment, as well as behaviour related to the social and cultural environment, and genetics (WHO Health Topics, 2015).

4. Environmental Health Hazard

Environmental hazard is the state of events which has the potential to threaten the surrounding natural environment and adversely affect people's health.

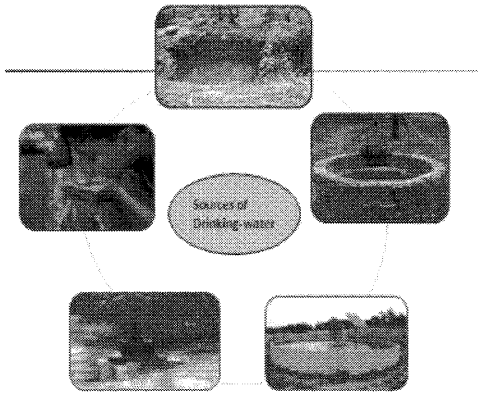
5. The Importance of Water for Overall Health

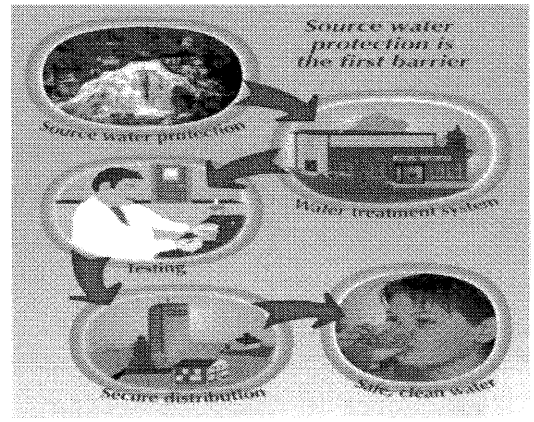
Without food, a person in excellent physical condition might survive 6 weeks; without water, survival potential is measured in days. Dieticians recommend that adults drink eight 8-ounce glasses (nearly 2 liters) of water daily. To assure good health, this adequate intake of water must be of satisfactory sanitary quality.

All living creatures, including humankind, need water for survival. Humans directly and indirectly consume water for drinking, cooking, and food production. They use it for bathing, household uses, industry and manufacturing, and waste disposal. Humans also use water environments for recreation, tourism, and ecosystem management. Therefore fresh water is one of our most vital resources, and when our water is polluted it is not only devastating to the environment, but also to human health.

6. Sources of Drinking Water

Virtually every stream, lake, river and aquifer can be used as a drinking water source. Protecting these source waters from contaminants is a major national priority in protecting public health through ensuring a clean, safe drinking water supply.





7. The Quality of Drinking Water

The quality of drinking water is a powerful environmental determinant of health. Drinking water quality management has been a key pillar of primary prevention for over one-and- a- half centuries and it continues to be the foundation for the prevention and control of waterborne diseases. Water is essential for life, but it can and does transmit disease in countries in all continents-from the poorest to the wealthiest.

8. Contamination of Drinking Water with Pathogenic Microorganisms

Microbial contamination of drinking water is one of the serious threats to human health. Infectious diseases caused by pathogenic bacteria, viruses, protozoa and helminths are the most common and widespread health risk associated with drinking water. Human health effects caused by waterborne transmission vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, cholera, typhoid and hepatitis. The most predominant waterborne disease, diarrhoea, has estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths each year in the world (WHO, 2010). Among ten leading causes of morbidity in Myanmar, diarrhoea and acute gastroenteritis of presumed infectious origin rank as four.

Drinking water in developing countries often is scarce and frequently is contaminated. This Liberian man in western

Africa was found to have benefits from clean water supplied by a new well constructed with the aid of UNICEF (United Nations International Children's Fund). But a multitude of different microorganisms, or microbes, can affect the quality of a water supply.

