ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 11,November 2017

Solutions for Major Challenges of Industrial Water Pricing in Mandalay

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Abstract: **For sustainable water management, the role of water pricing is widely recognized in many areas of the world because of the increasing scarcity of water resources and high competition between water users and environmental degradation. The situational analysis of existing water infrastructure in Mandalay was conducted and, major aspects for challenges to industrial water pricing are found out. The questionnaire survey was also performed based on "Statistics Canada, Industrial Water Survey: Manufacturing Industries, 2011" to determine the industrial water demand and cost of water. In this study, industries surveyed for industrial water use in Mandalay industrial zone are six large size factories and three SMEs. Totally nine numbers of factories are surveyed in Mandalay industrial zones. Other four numbers of surveyed factories in this study are under Kyaukse government industrial zone. These four factories are large size industries. Industries are categorized according to standard industrial classification (SIC) code. From the demand side management, price elasticity of water demand for selected industries is evaluated using mid-point formula. The secondary academic sources such as papers, journals and books were studied and adopted to search the possible solutions to challenges of industrial water pricing and they are proposed. As a conclusion, eleven numbers of solutions to challenges of industrial water pricing are proposed from this research.**

Index Terms **— challenges, industrial water pricing, Mandalay, possible solutions, situational analysis**

I. INTRODUCTION

A sustainable framework of legislation for the rapid industrial developments is needed. Mandalay does not have the improved source of water in all of its three industrial zones. There are three industrial zones in Pyigyitagon township, Mandalay. There is no surface water supply from municipal source in Mandalay industrial zones and almost all industries tend to depend on groundwater and they consume unlimited groundwater. The industrial zones are very far from surface water source, Ayeyarwady river and Sedawgyi reservoir. So, they cannot easily get surface water and, extract groundwater indefinitely by digging tube wells. Groundwater depletion is primarily caused by consistent groundwater extraction in Mandalay. Eleven major challenges to water pricing are found out in the previous research as a preliminary study for Mandalay. The key factors which cause lack of water infrastructure in Mandalay are the fact that those are inadequate funds to build and operate infrastructure, less investment in water supply and sanitation, the increase amount of water demand over supply due to high population growth and increased economic activities. For industries in Mandalay Region, there is no appropriate industrial water tariff structure. The Mandalay City Development Committee is not in charge of the regulation to the industrial zones. Due to lack of pricing of water for industries and lower pricing of water for domestic and commercial sectors, public appreciation for the value of water is gradually decreased. One of the main factors for lack of public appreciation on the value of water in Mandalay is Non-Revenue Water (NRW) in terms of leakage, illegal connection and billing errors. Most anticipated water public-private-people-partnerships (PPPPs) did not overcome contracting stage because of cost concerns, the limited financial resource and technical capacity of utilities. Lack of stakeholder support for water public-private-people-partnerships (PPPPs) projects is a significant reason for PPPPs in Mandalay. The main constraint concerned with going green is lack of recycling wastewater from households and industries. According to industrial water survey, most industries do not recycle wastewater from industrial production processes. El Niño, a weather phenomenon occurred in Myanmar during summer in 2016. Likewise, Mandalay also suffered from El Niño. The negative impacts of El Niño may either be flood or drought or cyclic order of both. El Niño greatly impacts on the water supply, energy supply and agriculture sectors in most areas of Mandalay due to drought which causes aridity of the soil and losses of water resources or intense rainfall which causes floods and water resources contamination.

In Mandalay, groundwater level or pressure declination is concerned with groundwater extractions for stock or industries and dwellings and, recharge is decreased due to drought conditions and urbanization which was being increased in impervious surface. Before 1993, Mandalay was composed of four townships and impervious area was 57.91 km2. From 1993 to 2010, it was increased to 118.41 km2 but it becomes increased upto 315.36 km2 at current condition [2]. In Mandalay, as for now, there is no law concerning the groundwater abstraction by the various industries. In the Union of Burma, "THE UNDERGROUND WATER ACT

[Burma Act IV, 1930]" was enacted whereas it is expedient to conserve and protect underground sources of water supply since 21st June, 1930 [5]. Although the act was enacted for groundwater users, it is not alive.

