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Integrated Water Resources Management in Myanmar

Water usage and introduction to water quality criteria for lakes and rivers in Myanmar
Preliminary report

Norwegian Institute for Water Research

– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

The purpose of the report is to present some first recommendation for the development of Myanmar ecological quality criteria using the system of the EU Water Framework Directive (EU WFD) as baseline, with main focus on the characterization and classification processes. As background for the recommendations we first give an overview of the main water use categories in Myanmar. We then provide preliminary suggestions for typology criteria and indices for assessing ecological status in lakes and rivers in Myanmar. The typology factors and physico-chemical parameters are based on common used factors in the EU countries. The biological elements include phytoplankton and aquatic macrophytes for lakes, and benthic invertebrates for rivers. In this first phase we present the official and intercalibrated Norwegian indices and boundaries, and some additional indices.

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2. Nasjonalt vanndirektiv i Myanmar	2. National Water Framework Directive in Myanmar
3. Karakterisering	3. Characterisation
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Preliminary report

Preface

Water quality standards and criteria are important pillars in a nation's water quality management programme. This report presents an introduction to characterisation and classification of water quality as outlined in the EU Water Framework Directive (EU WFD). The EU WFD is used as a baseline for depicting adapted water quality criteria for Myanmar conditions. Activities leading to recommendations for adapted water quality criteria are implemented as part of the project, Integrated Water Resources Management – Institutional Building and Training, hereafter called the 'IWRM project'.

The IWRM project is a collaboration between the Norwegian Institute for Water Research (NIVA) and the Ministry of Natural Resources and Environmental Conservation (MONREC). The project is part of the Norwegian – Myanmar Bilateral Environment Programme 2015-2018, and is funded by the Norwegian Ministry of Foreign Affairs. The project leader at MONREC is U Bo Ni, director of Watershed Management Division, Forest Department, and researcher Ingrid Nesheim is the project leader at NIVA. The steering group has representatives from the Forest Department (FD), Irrigation and Water Utilization Management Department (IWUMD), the Directorate for Water Resources and Improvement of River Systems (DWIR) and NIVA. The project leaders have a close dialogue with the National Water Resources Committee in Myanmar. The development goal of the IWRM project is to make a significant and positive contribution to the implementation and functioning of Integrated Water Resources Management in Myanmar, for inland waters at the national level. The objective is to establish methods and standards for Integrated Water Resources Management and to support initiation of the implementation process.

The current report is a deliverable under output 2: 'Establishment of water quality criteria'. The report has been prepared by Marit Mjelde, Andreas Ballot, Thida Swe, Tor Erik Eriksen, and Ingrid Nesheim (NIVA) and Toe Toe Aung (MONREC).

We hope the report can be useful regarding future classification of ecological status in water bodies in Myanmar.

Oslo, 31.5.2017

Marit Mjelde

စကားချီး

နိုင်ငံတစ်ခု၏ ရေသယံဇာတများအားစီမံအုပ်ချုပ်လုပ်ကိုင်ရာတွင် ရေအရည်အသွေးဆိုင်ရာ အဆင့်အတန်းနှင့် စံများသတ်မှတ်ခြင်းသည် အရေးပါသည့် လုပ်ငန်းတစ်ရပ်ဖြစ်ပါသည်။ ဤအစီရင်ခံစာတွင် ရေအရင်းအမြစ်များ၏ အတန်းအစားနှင့် သွင်ပြင်လက္ခဏာများကို ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်အပေါ်အခြေခံ၍ သတ်မှတ်ခြင်းအားမိတ်ဆက်တင်ပြထားသည်။ မြန်မာနိုင်ငံရှိရေအရင်းအမြစ်များ၏ အရည်အသွေးစံများသတ်မှတ်ဖော်ပြနိုင်ရန်အတွက် ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်ကိုအခြေခံအဖြစ်အသုံးပြုထားသည်။ နော်ဝေနိုင်ငံ၏ ရန်ပုံငွေထောက်ပံ့မှုဖြင့် ရေသယံဇာတ ဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်းတစ်ရပ် ဆောင်ရွက်လျက်ရှိပြီး စီမံကိန်းလုပ်ငန်းများတွင် မြန်မာနိုင်ငံအတွက် ရေအရည်အသွေးဆိုင်ရာ စံများသတ်မှတ်ခြင်း လုပ်ငန်းစဉ်လည်းအပါအဝင်ဖြစ်သည်။

ရေသယံဇာတဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်းသည် နော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာနနှင့် မြန်မာနိုင်ငံ၊ သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင် ထိန်းသိမ်းရေးဝန်ကြီးဌာနတို့၏ပူးပေါင်းဆောင်ရွက်မှုလုပ်ငန်းတစ်ရပ်ဖြစ်သည်။ အဆိုပါစီမံကိန်းသည် နော်ဝေ-မြန်မာနှစ်နိုင်ငံပတ်ဝန်းကျင်ကဏ္ဍပူးပေါင်းဆောင်ရွက်မှုအစီအစဉ် (၂၀၁၅-၂၀၁၈) တွင် ပါဝင်သည့် စီမံကိန်း ၃ ခုအနက်မှ တစ်ခုဖြစ်ပြီးနော်ဝေနိုင်ငံ၊ နိုင်ငံခြားရေးဝန်ကြီးဌာနမှ ရန်ပုံငွေထောက်ပံ့ပေးသည်။ မြန်မာနိုင်ငံ၊ သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဝန်ကြီးဌာန၊ သစ်တောဦးစီးဌာနဘက်မှ ရေဝေရေလဲဒေသအုပ်ချုပ်ရေးဌာနမှ ညွှန်ကြားရေးမှူး၊ ဦးဘိုနီကစီမံကိန်း တာဝန်ခံအဖြစ်ဆောင်ရွက်ပြီးနော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာနဘက်မှ သုတေသနပညာရှင် Dr. Ingrid Nesheim က စီမံကိန်းလုပ်ငန်းခေါင်းဆောင်အဖြစ်ဆောင်ရွက်သည်။ လုပ်ငန်းများအောင်မြင်စေရန် စီမံကိန်းလုပ်ငန်းကော်မတီတစ်ရပ် ဖွဲ့စည်းဆောင်ရွက်လျက်ရှိပြီး သစ်တောဦးစီးဌာန၊ ရေအရင်းအမြစ်နှင့်မြစ်ချောင်းများဖွံ့ဖြိုးတိုးတက်ရေးဦးစီးဌာနတို့မှ တာဝန်ရှိပုဂ္ဂိုလ်များအပြင် နော်ဝေနိုင်ငံ ရေသုတေသနဌာနမှ ပညာရှင်များကအဖွဲ့ဝင်များအဖြစ်ပါဝင်ကြသည်။ စီမံကိန်းတာဝန်ခံများအနေနှင့် မြန်မာနိုင်ငံအမျိုးသားရေသယံဇာတကော်မတီနှင့်လည်း နီးကပ်စွာပူးပေါင်းဆောင်ရွက်လျက်ရှိသည်။ ရေသယံဇာတဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်း၏ ရည်ရွယ်ချက်ပန်းတိုင်မှာ နိုင်ငံ၏ရေသယံဇာတမူဘောင်ဆိုင်ရာ ညွှန်ကြားချက်များနှင့်အညီ ရေသယံဇာတများအားစီမံအုပ်ချုပ်လုပ်ကိုင်နိုင်ရန်ဖြစ်ပြီးရေတိုရည်ရွယ်ချက်မှာမြန်မာနိုင်ငံအတွင်း ဘက်စုံရေသယံဇာတစီမံခန့်ခွဲမှုဆိုင်ရာလုပ်ထုံးလုပ်နည်းနှင့်စံများရေးဆွဲသတ်မှတ်ရန်နှင့် လက်တွေ့အကောင်အထည်ဖော်မှုလုပ်ငန်းများ စတင်နိုင်ရေးအတွက် အထောက်အကူပြုနိုင်ရန်ဖြစ်သည်။

စီမံကိန်းလုပ်ငန်းစဉ် အမှတ် (၂) ဖြစ်သော"ရေအရည်အသွေးဆိုင်ရာ စံများဖော်ထုတ်သတ်မှတ်ခြင်း" ခေါင်းစဉ်အောက်မှ ဤအစီရင်ခံစာအားရေးသားဖြစ်ပေါ်ခြင်းဖြစ်ပါသည်။ ဤအစီရင်ခံစာကိုနော်ဝေပညာရှင်များဖြစ်သည့် Dr. Ingrid Nesheim၊ Tor Erik Eriksen၊ Andreas

Ballot နှင့် MaritMjelde ၊ မြန်မာနိုင်ငံမှပညာရှင်များဖြစ်ကြသည့် ဒေါ်သီတာဆွေနှင့် ဒေါက်တာတိုးတိုးအောင်တို့ကပူးပေါင်းရေးသားပြုစုခဲ့ခြင်းဖြစ်သည်။

ဤအစီရင်ခံစာသည် အနာဂတ်ကာလတွင် မြန်မာနိုင်ငံအတွင်းရှိ ရေအရင်းအမြစ်များနှင့် ပတ်သက်သည့် ပတ်ဝန်းကျင်ဆိုင်ရာအရည်အသွေးများကို အတန်းအစားခွဲခြားသတ်မှတ်ရာ၌ အထောက်အကူဖြစ်လိမ့်မည်ဟု ယုံကြည်မိပါသည်။

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Summary

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This report is one of the deliverables of the project *Integrated water resources management – Institutional building and training*, a collaboration between the Ministry of Natural Resources and Environmental Conservation (MONREC) and the Norwegian Institute for Water Research (NIVA) under the Norwegian – Myanmar Bilateral Environment Programme 2015 – 2017.

The purpose of this report is to present some preliminary recommendations for the development of a Myanmar ecological water quality criteria using the system of the EU Water Framework Directive (EU WFD) as a baseline. The aim of the EU WFD is to establish a framework for the protection of surface waters (including rivers, lakes, transitional and coastal waters) and ground waters throughout the EU territory. The main environmental objectives are to achieve and maintain good status for all surface waters and ground waters by a target date, and to prevent deterioration and ensure the conservation of high water quality where it still exists.

As background for the suggested typology criteria and indices for assessing ecological status, we have given a brief description of the biophysical and socio-economic situation and an overview of the main water use categories in Myanmar. Related to each water use category we present information about water use criteria as applied currently in Myanmar.

The report provides a schematic description of the characterisation and classification processes of water quality assessments according to the EU WFD in Europe.

The characterisation process includes identification of water bodies, typology (identification of surface body types), identification of pressures, register of protected water bodies, preliminary assessment of reference conditions and a preliminary classification of the water bodies.

The EU WFD classification scheme for water quality aims to describe the biological response due to specific pressures, e.g. elevated nutrients or hydromorphological alteration, and includes five status classes: high, good, moderate, poor and bad. 'High status' is defined as the biological, chemical and morphological conditions associated with no or very low human pressure. This condition is the same as or close to the 'reference condition', i.e. the best status achievable, and all reference water bodies should be classified as having high or good ecological status, and good chemical status. The boundary between good and moderate status is therefore the most important basis for the assessment of ecological status for natural water bodies.

The EU WFD biological water quality elements include phytoplankton, aquatic macrophytes, phytobenthos, benthic macroinvertebrates and fish. The primary producers, aquatic macrophytes and phytoplankton, are considered to be excellent indicators for ecological status assessment of lake ecosystems and slow-flowing rivers because they respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, and water level change. Phytobenthos are the most relevant primary producers in rivers, especially in fast-flowing sites, however sometimes also in lakes. Benthic macroinvertebrates constitute important links between primary producers, detrital deposits and higher trophic levels in aquatic ecosystems and are an important indicator, especially in rivers. The fish are a recommended element for both rivers and lakes. They are primarily sensitive to abstraction of water and morphological alterations.