9. Sources of Microbial Contamination

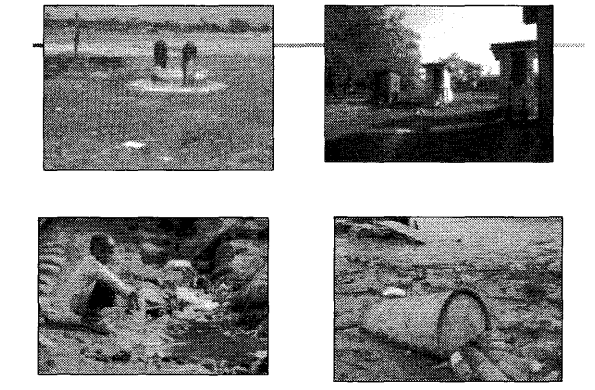
Examples of how human and animal waste may contaminate a water supply include, but are not limited to, the following:

- Failure of an on-site sewage disposal system (e.g., septic system) that causes direct infiltration to groundwater and/or provides runoff to surface water;
- Discharge of untreated or improperly treated sewage into rivers and reservoirs, such as during operational malfunctioning or during heavy storms with excessive storm water runoff.

10. Microbial Pathways and Human Health Effects

All waterborne pathogens are transmitted to humans through drinking or otherwise ingesting contaminated water. Therefore, the keys to breaking the process of transmission of these microbes are to (1) protect the water source by preventing contamination, and (2) protect the population from ingestion of contaminated water by treating a contaminated water supply and limiting its use.

11. Chemical / Toxicological Contamination of Drinking Water



MAMS, 7th March 2015

Millions of people are exposed to unsafe levels of chemical contaminants in their drinking water. Common toxic chemicals are mercury, lead, aluminium, arsenic and cadmium. The most significant sources of water pollution are lack of inadequate treatment of human wastes and inadequately managed and treated industrial and agricultural wastes. Or it may be linked to naturally occurring arsenic and fluoride, which can cause cancer and tooth skeletal damage, respectively.

12. Arsenic

Arsenic is one of the most important inorganic contaminants found in drinking water. This metalloid occurs as a natural component of underground rocks worldwide, with small quantities being dissolved in groundwater as a result of weathering. The inorganic salts of arsenic are tasteless and odorless, but highly toxic to humans. If ingested over long periods, even low concentrations can cause damage to health, including hyperpigmentation of the skin, disorders of liver and kidney function, and various types of cancer.

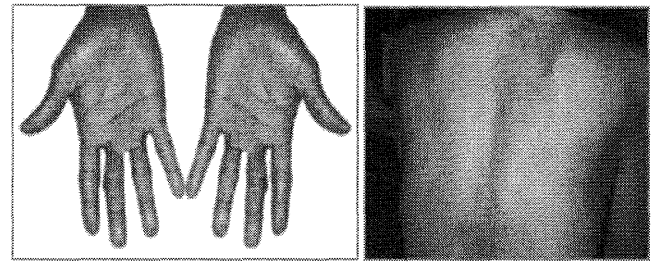
Drinking water rich in arsenic over a long period leads to arsenic poisoning or arsenicosis. Many waters contain some arsenic and excessive concentrations are known to naturally occur in some areas. The health effects are generally delayed and the most effective preventive measure is supply of drinking water with permissible arsenic concentration.

12.1 Chronic arsenic poisoning (ARSENICOSIS)

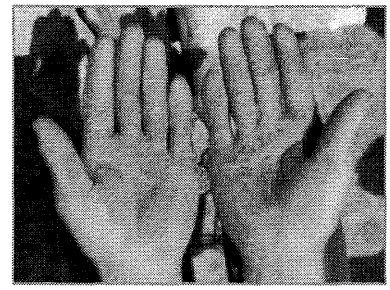
Arsenicosis is a chronic condition due to prolonged exposure of arsenic above safe level usually manifested by characteristic skin lesions with or without involvement of internal organs and malignancies.