Therefore, water pricing is difficult to set due to these challenges in water sectors and, solutions to challenges of industrial water pricing should be looked for Sustainable Development Goal (SDG) for national water resources.

II. MATERIALS AND METHODOLOGY

The questionnaire survey has been conducted by selecting industries in Mandalay industrial zones in order to determine the industrial water demand and cost of water. The questionnaire set based on the "Statistics Canada, Industrial Water Survey: Manufacturing Industries, 2011" has been launched [3]. Mid-point formula is used to evaluate the price elasticity of water demand for selected industries from the demand side management in accordance with SIC code namely CON, OTI, PAP, MTL, TXT, FAD and BRW [4]. The situational analysis of existing water infrastructure in Mandalay is done. The questionnaire set supports to get challenges and solutions to industrial water pricing for the case of Mandalay. The materials used in this paper are secondary academic sources such as journals, papers and books. Moreover, international solutions for water management help to get possible solutions of industrial water pricing for the case of Mandalay.

III. RESULTS AND DISCUSSIONS

Based on situational analysis, questionnaire survey and literature, the following solutions to challenges of industrial water pricing can be proposed for this case study.

1. Solutions for Lack of Infrastructure in Water Supply

For this challenge, existing broken systems should be repaired and sustainable systems for new infrastructural development should be promoted and employed. As new projects are undertaken and old ones are repaired, life-cycle analysis makes sense to evaluate all foreseeable costs including construction, maintenance, operation, environmental impact, and any other associated costs. This helps municipalities or the owners of infrastructure to budget for ongoing maintenance, avoid creating systems that are unaffordable, and anticipate future needs. By performing a cost-benefit analysis, water supply infrastructures can be figured out whether or not the project is worth it. Involving communities in adopting new strategies can increase acceptance of new water systems. Communities can be taught to maintain and operate water systems, and can help determine what type of system best suits local conditions. Water conservation measures that rely on the community are often more effective when they provide income for the community. To improve investment in water supply and sanitation, public-private-people-partnerships (PPPPs) should be involved. The private sector finances the capital investment and recovers the investment over the course of the contract.

Rainwater harvesting, one of the ancient methods for collecting water from roofs, cisterns, and other sources, should divert runoff into ponds and reservoirs for urban areas of Mandalay. It is also useful for domestic use. It is important to save the water for the future of Mandalay and to develop rain water harvesting system through technical and financial prospects. Rainwater harvesting can be a solution for water scarcity and lack of infrastructure. Sequential water uses involving with capturing and treating water that has been used in one sector can be directed to other uses. Domestic use requires the cleanest water, so the ideal order is the household first, then industry, and agriculture. Water and wastewater utilities are typically the largest consumers of energy in municipalities, often accounting for 30 to 40 percent of total energy consumed [1]. It could be televised and addressed by ongoing questions such as how to fund immediate and ongoing infrastructure needs and how to sustain an integrated, cooperative plan while maintaining local, community control. The existing national transmission grid should be modernized to meet the current energy demand, resulting in bottlenecks and an increased risk of blackouts. By expanding the grid in wind, the increased demand would be helped and a shift to renewable energy sources would be encouraged. Investing in energy efficiency in water sector systems can significantly reduce operating costs.

2. Solutions for Lack of Industrial Water Tariff

Possible strategies include imposing water tariffs; charging for extracting water; pricing water at cost; and offering conservation subsidies. The price elasticity of water demand is evaluated in previous research in accordance with the various groups of selected industries. So adopting this price elasticity of water demand as a basis of industrial water pricing, the price should be set at a level that allows a fair return on the investment to recover the cost of financing and to meet the contractual obligations. An appropriate level of base tariff can be established by considering the cost of capital. To reduce the excessive extraction from groundwater, develop the industrial water supply and appear the wastewater tariff, a potential solution is the increasing block tariff (IBT) that dividing water use into tiers, or blocks, where the price per unit of water increases with increased consumption. The price of water is the lowest for the amount in the first block. Once water usage hits the second block, the amount of water exceeding the first block will be paid at the second block's price, and so on. An IBT is a relatively simple solution to these problems and the right features can greatly help with water distribution. The number of blocks should be based on consumption patterns of the area or the industry.