The main focus in the EU WFD is the status of the biological elements. However, the physico-chemical elements are included as supporting quality elements and assigned to detect the main pressures for rivers and lakes; secchi depth, oxygen and nutrients indicate eutrophication pressures, pH, ANC and LAL indicate acidification, and heavy metals indicate pollution from mining etc. The hydromorphological

elements is included as another supporting quality element, and describes water flow conditions and water level regulations.

According to EU WFD, all member states are required to design monitoring programs, including surveillance monitoring, operational monitoring and investigative monitoring. Based on the results of monitoring, the water body characterisation might be refined and status assessment carried out by considering biological, chemical and hydro-morphological quality elements. Status assessment is necessary to classify the status of the water body as required by the WFD.

We provide in this report preliminary suggestions for typology criteria and indices for assessing the ecological status in lakes and rivers in Myanmar. The typology factors and physico-chemical parameters are based on common used factors in EU countries. The biological elements include phytoplankton and aquatic macrophytes for lakes, and benthic invertebrates for rivers. In this first phase, we present the official and intercalibrated Norwegian indices and boundaries, and a few additional suggestions for Myanmar water bodies.

The final classification system of ecological status in Myanmar lakes and rivers has to include indices and boundaries developed exclusively for Myanmar, based on a larger dataset from Myanmar water bodies.

A recommended monitoring programme for Myanmar lakes and rivers is suggested. In addition, we recommend giving priority to taxonomic competence building and increase the knowledge about aquatic flora and fauna and important determinants. Identification of reference conditions and establishment of data management and databases are essential.

အစီရင်ခံစာအကျဉ်းချုပ်

ဤအစီရင်ခံစာကိုနော်ဝေ - မြန်မာနှစ်နိုင်ငံပတ်ဝန်းကျင်ဆိုင်ရာ ပူးပေါင်းဆောင်ရွက်မှုအစီအစဉ် (၂၀၁၅-၂၀၁၇) တွင် ပါဝင်သောစီမံကိန်းတစ်ခုဖြစ်သည့် ရေသယံဇာတဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်းမှ ပြုစုတင်ပြခြင်း ဖြစ်ပါသည်။ အဆိုပါစီမံကိန်းကို သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင် ထိန်းသိမ်းရေးဝန်ကြီးဌာနနှင့် နော်ဝေနိုင်ငံရေသုတေသနဌာနတို့မှ ပူးပေါင်းအကောင်အထည်ဖော်ဆောင်ရွက်လျက်ရှိပါသည်။

ဤအစီရင်ခံစာ၏ ရည်ရွယ်ချက်မှာဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်ကိုအခြေခံအဖြစ်အသုံးပြု၍ မြန်မာနိုင်ငံ၏ ရေအရည်အသွေးဆိုင်ရာစံများကိုကြိုတင်အကြံပြုတင်ပြရန်ဖြစ်ပါသည်။ ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်ပြဋ္ဌာန်းရခြင်း၏ ရည်ရွယ်ချက်မှာအဖွဲ့ဝင်နိုင်ငံများ၏နယ်နိမိတ်အဝန်းအဝိုင်းအတွင်းရှိမြေပေါ် (မြစ်၊ ချောင်း၊ ရေကန်နှင့် ပင်လယ်ကမ်းရိုးတန်းဒေသရေချိုရေငံစပ်ဇရိယာများရှိ ရေအရင်းအမြစ်များအပါအဝင်) နှင့် မြေအောက်ရေအရင်းအမြစ်များအားထိန်းသိမ်းကာကွယ်နိုင်ရန်ဖြစ်ပါသည်။ သတ်မှတ်ကာလအတွင်းဖော်ပြပါ ရေအရင်းအမြစ်များ၏ပတ်ဝန်းကျင်ဆိုင်ရာရေအရည်အသွေးအားကောင်းမွန်သည့်အနေအထားသို့ ပြန်လည်ထိန်းသိမ်းထားရန်နှင့် လက်ရှိကောင်းမွန်လျက်ရှိသောရေအရည်အသွေးမှ ယိုယွင်းလျော့နည်းသွားခြင်းမရှိအောင် ကြိုတင်ကာကွယ်ထားရန်ဖြစ်သည်။

ဤအစီရင်ခံစာတွင် ရေအရင်းအမြစ်များ၏ ပတ်ဝန်းကျင်ဆိုင်ရာအရည်အသွေးကို စံချိန်စံညွှန်းများနှင့်အညီဆန်းစစ်ရာတွင် အခြေခံဖြစ်သည့် မြန်မာနိုင်ငံ၏ဇီဝရူပနှင့် လူမှုစီးပွားရေးဆိုင်ရာအခြေအနေနှင့် ရေအသုံးချမှုပုံစံအမျိုးမျိုးကိုလည်းအကျဉ်းချုပ်ဖော်ပြထားသည်။ ရေအသုံးချမှုအမျိုးအစားအလိုက် မြန်မာနိုင်ငံတွင် လက်ရှိအသုံးပြုလျက်ရှိသော ရေအရည်အသွေးတိုင်းတာသည့်စံနှင့်အညွှန်းများကိုလည်းတင်ပြထားသည်။

ဥရောပသမဂ္ဂ၏ရေသယံဇာတမူဘောင်နှင့်အညီရေအရည်အသွေးဆန်းစစ်မှုလုပ်ငန်းစဉ်တွင်အပါအဝင်ဖြစ်သည့် ရေအရင်းအမြစ်များ၏ သွင်ပြင်လက္ခဏာဖော်ထုတ်ခြင်းနှင့် အမျိုးအစားခွဲခြားခြင်းတို့ကိုလည်းအစီရင်ခံစာတွင် ဇယားများဖြင့်ဖော်ပြထားသည်။