12.2 Signs and symptoms of arsenicosis

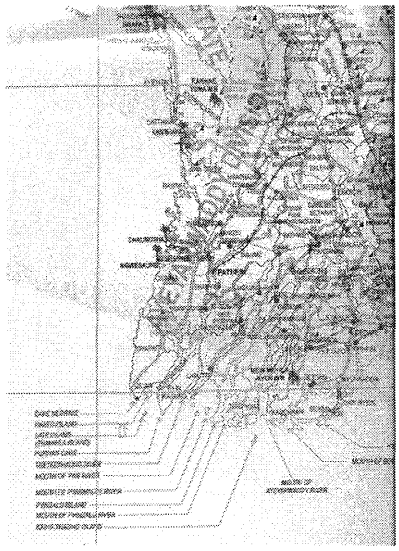
Melanosis



Severe hyperkeratosis of palms



12.3 Arsenic contamination in some areas of Myanmar



12.4 Assessment of arsenic content in ground water and the prevalence of arsenicosis in Kyonpyaw & Thabaung Townships, Ayeyarwady Division in 2002

A total of 25 villages from Kyonpyaw and Thabaung townships were investigated for arsenic contamination. Among 2074 subjects of study population, 5 subjects with skin manifestations were suspected for arsenicosis. Nail samples were tested for As level (Normal range– 430 to 1080 µg/kg). Two probable cases of arsenicosis had been detected. Sixty six point six percent (66.6%) of well water in 25 villages from Kyonpyaw and Thabaung Townships in Ayeyawady Division also has high arsenic levels.

12.5 Active case detection of arsenicosis in Ayeyarwady and Bago Divisions in 2004

❖ Ayeyarwady Division

Among 18 subjects with skin manifestations, 4 probable cases (2 from Zinpyunkone, 1 from Innyee in Kyonpyaw and 1 from Yaybosu in Hinthada township) were found to have arsenicosis.

❖ Bago Division

From 4 subjects with skin manifestations, one probable case (Thuyethamain in Waw Township) was observed. In 2005-2006, no clinical arsenicosis case was identified.

12.6 An analysis of arsenic content in drinking water sources from Ayeyarwady Region in January, 2013

A total of 123,962 drinking water samples in 17 townships were tested.

- 53.82 % (66,722) was arsenic free,
- 16.99 % (21,062) contained arsenic within the range of 1 to 10µg/l,
- 20.99 % (26,017) samples were within the range of 11µg/l to 50µg/ l
- 6.22 % (7,712) between 51µg/l and 100µg/l and
- 1.98 % (2,449) was higher than 100µg/l.

Ye Hein Htet et al. studied a total of 236 participants from four villages of Kyaungone Township, Ayeyarwady Region for utilization pattern of drinking water in rural households of arsenic contaminated areas and their awareness on arsenic contamination. In this study, the majorities (68.64%) did not have knowledge on safe drinking water such as color, turbidity, smell, taste, temperature, germs and only 30.51% knew about arsenic poisoning. Among total 96 water samples taken from the participant's well, 63 water samples had more than 50 ppb (1µg/l=1ppb) which is Myanmar National Standard for arsenic in drinking water and the mean arsenic level was 67.46 ppb.

12.7 Effectiveness and applicability of arsenic remediation method by using Schwertmannite in arsenic contaminated ground water in Myanmar (2010-2011)

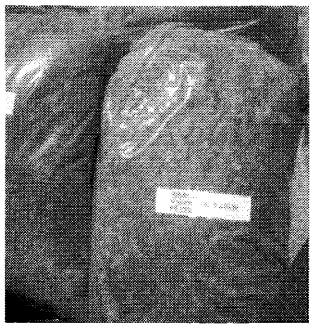
Many wells are drilled into ground deposit for public water supply in Myanmar, especially in rural areas. The release of arsenic from the arsenic-bearing aquifer sediments may have polluted the well. A variety of technologies have been used for the treatment of arsenic in water:

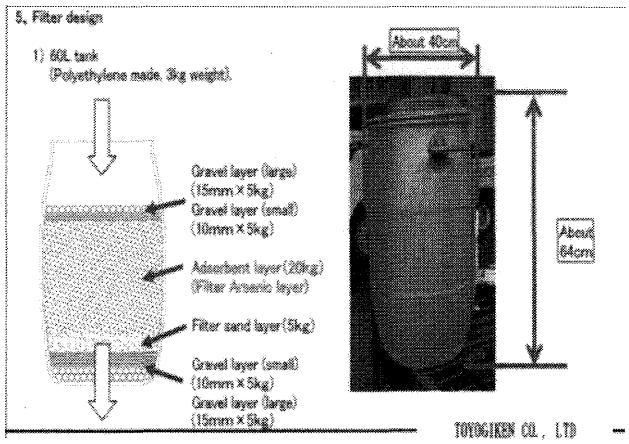
- co-precipitation with ferric chloride,
- lime softening,
- filtration using exchange resins,
- adsorbents (activated alumina, iron base adsorbent) membrane filtration process.