3. Solutions for Lack of Public Appreciation for the Water-Value

Possible strategies for industrial water tariff have been described in article 3.2. Pricing of water for domestic and commercial sectors should be set to recover the entire charges including water distribution costs. At this moment, economic, cultural and socio-economic values of water should consider in Mandalay. Therefore, education programs are necessary to carry out regularly for increasing public awareness of these values. The most traditional and basic method is to have a team of leak detection specialists who check all pipes on a regular basis. Since leak noise can be detected, this work is done with a wide range of listening devices, ranging from simple mechanical listening sticks to electronic ground microphones or even leak noise correlators. Every part of the network must be surveyed once a year, the average leakage run time (awareness time) is 6 months. To reduce awareness time, the survey frequency can be increased and leak detection efforts should be well targeted. The billing system is the only source of metered consumption that can help determining the volume of non-revenue water (NRW) through an annual water audit. Most billing systems are designed to deliver accurate bills to customers and correctly account for the bills. However, there are many day-to-day processes in operating a billing system that have the potential to corrupt the integrity of the consumption data, depending on the design of the particular system. To be able to determine how much water is lost in specific parts of the network, the network must be split in hydraulically discrete zones and the inflow to these zones must then be measured. By computing the volume of leakage in each zone, leak detection specialists can better target their efforts. Ideally, when the entire distribution network is split, the utility has several advantages as follows:

1) The volume of non-revenue water (NRW) can be calculated on a monthly basis.
2) The components of NRW such as physical and commercial losses can be quantified by analyzing flow and pressure data.
3) Leak detection works can be prioritized.
4) New pipe bursts can be identified immediately by monitoring the minimum night flow, and therefore awareness time will be reduced from several months to several days or even less.
5) When leakage is eliminated, utilities can better gauge the existence of illegal connections or other forms of water theft and can take action.

By following such process of hydraulically discrete zones in network, solutions to challenges for lack of public appreciation for the water value can be achieved.

4. Solutions for Lack of Public-Private-People-Partnerships (PPPPs)

One of the PPPP approaches is a win-win solution for infrastructure development and financing. By involving private sector in water infrastructure, it can support funds to build and operate industrial water infrastructure and solve the difficulties of the existing water infrastructure. Moreover, communities in city can get profits from supporting water infrastructure. A major responsibility of the government or the regulator is not to allow any excessive profit to the private sector in a public-private-people-partnerships (PPPPs) deal. When seeking to involve the private-sector in water and sanitation infrastructure projects, a host country's legal framework should be considered. Regulation of the sector (including regulation of tariffs, performance and standards) is important for all service delivery, whether provided by the private or public sector. Regulation of tariffs and regulatory risk are crucial to PPPPs in the water sector. PPPPs are an important tool in improving utility performance, leveraging finance, and stimulating a much-needed sense of competition and accountability in an otherwise monopolistic water and sanitation sector. This considers the options and issues for private sector participation (PSP) and priorities in economic evaluation, financing, revenue collection and cost-recovery. It is important that the type of PSP is matched to the context of water supply and that the interests of the poor and unserved are not compromised. PSP is already common in many urban areas, usually on a small scale (single vendors, private toilets and bathing facilities, water truckers etc.) and usually catering for needs of the unserved. PSP for large scale suppliers has received increasing coverage recently, much of it controversial, both in developed and developing countries.