ရေအရင်းအမြစ်၏ သွင်ပြင်လက္ခဏာဖော်ထုတ်ခြင်းလုပ်ငန်းစဉ်တွင် ရေအရင်းအမြစ်များတည်ရှိရာနေရာအမျိုးမျိုးနှင့် တည်ရှိမှုအနေအထားများအားဖော်ထုတ်ခြင်း၊ ၎င်းတို့အပေါ်တွင်ကျရောက်နေသောဖိအားများအားဆန်းစစ်ခြင်း၊ ထိန်းသိမ်းကာကွယ်ထားသည့် ရေအရင်းအမြစ်များဖော်ထုတ်ခြင်း၊ ၎င်းတို့၏ အခြေအနေအားပဏာမဆန်းစစ်ခြင်းနှင့် အမျိုးအစားခွဲခြားခြင်းစသည့်လုပ်ငန်းများပါဝင်သည်။ ဥရောပသမဂ္ဂ၏ရေသယံဇာတမူဘောင်နှင့်အညီ ရေအရင်းအမြစ်အမျိုးအစားခွဲခြားမှုဇယားရေးဆွဲရခြင်း၏ ရည်ရွယ်ချက်မှာ ရေအရင်းအမြစ်တစ်ခုခုအပေါ်ကျရောက်နေသည့် ဖိအားအမျိုးအစားအလိုက် (ဥပမာ- ရေအတွင်းအာဟာရဓါတ် များပြားလာမှု

သို့မဟုတ် ရေထုဖွဲ့စည်းပုံပြောင်းလဲမှုတို့အပေါ်တွင်) ဇီဝဗေဒဆိုင်ရာတုံ့ပြန်မှုကို ဖော်ပြနိုင်ရန်ဖြစ်သည်။ တုံ့ပြန်မှုအလိုက် ရေသယံဇာတ၏ အရည်အသွေးအားအလွန်ကောင်း၊ ကောင်း၊ သင့်၊ ညံ့နှင့် အလွန်ညံ့ဟူ၍ အမျိုးအစား ၅ မျိုးခွဲခြားထားသည်။ အလွန်ကောင်းဟုသတ်မှတ်ခံရပါက ထိုရေအရင်းအမြစ်၏ ဇီဝ၊ ဓါတုနှင့် ဖွဲ့စည်းပုံအနေအထားများအပေါ်တွင် လူကြောင့်ဖြစ်သောဖိအားများ မရှိသလောက်နည်းပါးသေးသည် (သို့မဟုတ်) လုံးဝမရှိသေးဟုဆိုနိုင်သည်။ တစ်နည်းအားဖြင့် အဆိုပါအနေအထားသည် မိမိတို့လိုချင်သည့်အနေအထား (သို့မဟုတ်) ထိန်းသိမ်းကာကွယ်ရာတွင် ရည်ညွှန်းဦးတည်ရမည့် အရည်အသွေးသတ်မှတ်ချက်ဟု ဆိုနိုင်သည်။ အလွန်ကောင်း အနေအထားသည် ရေအရင်းအမြစ်တစ်ခု၏ ဂေဟစနစ်အနေအထားနှင့် ဓါတုအနေအထားများ ကောင်းသည်ဟုလည်းဆိုနိုင်သည်။ သဘာဝရေအရင်းအမြစ်များ၏ ဂေဟအခြေအနေအားဆန်းစစ်ရာတွင် သင့်အနေအထားနှင့် အလွန်ကောင်းအနေအထားတို့အကြားတွင် ရှိနေရန်အလွန်အရေးကြီးသည်။

ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်နှင့်အညီရေအရင်းအမြစ်များ၏ ဇီဝအခြေအနေကို ဆန်းစစ်ရာတွင် ငါးများအပါအဝင် phytoplankton, aquatic macrophytes, phytobenthos, benthic macroinvertebrates တို့ကိုအခြေခံ၍ဆောင်ရွက်သည်။ ရေကန်များနှင့် ရေစီးဆင်းမှုနှေးကွေးသည့် မြစ်တို့၏ ဂေဟစနစ်များအားဆန်းစစ်ရာတွင် primary producer များဖြစ် သော aquatic macrophyte များနှင့် phytoplankton များ၏အနေအထားများကိုအရေးပါသည့် ညွှန်းကိန်းများအဖြစ် အသုံးပြုကြသည်။ အကြောင်းရင်းမှာ ၎င်းတို့သည်ရေတွင် အာဟာရဓါတ်များ တိုးပွားလာမှု၊ အလင်းရောင်ရရှိမှု၊ ဓါတုအဆိပ်များပျော်ဝင်မှု၊ သတ္တုဓါတ်များတိုးပွားမှု၊ ပိုးသတ်ဆေးများပါဝင်မှု၊ ရေညစ်ညမ်းမှုနှင့် ရေထုဖွဲ့စည်းပုံပြောင်းလဲမှုစသည်တို့ကို သိသာစွာတုံ့ပြန်နိုင်မှုကြောင့်ဖြစ်သည်။ benthic macroinvertebrates ကိုအထူးသဖြင့် မြစ်များ၏ဇီဝအနေအထားအား ဆန်းစစ်ရာတွင်အသုံးပြုကြသည်။ ၎င်းတို့သည် primary producer များ၊ နုံးအနည်များနှင့် ရေသတ္တဝါအကြီးစားများတည်ရှိမှုတို့နှင့် ဆက်နွယ်ရှင်သန်နေသောကြောင့်ဖြစ်သည်။ ကန်များနှင့် မြစ်များနှစ်မျိုးလုံး၏ ရေအရည်အသွေးအားဆန်းစစ်ရာတွင်ငါးများ၏ အနေအထားကို အညွှန်းကိန်းအဖြစ်သုံးကြခြင်းမှာ ၎င်းတို့သည် ရေထုတ်ယူသုံးစွဲမှုနှင့်ရေထုအနေအထား ပြောင်းလဲမှုတို့အပေါ်တွင် မူတည်၍ တုံ့ပြန်ပြောင်းလဲမှုရှိသောကြောင့်ဖြစ်သည်။

ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်အရ ရေသယံဇာတများ၏ အရည်အသွေးဆန်းစစ်ရာတွင် ဇီဝဗေဒကိုအခြေခံ၍ ဆောင်ရွက်သည်။ သို့သော်လည်းရေကန်နှင့် မြစ်ချောင်းများအတွင်းရှိရေ၏အရည်အသွေးကိုဆန်းစစ်ရာတွင် ရေ၏ရူပဓါတုဆိုင်ရာအခြေခံများကိုလည်း ဖြည့်စွက်အသုံးပြုသည်။ အောက်ဆီဂျင်နှင့် အာဟာရဓါတ်များပါဝင်မှုသည် eutrophication pressure ရှိနေမှုကို ညွှန်ပြနိုင်ပြီး pH ၊ ANC နှင့် LAL တို့သည် ရေတွင်အက်စစ်ဓါတ်ပါဝင်မှုကို ညွှန်ပြနိုင်သည်။ Heavy metals များပါဝင်မှုကသတ္တုလုပ်ငန်းများကြောင့် ရေထုညစ်ညမ်းမှုဖြစ်နေကြောင်းကို

ညွှန်ပြနိုင်သည်။ Hydromophological elements များဖြင့် ရေစီးဆင်းမှုအခြေအနေနှင့် ရေမျက်နှာပြင်ပြောင်းလဲမှုကို ညွှန်ပြနိုင်သည်။

ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင်နှင့်အညီအဖွဲ့ဝင်နိုင်ငံများသည် Surveillance Monitoring၊ Operational Monitoring နှင့် Investigative Monitoring များပါဝင် သော Monitoring အစီအစဉ်ကိုရေးဆွဲဆောင်ရွက်ရသည်။ Monitoring လုပ်ငန်းမှ ရရှိသောဇီဝဓါတုနှင့် Hydromophological အချက်အလက်များကိုအခြေခံ၍ ရေအရင်းမြစ်များ၏ သွင်ပြင်လက္ခဏာ များကိုပြန်လည်ပြင်ဆင်သတ်မှတ်ခြင်းနှင့် အဆင့်အတန်းဆန်းစစ်ခြင်းတို့ကိုဆောင်ရွက်သည်။ အဆင့်အတန်းသတ်မှတ်ခြင်း ဥရောပသမဂ္ဂရေသယံဇာတမူဘောင်တွင် ပြဋ္ဌာန်းချက်အရ ရေအရင်း အမြစ်များ၏ အဆင့်အတန်းသတ်မှတ်ခြင်းကိုဆောင်ရွက်ရန်လိုအပ်သည်။

ဤအစီရင်ခံစာတွင် မြန်မာနိုင်ငံအတွင်းရှိမြစ်၊ ချောင်းနှင့် ရေကန်များအတွင်းရှိ ရေအရည် အသွေးကိုဆန်းစစ်ရာတွင် အသုံးပြုသင့်သည့် စံနှင့်အညွှန်းများကို အကြံပြုတင်ပြထားပါသည်။ အစီရင်ခံစာပါ ရေအရည်အသွေးအဆင့်ပြကိန်းအမျိုးအစားများနှင့် ရေတွင်ရှိသင့်သည့် ရူပဓါတု ကန့်သတ်ချက်များကို ဥရောပသမဂ္ဂနိုင်ငံများတွင်လည်းအသုံးပြုလျက်ရှိသည်။ ဇီဝဗေဒအခြေခံများ ဖြစ်သော Phytoplanktonနှင့် Aquatic macrophytes တို့ကိုရေကန်များအတွင်းရှိ ရေအရည် အသွေးကိုတိုင်းရာတွင်လည်းကောင်း၊ Benthic macroinvertebrates များကိုရေကန်အတွင်းရှိ ရေအရည်အသွေးကိုတိုင်းတာရာတွင် လည်းကောင်းအသုံးပြုသည်။ ဤစီမံကိန်းပထမပိုင်း (First Phase) တွင် နော်ဝေနိုင်ငံ၌ တရားဝင်နှင့်လက်တွေ့တိုင်းတာ အသုံးပြုလျှက်ရှိသော အညွှန်းနှင့် သတ်မှတ်ချက်များကိုဤအစီရင်ခံစာတွင် တင်ပြထားပြီးမြန်မာ့ရေအရင်းအမြစ်များအတွက် အသုံး ပြုသင့်သောအညွှန်းနှင့် သတ်မှတ်ချက်များကိုလည်းဖော်ပြထားသည်။

မြန်မာနိုင်ငံအတွင်းရှိရေအရင်းအမြစ်များနှင့်ဆိုင်သည့် သတင်းအချက်အလက်များ စုစည်း ရရှိပြီးပါက ၎င်းတို့အပေါ်တွင်အခြေခံ၍ ပြုစုထားသည့် ရေအရည်အသွေးဆိုင်ရာ စံနှင့်သတ်မှတ် ချက်များကိုအသုံးပြု၍ နိုင်ငံအတွင်းရှိရေကန်နှင့်မြစ်ချောင်းများ၏ ဂေဟအခြေအနေကို အကဲဖြတ် သည့် စနစ်တစ်ခုကိုဖော်ထုတ်နိုင်မည် ဖြစ်ပါသည်။ မြန်မာနိုင်ငံအတွင်းရှိရေကန်နှင့် မြစ်ချောင်းများ အတွင်းရှိရေသယံဇာတများကိုဆန်းစစ်ခြင်းအစီအစဉ်အားအကြံပြုတင်ပြထားပြီးဖြစ်ပါသည်။ ထို့ အပြင် မြန်မာ့ရေသယံဇာတပညာရှင်များအား ရေတွင်နေသက်ရှိများကို သိပ္ပံနည်းကျ အမျိုးအစား ခွဲခြားခြင်းနည်းပညာတိုးတက်စေရန်နှင့် ရေတွင် ပေါက်ရောက်ရှင်သန်သည့် အပင်၊ တိရစ္ဆာန်တို့နှင့် ပတ်သက်သည့်ဗဟုသုတပွားများလာစေရေး တို့ကိုဦးစားပေးအဖြစ် ဆောင်ရွက်ရန်လည်းအကြံပြု ထားပြီးဖြစ်ပါသည်။ ရေသယံဇာတဆိုင်ရာ သတင်းအချက်အလက်စုစည်းခြင်းနှင့်စီမံခန့်ခွဲခြင်း၊ ရေသယံဇာတများ၏ လက်ရှိအခြေအနေအား ဆန်းစစ်ဖော်ထုတ်ခြင်းလုပ်ငန်းများတွင်လည်း မြန်မာပညာရှင်များ၏ ကျွမ်းကျင်မှုကို မြှင့်တင်ပေး ရန်လိုအပ်လျက်ရှိပါသည်။