Since there are many types of iron base adsorbent media, Associate Professor Tsutomu Sato of Kanazawa University found in year 2000 that Schwertmannite stably adsorbs arsenic and has revealed the mechanism. Schwertmannite is ferrioxide hydroxylation hydrosulfate mineral and was formally registered in 1994 by International Mineralogical Association. It is a low crystalline iron mineral, naturally occurs in the sulfuric acid mine drainage by iron bacterial oxidation. Since it is a natural mechanism to remove heavy metal arsenic, it can be considered as a low environmental load process.

12.8 Schwertmannite Filter

A series of test in Bangladesh using Schwertmannite showed reduction of arsenic level from 0.6 mg/L to 0.01





mg/L, i.e., standard of drinking water in Japan. In Aung Thapyay village, Zalun Township, Ayeyarwady Region, water samples from 12 arsenic contaminated tube wells were collected and filtered by Schwertmannite. The arsenic concentrations ranging from 89.15 – 293.49 ppb were reduced to 12.32 – 30.87 ppb.

13. Arsenic Contamination of Water Sources in Rural Myanmar

Arsenic contamination of drinking water sources is an emerging public health issue in Myanmar. In early 2000, Save the Children UK's (SC UK) Water and Sanitation Programme identified arsenic contamination of groundwater in rural Ayeyerwady River Delta project communities. Since that time, there has been growing interest, concern and action related to arsenic testing, communication and mitigation in Myanmar.

The magnitude of arsenic contamination of groundwater sources in Myanmar is unknown, as no comprehensive studies have been conducted. After the severe flooding of 1997 in Myanmar, SC UK initiated a water and sanitation rehabilitation project in 12 flood-affected rural townships. The project facilitated the construction of 50,000 household latrines and constructed/rehabilitated village drinking water sources including 957 sludger-drilled shallow tube wells (STW). More than 60% of project achievements – 30,000 household sanitary latrines and 615 water supply projects were located in four Ayeyarwady Division townships.

Based upon geographical similarities between Myanmar and Bangladesh delta-regions, SC UK expressed suspicions of arsenic contamination of groundwater, especially in those communities located in the Ayeyarwady River Delta. A preliminary water quality survey was carried out by SC UK in 63 project communities during March-May 2000. The findings showed that arsenic contamination in excess of the proposed Myanmar national standard of 0.05 mg/l was present in 35% of the 145 inspected shallow tube wells, thus confirming initial concerns.

13.1 Extensive water quality surveys

In early 2001, SC UK conducted a comprehensive water quality survey in 327 villages and wards, covering an area of approximately 550 square kilometers in four Ayeyarwady Division Townships (Thabaung, Laymyathna, Hinthada, and Kyonpyaw townships). The survey covered 1,969 drinking water sources including 1,912 STWs. The purpose of the survey was to: 1) assess the bacteriological safety of STWs for drinking water purposes; 2) check for the presence of arsenic in STWs in order to determine the extent and severity of the problem and if possible to help explain the pattern of occurrence; 3) measure five other water quality parameters considered particularly relevant: iron, manganese, pH, electrical conductivity and temperature; 4) rapidly assess the physical condition and use of SC UK water and sanitation instillations two years after implementation; and 5) to provide supplementary data for the newly initiated country-wide Myanmar National Water Quality Surveillance and Monitoring Programme.

13.2 Results and findings

Overall, water samples containing arsenic levels in excess of 0.01mg/l (WHO Standard) were detected in 45% of the STWs examined: Kyonpyaw 44% (n=705); Hinthada 31% (n=372); Laymyathna 33% (n=324); and Thabaung 65% (n=511). The highest concentration of arsenic detected was 0.50 mg/l in 9 STWs (0.5% of the total samples). A total of 21% of the samples exceeded 0.05mg/l, the proposed Myanmar National Standard (Figure 1). Overall, 55% of the samples showed no measurable level of arsenic.