Corporate Private Sector Participation (PSP)

The private sector should be perceived to be able to deliver the following important benefits:

1) Bringing technical and managerial expertise to the sector.
2) improving operating efficiency.
3) resulting in large-scale injections of capital and greater efficiency in the use of capital.
4) Reducing the need for subsidies.
5) increasing responsiveness to consumer needs and preferences.

Small-scale Private Sector Participation

In these cases, PSP seeks to provide water where no public provision is made. The municipal authority may:

(i) have obligations to do so but choose not to do so, or are unable to, either because of cost, revenue collection doubts, lack of political will, or

(ii) choose because the population are illegal tenants (squatters) and they want to avoid legitimizing occupation or investing in infrastructure for people who may be ejected.

Operational efficiency is the most consistent contribution of PPPPs to utility performance, resulting in the reduction of nonrevenue water, improvement in bill collection, and better labor productivity. PPPPs in infrastructure are normally financed on project basis. The project finance may come from a variety of sources. The main sources include equity, debt and government grants. Financing from these alternative sources have important implications for the project's overall cost, cash flow, ultimate liability on concerned parties, and claims to project incomes and assets.

To promote PPPPs, governments often provide subordinate loans to reduce default risk and thereby reduce the debt burden and improve the financial viability of the projects. Government grants can be made available to make PPP projects commercially viable, reduce the financial risks of private investors, and achieve some socially desirable objectives such as to induce growth in a backward area. Theoretically, a PPPP project is favoured only when its generated benefits/revenues exceed the total costs including the additional costs compared with a public sector project. To ensure this, government regulations guiding PPPP schemes may establish some value for money or public sector comparator (PSC) criterion. There are five main ways to compensate a private investor of a PPPP project:

• Direct charging of users
• Indirect charging of (third party) beneficiaries
• Cross-subsidization between project components
• Payment by the government (periodic fixed amount or according to use of the facility or service)
• Grants and subsidies.

Following are the main models of PPPPs.

a) Build Operate and Transfer (BOT): This is the simple and conventional PPPP model where the private partner is responsible to design, build, operate (during the contracted period) and transfer back the facility to the public sector. Role of the private sector partner is to bring the finance for the project and take the responsibility to construct and maintain it. In return, the public sector will allow it to collect revenue from the users.

b) Build-Own-Operate (BOO): This is a variant of the BOT and the difference is that the ownership of the newly built facility will rest with the private party here. The public sector partner agrees to 'purchase' the goods and services produced by the project on mutually agreed terms and conditions.

c) Build-Own-Operate-Transfer (BOOT): This is also on the lines of BOT. After the negotiated period of time, the infrastructure asset is transferred to the government or to the private operator. This approach has been used for the development of highways and ports.

d) Build-Operate-Lease-Transfer (BOLT): In this approach, the government gives a concession to a private entity to build a facility (and possibly design it as well), own the facility, lease the facility to the public sector and then at the end of the lease period transfer the ownership of the facility to the government.

e) Lease-Develop-Operate (LDO): Here, the government or the public sector entity retains ownership of the newly created infrastructure facility and receives payments in terms of a lease agreement with the private promoter.

f) Rehabilitate-Operate-Transfer (ROT): Under this approach, the governments/local bodies allow private promoters to rehabilitate and operate a facility during a concession period. After the concession period, the project is transferred back to governments/local bodies.

g) DBFO (Design, Build, Finance and Operate): In this model, the private party assumes the entire responsibility for the design, construction, finance, and operate the project for the period of concession.

h) Management contract: Here, the private promoter has the responsibility for a full range of investment, operation and maintenance functions. He has the authority to make daily management decisions under a profit-sharing or fixed-fee arrangement.

i) Service contract: This approach is less focused than the management contract. In this approach, the private promoter performs a particular operational or maintenance function for a fee over a specified period of time.

5. Solutions for Lack of Going Green

In the face of increasing challenges to groundwater abstraction for domestic and industrial processes in Mandalay area, water reuse can be an attractive option to increase efficiency and ensure sustainable supplies of water.