၂၀၁၇ ခုနှစ်တွင်ရေးသားသည်။

ရေးသားပြုစုသူများ ။ ။ Marit Mjelde ၊ Andreas Ballot ၊ Thida Swe ၊ Tor Erik Eriksenနှင့် Dr. Ingrid Nesheim

ထုတ်ဝေသူ ။ ။ နော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာန (Norwegian Institute for Water Research၊ ISBN 978- 82- 577 - 6898-0

1. Introduction

Water quality standards are laws or regulations being adopted to enhance water quality, and to protect human health and ecosystems. Water quality criteria describe the quality of water that will support a designated use and may be expressed as either numeric limits or in a narrative statement.

Standards may refer to quality criteria for a specific type of water use, but may also apply to emission standards, that is, quantitative limits on the permissible amount of specific pollutants that may be released from specific sources over specific timeframes. Assessing water quality in a water body is relevant from two viewpoints: 1. To describe the degree of pollution or degree of the human impact, and 2. The suitability of a waterbody for specific usage. The EU Water Framework Directive uses an ecosystem-based approach for characterising and classifying water quality using ecological water quality criteria. In the EU WFD, water quality criteria refer to three water quality elements: biological, chemical, and hydro-morphological.

The National Water Resources Committee (Myanmar) adopted the National Water Framework Directive (NWFD) in 2014. The NWFD presents seven principles for achieving good ecological status for the water quality elements in Myanmar water bodies and river basins (Appendix B). We want to highlight the following two principles related to the topic of this report:

NWFD, Principle (1): Good status for all ground water and surface water. The Directive aims for 'good status, i.e. clean and sufficiently stored' for all ground water and surface water (rivers, lakes, transitional waters, and coastal waters) in Myanmar.

NWFD, Principle (3): The ecological and chemical status of surface waters should be assessed according to the following criteria:

- *Biological quality (fish, benthic invertebrates, aquatic flora)*
- *Hydro-morphological quality such as status of river banks, river bank structures, river training works, river continuity or substrate of the river bed*
- *Physical-chemical quality such as temperature, oxygenation and nutrient conditions*
- *Chemical quality that refers to environmental quality standards for river basin specific pollutants. These standards specify maximum concentrations for specific water pollutants. If even one such concentration is exceeded, the water body will not be classed as having a 'good ecological status'.*

The purpose of this report is to present some preliminary recommendations for the development of a Myanmar ecological quality criteria, using the system of the EU WFD as a baseline. The report provides a schematic description of the characterisation and classification processes of water quality assessments according to the EU WFD in Europe, and gives preliminary suggestions for typology criteria and indices for assessing the ecological status in lakes and rivers in Myanmar. Along with secondary and mostly grey literature, with this report we aim to form the baseline for assessing preliminary ecological status in Inlay Lake and Bago River.
When providing recommendations concerning the characterisation and classification in Myanmar, we primarily refer to the EU Water Framework Directive. Experiences of classification systems and biological status assessments from elsewhere, such as from South Africa and other Asian countries, in addition to a workshop with Myanmar experts, will be used as input and included in a final report on ecological water quality criteria in Myanmar to be published in 2018.

This report is one of the deliverables[1]of the project *Integrated water resources management – Institutional building and training*, a collaboration between the Ministry of Natural Resources and Environmental Conservation (MONREC, previously MOECAF) and the Norwegian Institute for Water Research (NIVA) under the Norwegian – Myanmar Bilateral Environment Programme 2015 – 2017. This report refers to the project deliverable, "Framework notes and recommendations for Integrated Water Resource management in

[1] The deliverable is compilation of the work related to activities 4.2-4.7.

Myanmar" by Nesheim and Platjouw (2016), where an overall presentation of the EU WFD and other IWRM frameworks along with recommendations for IWRM in Myanmar are given.

This report provides a short overview of water use in Myanmar and related water use requirements in Chapter 2 to set the context with regard to water use, pressures, water availability and water quality standards. In Chapter 3, characterisation and classification of water bodies to determine ecological status according to the EU WFD are described, and in Chapter 4, The EU WFD is used as an example for characterisation, classification and monitoring of water bodies in Myanmar. Chapter 5 provides an overview of biological and chemical status assessment in other Asian countries, and Chapter 6 lists some preliminary recommendations.

2. Water usage in Myanmar

2.1 Introduction

Water is the key to all life and hence essential to protect for enabling sustainable development. Water is used to sustain livelihoods, as a source for economic development, and for recreational activities. Water supports the full range of human activities and is the basis of the global ecosystem. To help identify requirements for healthy use of water, international and national standards and guidelines have been produced e.g., Guidelines for drinking water quality (WHO, 2011), Water Quality for Agriculture (FAO, 1995). International guidelines have been produced to recommend international standards and as a source of information on water quality and human and environmental health. Countries that have not yet developed or specified national standards typically refer to international guidelines produced by UN institutions. Two types of standards are considered when discussing water quality; standards for specific types of water use, and emission standards referring to quantitative limits on the permissible amount of specific pollutants that may be released from specific sources over specific timeframes. National standards commonly form a legal basis for controlling pollution entering the waters from a variety of sources (e.g., industrial facilities, wastewater, wastewater treatment plants, and stormwater drains, while international standards only serve as guidelines.