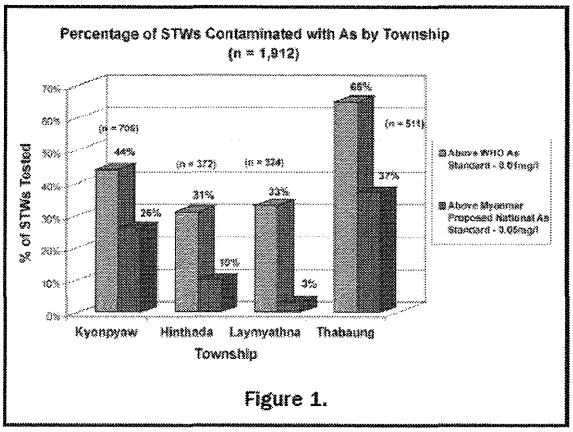


Figure 1.

Tube well depth and arsenic levels were analyzed (Table 1). All the STWs investigated in the survey were constructed by the traditional sludger drilling technique or improved sludger method.

Table 1 STWs by depth and arsenic level

Kyonpyaw							
	As mg/l						
Depth ft	0	£0.05	0.1	0.2	0.3	0.4	0.5
0~50ft	156	15	11	0	0	0	0
51~80	36	23	13	0	0	0	1
81~150	71	36	34	8	3	2	5
151~200	113	53	66	4	2	0	2
201~250	18	12	10	0	1	0	0
251~300	4	1	2	0	0	0	0
> 300	0	0	0	0	0	0	0

Hinthada							
	As mg/l						
Depth ft	0	£0.05	0.1	0.2	0.3	0.4	0.5
0~50ft	91	8	1	0	0	0	0
51~80	49	18	6	2	3	0	0
81~150	54	21	7	7	2	2	0
151~200	25	23	7	1	0	0	0
201~250	27	6	1	0	1	0	0
251~300	9	1	0	0	0	0	0
> 300	0	0	0	0	0	0	0

Thabaung							
	As mg/l						
Depth ft	0	£0.05	0.1	0.2	0.3	0.4	0.5
0~50ft	8	0	0	0	0	0	0
51~80	10	5	1	1	0	0	0
81~150	93	81	55	38	20	7	1
151~200	65	60	33	22	8	0	0
201~250	3	1	0	0	0	0	0
251~300	0	0	0	0	0	0	0
> 300	0	0	0	0	0	0	0

Laymyathna							
	As mg/l						
Depth ft	0	£0.05	0.1	0.2	0.3	0.4	0.5
0~50ft	48	4	1	0	0	0	0
51~80	24	11	1	1	0	0	0
81~150	73	35	7	0	0	1	0
151~200	32	26	3	0	0	0	0
201~250	26	9	1	0	0	0	0
251~300	10	9	0	0	0	0	0
> 300	2	0	0	0	0	0	0

The majority of arsenic affected tube wells lie within the depth range of 80-200ft.

The relationship between iron and arsenic was also examined (Table 2).

Table 2 Number of STWs corresponding to different combinations of As and Fe contamination

	As (mg/l)						
Fe (mg/l)	0	£0.05	0.1	0.2	0.3	0.4	0.5
£1	596	42	17	0	1	0	1
2~3	119	26	17	0	4	2	1
4~5	167	155	114	9	12	2	3
7.5	61	92	54	7	14	3	2
10	91	82	55	1	9	3	0
>10	29	55	10	0	2	2	0

Among the set of STWs with arsenic contamination exceeding 0.05mg/l, 47% had iron content in the high range of 7.5 ~ >10mg/l, 48% in the medium range of 2 ~ 5mg/l and 5% in the low range of £1mg/l (£= less-than or equal to).

14. "Promoting Environmental Health in Arsenic Contaminated area in Myanmar"

Project purpose

To develop the implementation system of the environmental health by collecting and analyzing the basic health data and taking countermeasure against unsanitary drinking water in the arsenic contaminated areas.