A variety of terms are used to describe water reuse, including water reclamation or water recycling. Wastewater is collected and conveyed to a nearby facility, where it undergoes treatment before being distributed to customers for reuse. This is commonly referred to as recycled water (or municipal recycled water). In other cases, wastewater is reused on site with little or no treatment, referred to as onsite reuse. A home may be equipped with a gray water system that collects wastewater from a clothes washer and uses it to irrigate a garden. Likewise, an office building may be equipped with a system that treats wastewater and reuses a portion for flushing toilets and other non-potable applications. The term water reuse refers broadly to wastewater that is intentionally captured and used for another beneficial purpose, such as for irrigation, industrial processes, or augmentation of drinking-water supplies. It includes onsite reuse as well as municipal recycled water.

For the increase amount of water demand over supply due to high population growth in Mandalay, new natural sources of water become scarcer and more expensive, some options are being turned to desalination and treatment and reuse of wastewater, while continuing to use older methods.

Water reuse in the textile industry

The textile industry is very water intensive. Water is used for cleaning the raw material and for many flushing steps during the whole production. Produced waste water has to be cleaned from, fat, oil, color and other chemicals, which are used during the several production steps. The cleaning process depends on the kind of wastewater and also on the amount of used water. It appears to be, that membrane filtration would be a preferable option compared to other wastewater treatment techniques because of the constant quality of effluent that is partly or almost completely softened and free of color and surfactants.

Water reuse in the paper industry

Because of the increased environmental awareness and stringent legislation the paper industry are forced to reduce their water consumption. Normally the wastewater from a paper plant is biologically treated, but the quality of the effluent may be good enough for disposal but it is not suitable for reuse as process water. One method to treat the water is membrane filtration. Another technique that can be used is the membrane bioreactor (MBR).

Water conservation in distillery factory

Alcohol distilleries are highly water intensive units generating large volumes of high strength wastewater that poses a serious environmental concern. This paper aimed at identifying options for improved water use in this sector through a case study in a local distillery. It emerged that optimization of cooling tower operation, innovative ways to reuse wastewater streams like spent lees and spent wash and employing semi-continuous/continuous fermentation could reduce water use in distilleries.

Water reuse in the food and beverage industry

The food and beverages processing industry requires a huge amount of water. One of the main problems is the amount of wastewater continuously produced in the food plants. The water is used as an ingredient, a cleaning agent, for boiling and cooling purposes, for transportation and conditioning of raw materials.

Spent process water in the food industry can be desalinated and organics can be removed so as to fulfill the requirements for water reuse. Food industry standards specify that, spent process water intended for reuse (even for cleaning purposes) must be at least of drinking quality.

6. Solutions for Climate Change Patterns

The relationship between water, energy and climate change is a significant one. That relationship is falling out of balance jeopardizing food, water and energy security. Climate change is a phenomenon that can be no longer denied as its effects have become increasingly evident. As the earth's temperature continues to rise, a significant impact on fresh water supplies can be expected. The systems used to treat and deliver public water supplies require large amount of energy produced mainly by burning coal, natural gas, oil and other fossil fuels. So, this causes climate change. In addition, bottled water leads to contribute to greenhouse gas emissions by using fuel to make plastic bottles. Therefore, it is necessary to reduce emissions, prevent climate change and protect threatened fresh water sources.

The first is mitigation using policy, technology and other actions to reduce the greenhouse gas emissions responsible for climate change. Transition to a lower-carbon economy is needed. Steps along this path will include improving energy efficiency; increasing the use of low- and zero-carbon energy sources such as wind, solar, and nuclear power; and developing carbon capture and storage technologies. The second is bolstering resilience to climate impacts making sure that businesses and communities can withstand the changes in the climate that people cannot avoid.