The purpose of this chapter is to provide a Myanmar country context to the main topic of the report, namely to introduce ecological water quality criteria in Myanmar, including preliminary recommendations. In the following chapter, we first briefly describe the biophysical and socio-economic situation (Section 2.2), and then describe the main water use categories in Myanmar (Section 2.3). These water use categories were identified from interviews with experts in Myanmar, but they also reflect typical water use categories on an international level. Categories are presented with a brief reference to magnitude and environmental impact. We present information about water use criteria as applied currently in Myanmar, in relation to each water use category. If water use criteria for a specific water use is not available in Myanmar, where relevant we refer to international criteria.

2.2 Myanmar context

Myanmar is the largest country in South East Asia, consisting of 676 590 km^2 including mountainous areas, lowlands, deltas, and coastal areas. Mountains rise to more than 5 800 m above sea level in Kachin State in the north, and over 2000 m in Shan, Rakhine and Chin States. The long coastline runs from the Andaman Sea to the east and along the Bay of Bengal to the west (Figure 2.1). The climate is seasonal, with a cold season from November to January, followed by a dry season from February to April and then a wet season from May to October. About ninety percent of the annual rainfall is received from mid-May to mid-October, varying geographically, from around 5000 mm in the southern delta area, to 750 mm in the central dry-land area (Figure 2.2). The country has vast water resources; however, the resources are both spatially and temporally unevenly distributed following seasonal patterns. The internal total renewable water resources in Myanmar are estimated to be about 1000 km^3 per year (FAO 2014). This contains surface water (lakes and rivers) and groundwater (including river base flow). In total, there are four major rivers, including the Ayeyarwady, Chindwin, Sittaung and Thanlwin River, five river basins where three of these are international basins, and two coastal areas, Rakhine State and Tanintharyi State. The largest international river is Thanlwin, covering about 18% of the territory, while the source of the river is in China.

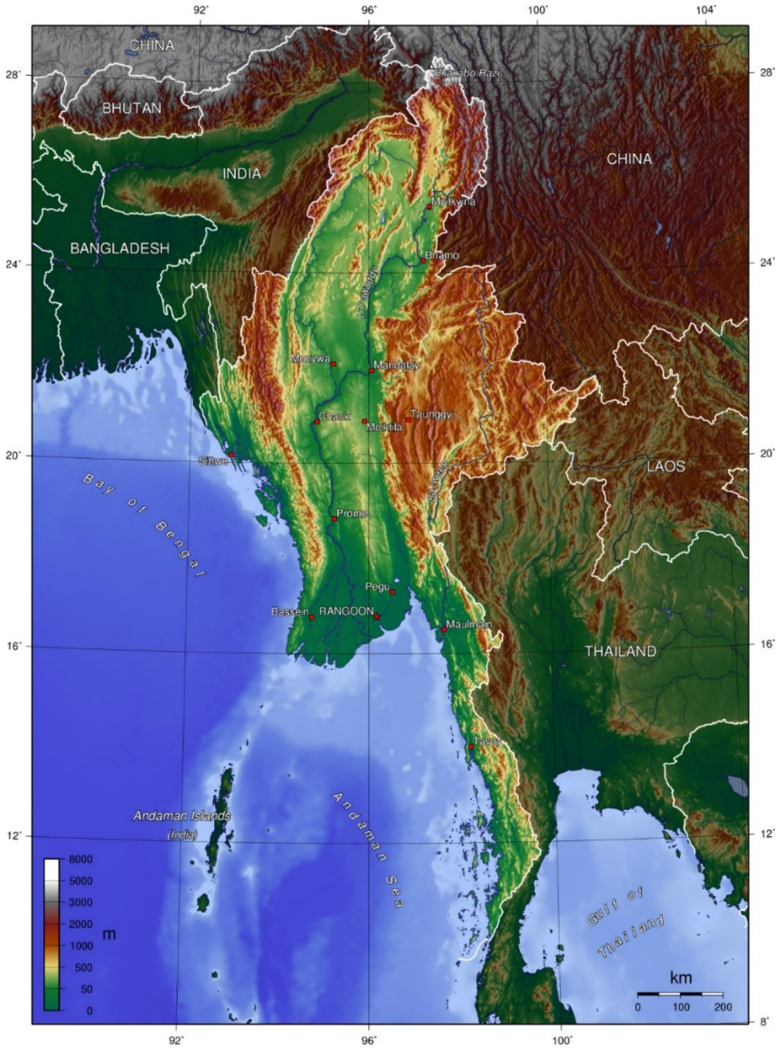

Figure 2.1. The topographic map of Myanmar shows the long coastline, deltas, lowlands and large mountainous areas (Source: https://commons.wikimedia.org/wiki/Atlas_of_Myanmar).

The Myanmar population is 51 million multi-ethnic people (census April 2014), which live in 14 Regions and States[2]. Among these, the Bamar account for approximately two-thirds, the Shan and Kayin populations each account for approximately 10 percent, while the Wa, Chin, Akha, Kachin, Kayar (Karenni), Lahu, Kokang, Tavoyan, Pa-Oh, Naga, Mon, Kayan, Rakhine (Arakan), Palaung, Danu, Indian, and Chinese population each make up about five percent in total (Wikipedia, retrieved May 2017). Overall population density is 70 inhabitants per km^2, but the density varies greatly from high density in the central areas to relatively low density in the mountainous areas and in the border states. Socio-economically, approximately 70 percent of the population live in rural areas and are subsistence farmers. Most of the water usage in Myanmar is from river reservoirs, and rivers, while groundwater usage has been more limited. Total water withdrawal in the year 2000 was $33km^3$, and most of the water usage is for irrigation of crops, see table 2.1 (FAO 2014). Groundwater is used for domestic purposes in cities, Yangon, Mandalay and Nay Pyi Taw in combination with water from reservoirs.

[2] Myanmar covers seven Regions and seven States which are constitutionally equivalent.