Three Main Activities;

1. Medical Part
   - ➢ To collect and analyze resident's basic health data
   - ➢ To conduct medical examination of the study population by project team
2. Water supply Part
   - ➢ To construct safe water facilities
   - ➢ To establish the maintenance system
3. Resident's awareness Part
   - ➢ To develop the awareness materials
   - ➢ To implement the awareness programs

Target Area

- ➢ Baseline survey in 7 villages; Htanzinhla, Dale-et, Shannkwin, Latechaung, Konetangyi, Thayattaw and Yaylegyi at Thabaung Township
- ➢ Implementation for the safe water supply in 1 or 2 villages

Project period

August 2015 to July 2018

15. Global Availability of Safe Water

In the millennium developmental goal, one of the targets is "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation"

The world has met the target of halving the proportion of people without access to improved sources of water, five years ahead of schedule. Between 1990 and 2012, 2.3 billion people gained access to improved drinking water sources. Over a quarter of the world's population has gained access to improved sanitation since 1990, yet one billion people still resort to open defecation.

The estimated 780 million people remained without access to an improved source of drinking water. Despite progress, 2.5 billion in developing countries still lack access to improved sanitation facilities (UNICEF/WHO, 2012). Between 1990 and 2010, in Myanmar, improved water sources increased in urban areas from 80% to 93% and more so in rural areas from 48% to 78% (WHO-UNICEF, 2014). However, improved water sources are not always safe (Shaheed et.al., 2014 a; Shaheed et.al., 2014 b).

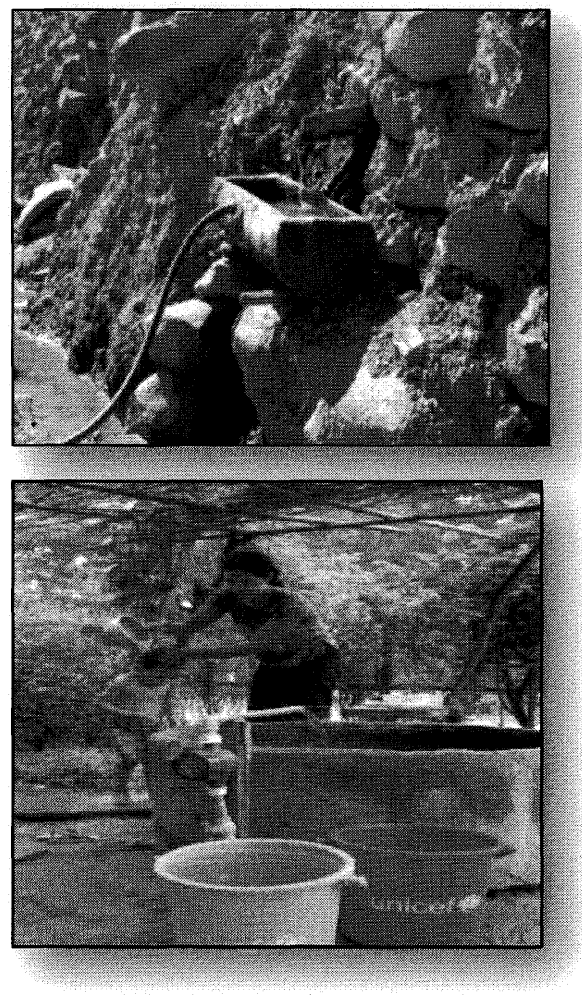
Safe water and the prevention of waterborne diseases are public health priorities in most developed countries, where clean water generally is available for about one-third of the world's population. However, water-related human health problems in developing countries are daunting.

During the International Drinking Water Supply and Sanitation Decade (from 1981 to 1990), concentrated efforts were made to extend services to unserved and underserved populations in developing countries. Some progress was made, but the overall effort failed. Underestimation of the problem's extent, inadequate funding, and the need for extensive hygiene and sanitation education among affected populations were contributing factors. The World Health Organization, the World Bank, and the entire international community must focus on capacity-building in developing countries. Only through these efforts can the ongoing cycle of death and disease be diminished.

15.1 Current condition of Myanmar

According to the WHO/UNICEF JMP 2015 data, the usage of surface water source is dramatically reduced and total water usage from improved sources is intentionally increased about 20% (53% to 73%) during between 1990 and 2015. This improvement is more remarkable in rural areas but piped on to premises is not absolutely increased.