To minimize damage, it can only be prepared for its consequences and strive to detect and predict more accurately. The El Nino cannot be prevented. Funding is crucial in an environmental emergency like the El Nino. Preparedness is one important factor also. Of course, the drought cannot be stopped but its effects can be at least minimized. The most complete models aim to represent as wide a range of physical processes such as floods and droughts as possible. The results thus far, though by no means perfect, give a better indication of the climatic conditions that will prevail during the next one or two seasons.

7. Solutions for Problems of Groundwater Abstraction

The problem of groundwater abstraction can be solved that there are three ways to help control of groundwater levels in such a way as to avoid or at least mitigate the negative side effects of aquifer exploitation. These include:

1)Controlling the quantity of groundwater abstracted;
2) Relocating the abstraction boreholes;
3)Modifying the timing of abstraction.

Controlling the quantity of the groundwater pumped is the most important option and the only option if regional groundwater levels and subsidence are to be stabilized. The options of relocating abstraction boreholes and modifying the timing of abstraction help to stabilize water levels locally, for example to prevent saline intrusion, protect critical water supply boreholes or limit dewatering of wetlands.

Solutions to Groundwater Depletion are as follows:

1) As individuals, one of the things a difference can be done to make is to use less water for luxury purposes.
2)More comprehensive research and additional funding can help groundwater depletion.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 11,November 2017

3)One of the most effective ways to address the issue of groundwater depletion is to find alternative sources of water.
4)The extraction of groundwater should be regulated.
5)Rainwater harvesting can be a solution for problems of groundwater abstraction.
6)Rainwater Harvesting National Campaign should be seriously carried out because it can also be seen as a significant groundwater recharge process especially in the urban and built environment.
7)To reduce the excessive amount of groundwater abstractions in industries, innovative water tariff systems should be introduced to ensure both financial sustainability and affordability.
Mandalay Regional Government can establish a Water Regulatory Authority (WRA) to develop the groundwater recharge.

8. Solutions for Lack of Legal Instruments and Weakness of Groundwater Regulations

For urban water utilization, laws, acts and rules have been enacted including "THE UNDERGROUND WATER ACT [Burma Act IV, 1930]". Most of the laws are relating for urban water utilization and for ground water use, the laws are still under processing, but some are prepared to draw new concepts. In Mandalay, as groundwater is the most extracted natural resource (90% groundwater abstraction), laws, acts and regulations, for example: Groundwater Directive, Water Resources Act, Control of Pollution Act, Local Government (Water Pollution Act), Environmental Protection Act, Environmental Protection Agency Act, Environmental Act, Water Services Act, Myanmar Communities Act., etc should be enacted for groundwater users especially in both industrial sector and domestic sector.

9. Solutions for Lack of Proper Institutional Arrangement and Governance structure

Institutional arrangements characterizing governance affect how elements influence water sector performance. Capacity-building within organizations affects how ideas are generated and transmitted. Similarly, access to financial and operating information depends not only on procedures for collecting and authenticating data, but also on whether transparency is valued and implemented. The set of elements builds upon earlier approaches to the analysis of governance, and provides a comprehensive framework for characterizing the unique contexts facing infrastructure decision-makers around the world. For water resource management, governance processes determine decision making about water storage, types of water use, regulation of extraction from aquifers, regulation of discharges, and allocation between competing uses, including allocations to maintain basic environmental services. If government agencies are to play an important role in good water resources regulation and effective service delivery, it is crucial they invest in their staff, as well. This includes job training; taking advantage of the IT revolution to develop effective information systems for management and communication, including GIS-based tools; and improving office infrastructure, such as generators, filing systems, and furniture.

10. Solutions for Lack of Financial Instruments

While municipal bonds are the debt instrument of choice for utilities large enough to be able to attract capital from markets, the vast majority of water systems must rely on cash, state revolving loan funds, or other low-interest loan programs at the state and federal level. Other measures for improving distribution, such as repairing leaking distribution systems and sewer pipes, expanding central sewage systems, metering water connections, and rationing and restricting water use, can also play important roles. Water system collaboration allows capital improvement costs to be spread over more rate-payers. While collaboration can be a viable option, distance can be a deciding factor. Whichever funding option the system chooses, it is a worthwhile option for making costly improvements.