The coverage of sanitation shows the increasing of improved sanitation especially in rural areas and also decreasing trend in the opened defecation. The MDG drinking water target has already been surpassed according to trends in global drinking water coverage (1990-2012). To fulfill the aim of the target, the activities have to be done for the increasing piped on to premises in drinking water sources, decreasing the opened defecation and increasing the improved sanitation in all communities.



15.2 Milestones of drinking water quality standard in Myanmar

Since 1990, Department of Health has been working to establish the National Drinking Water Quality Standard (NDWQS) in Myanmar. The objective of NDWQS is to promote public health, safety and welfare by ensuring quality standards of drinking water and the scope and coverage is applicable to drinking water available in Myanmar and is not applicable to bottled drinking water. In Myanmar, Water Safety Plan activities are performed by assistance of UNICEF and by assistance of WHO at Pauk township, Wetlet township, Myaing township and Kachin State in May, 2014 to February, 2015.

Currently, rural water supply activities are mainly implemented by Department of Rural Development (DRD) which is under the Ministry of Livestock, Fisheries and Rural Development. DRD is now working with international partners, NGO, INGOs and UN Organizations. The Key

partners for DRD in Rural Water Supply Sector are World Bank Group, Japan International Cooperation Agency (JICA), Bridge Asia Japan (BAJ), UNICEF and UN-Habitat.

15.3 Suggested Strategies

To prevent arsenic contamination in drinking water

Strategies:

- To improve Awareness (Health Education) of potential arsenic contamination among the risk population.
- Preventive measures for arsenic contamination should be performed.
- Preparedness of the Diagnostic facility and Management measures should be made ready.

16. REFERENCES

WHO (2015).Health Topics; Available from URL:http://www.who.int/topics/health_services/en/

UNICEF/WHO (2012) update. Progress on drinking water and sanitation: New York, NY, USA, United Nations Children's Fund; Geneva, Switzerland, World Health Organization, Available from URL:http://www.unicef.org?media/files/JMPreport2012.pdf

WHO (2010, 2010 b). Emerging issues in water and infectious diseases. Geneva, Switzerland, World Health Organization.

Kapaj S, Peterson H, Liber K and Bhattacharya P (2006). Human health effects from chronic arsenic poisoning- A Review. J. Env. Sci. Health Part A 41: 2399-2428.

UN (United Nations) (2001). Synthesis report of arsenic in drinking water. World Health Organization, Geneva.

USEPA (United States Environmental Protection Agency) (2002). A pocket guide to protecting your drinking water.

Ye Hein Htet, Tin Nwe Nwe, Khin Moe Latt, Kyaw Soe, Khin Thet Wai, et al. (*2012).* Utilization pattern of drinking water in rural households of arsenic contaminated areas and their awareness on arsenic contamination. *Myanmar Health Sciences Research Journal.*

Jones E. M., (2000). Arsenic, Water Aid Bangladesh.

Kohnhorst A. and Pranabananda P, Testing Sample Arsenic Removal Methods, 26th WECD Conference.

Smith A., Lingas E. O., & Rahman M., (2000). Contamination of drinking water by arsenic in Bangladesh, Bulletin of the WHO.

Tun, K.M., (2002). Department of Medical Research, Personal Communication, Yangon

WHO-UNICEF (2014 update). Progress on Drinking Water and Sanitation-. Geneva, Switzerland, World Health Organization; New York, NY, USA, United Nations Children's Fund.

Shaheed A, Orgill J, Montgomery MA, Jeuland MA & Brown J (2014a)Why "improved" water sources are not always safe: Policy and Practice. Bull World Health Organ.; 92 (2): 283-289.

Shaheed A, Orgill J, Ratana C, Montgomery MA, Jeuland MA & Brown J (2014b). Water quality risks of 'improved' water sources: Evidence from Cambodia. Tropical Medicine and International Health; 19 (2):186-194.

WHO (2011, 2010b). Guidelines for drinking water quality 4th Edition. Geneva, Switzerland, World Health Organization.

WHO,UNICEF(2015). JMP Goals, Targets, Indicators: Global Monitoring. Available from: http://www.wssinfo.org/post-2015-monitoring/overview.