11. Solutions for Lack of Integrated Water Resources Management Professionals

The water sector should invest in recruitment, management and development of young staff, as well as put them at the forefront of design, development and implementation of current change processes.
Engineers, social scientists, farmers, accountants, plumbers, lawyers, communications experts, managers, economists, geographers – to name a few – are all involved in water management as 'water professionals'. The water training that goes with the new water culture has to be built in the entire national education systems from university courses to vocational training.
Successful examples of development of capacities of water professionals at scale have two elements in common. There is a strong national professional association that is connected to an international water professional's network. These national organizations are playing a key role in education. The second core element is the close linkage between academia and practice. To achieve this goal it is important for local universities to be part of the solution to local and regional problems. Linking science with practice, universities with public administration and utilities enables them to educate students to analyse national or local water problems and find appropriate solutions adapted to local circumstances.

Operation and maintenance of water and sanitation systems are chronically and universally under-resourced, in financial and human terms. Appropriate training, education and skills requirements to operate and maintain specific technologies need appropriate assessment to significantly benefit the sector.

IV. CONCLUSION

For implementing appropriate water pricing, the following conclusions can be set out based on this study.

1) For the development of infrastructure in water supply, broken and leakage water and wastewater systems should be repaired. For the needs of humanity, private sector investment should be encouraged to be more investment in water supply and sanitation. Water utilities will also need to practise appropriate design of system expansions/distribution and use higher quality works, materials, and equipment.

2) Water distribution system should be based on a pipe layout that is suitable and has no or less water stagnation within the pipe to avoid tuberculation, encrustation and sediment deposits. In addition, regulators and policy makers should require water utilities to do periodic water audits and regularly publish detailed water distribution system data, which can then be independently audited. It should be capable of supplying water at all the intended places with sufficient pressure head. It should be fairly water-tight as to keep losses due to leakage to be minimum.

3) The increasing block tariff (IBT) should be a potential solution of Industrial water tariff to reduce the overexploitation of groundwater and to improve recycling and reuse wastewater in order to save scarce water resources for Mandalay industrial zones.

4) Small-scale and corporate private sector participation should be cooperated to solve the lack of public-private-people-partnerships (PPPPs).

5) Domestic wastewater should be recycled as municipal recycled water and if it can only be reused on site with little or no treatment. Wastewater should be intentionally captured and used for many beneficial purposes such as for irrigation, industrial processes, and augmentation of drinking-water supplies. By reclamation of water (wastewater reuse), excessive groundwater exploitation at industries becomes reduced and sustainability of water can be achieved.

6) Changes in annual rainfall and temperature can be mitigated using policy, technology and other actions in order to reduce the greenhouse gas emissions contributed to climate change.

7) Ways to avoid or at least mitigate the negative side effects of aquifer exploitation should be taken into account as follows: the quantity of groundwater abstracted should be controlled; the abstraction boreholes should be relocated and the timing of abstraction should be modified.

8) In Mandalay, there should be enacted by laws, acts and regulations related to groundwater exploitation and groundwater users especially in various industrial sectors.

9) Government agencies play an important role in good water resources regulation and effective service delivery, they should invest in their staff for job training; advantage of the information technology (IT) revolution to develop effective information systems for management and communication, and development of water infrastructure.

10) For the development of water infrastructure, Mandalay City Development Committee should contract municipal bond and depend on loan funds or low-interest loan programs for water supply for industrial zones.

11) At the forefront of design, development and implementation of current change processes, young water professionals such as engineers, social scientists, farmers, accountants, plumbers, lawyers, communications experts, managers, economists, geographers should be invested in recruitment and integrated water resources management (IWRM).

This paper proposes the possible solutions for the challenges to industrial water pricing in Mandalay region and it is concluded that these solutions can be supported for the Myanmar National Water Policy in order that the Myanmar National Water Law can be enacted.

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