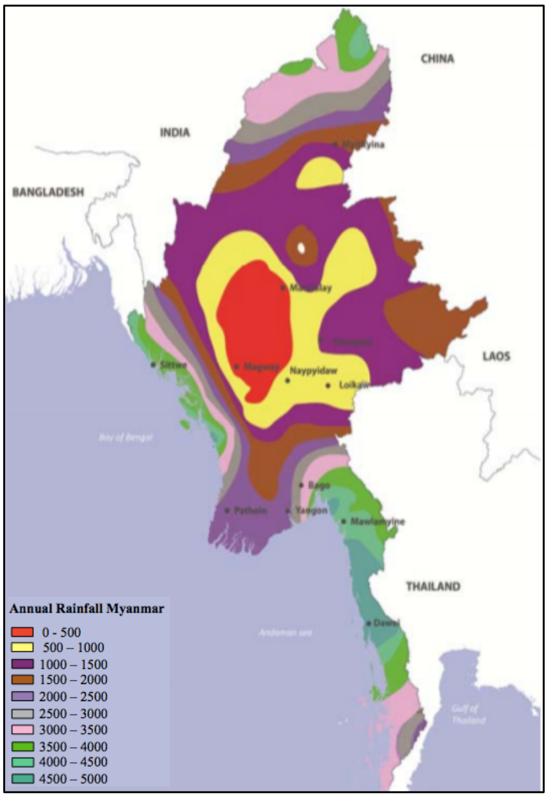

Figure 2.2. Left: States and regions in Myanmar (source: Facts.co). Right: Annual rainfall in Myanmar (Source: copied from presentation by Department of Meteorology and Hydrology, Ministry of Transport and Communications).

Table 2.1. Water withdrawal in Myanmar in 2000 (Source: adapted from FAO 2014)

Total and sector water withdrawal	amount (m3/year)	percent
Total withdrawal from surface water and groundwater	33 230 million	
Irrigation and livestock	29 575 million	89
Municipalities	3323	10
Industry	332	1
per inhabitant	33 230	2.8

Land cover in Myanmar includes forests (48 %), agricultural areas (19 %) and other land areas (33 %) (FAO, 2014). Most agricultural area is cultivated with rain-fed rice; however, to provide for cultivation of two to three crop cycles per year irrigated areas are increasing, with up to 27 percent of total cultivated area in recent years (Irrigation Department 2014). In 2014, 240 dams, 327 river pumping stations and 12,258 groundwater irrigation projects had been completed, while several more are planned. The delta area, including the lower parts of the Ayeyarwady and Bago basins are densely cultivated areas. In addition to irrigation, the rivers are important for transportation of agricultural products, for navigation between villages, and as sources for hydro-electric power. Water for hydropower is of significant interest, but only 46330.55 MW of an estimated potential of more than 100 000 MW from the country's rivers has been developed (Ministry of Electric Power, 2015). According to the Department of Hydropower Development Implementation, (2015) it is estimated that maximum power demand in 2030 will vary, from the minimum of around 9,100 MW to around maximum of 14,542 MW (Ministry of Electric Power, 2015). Myanmar's hydropower development activities and plans include five-year short-term plans and a 30-year strategic plan. Total planned hydropower development in Myanmar is 14,600 MW, which involves generating power for domestic use and exporting to neighbouring countries, especially China, Thailand and India. Appendix E lists hydropower plants in operation and planned hydropower plants.

Other land use activities include mining and logging activities along the upper reaches of river basins that cause erosion and sedimentation (Haruyama and Hlaing 2003). Mining activities cause water pollution from discharged mine effluents, and seepage from tailings and waste-rock impoundments.

Table 2.2. Hydropower Resources (2009), adapted from presentation by Director: U Min Khaing (Department of Hydropower implementation, Ministry of Electric Power, Jan 2015, Kempinski Hotel, NPT)

	Potential hydropower plants, number	Total capacity
< 10 MW	210	231.25 MW
10 MW < X > 50 MW	32	806.3 MW
> 50MW	60	45293.0 MW
Total	302	46330.55 MW

Three main ministries, the Ministry of Agriculture, Livestock and Irrigation (MOALI, the Ministry of Transport and Communications (MOTC) and the Ministry of Natural Resources and Environmental Conservation (MONREC) are responsible for water management, and a high number of departments and agencies work with water and water-related issues. The broad picture of water management refers to MONREC being responsible for overall environmental matters and therefore also for water ecosystems, MOALI is responsible for irrigation water quality in dams and reservoirs, and MOTC is responsible for water quality of large rivers. Yet the picture is fragmented and there is a lack of transparency regarding responsibilities and decision-making.

2.2.1 Water use categories and water use criteria

Rivers and lakes contain inorganic and organic substances, substances which are necessary for supporting life of organisms, such as nitrogen, phosphorus and iron, but, also hazardous substances, such as arsenic and mercury which cause health problems. Other harmful substances that may occur in water are parasites, infectious microorganisms, and organic and inorganic pollutants (e.g. pesticides). For this reason, water quality standards are provided to ensure safe use of water for different purposes.

Water use criteria have been developed for most types of water uses. Based on a literature review (FAO, 2014; South Africa's Water Quality Guidelines 1998; World Bank 1999, WHO 2011) and interviews with Myanmar authorities and stakeholders, the below six water use categories have been identified for Myanmar. For each of these we provide information in the section below on current water use and information of water use criteria and standards as used in Myanmar today. We provide international references to international water quality standards and criteria where relevant.

- public drinking water
- domestic uses, bathing and washing
- irrigation of agriculture
- use in aquaculture, including for propagation of fish, shellfish and wildlife
- recreational usage
- industrial use

Public drinking water in Myanmar

From 2005 to 2010 overall access to safe drinking water in Myanmar increased from 63% to 69%. There is still a big difference between the urban and rural context and access to safe drinking water for the poor versus the wealthy differs. 81% of the urban population had access to safe drinking water in 2010, versus only 65% of rural dwellers (MNPED et al. 2011). The majority, 71 % of Myanmar's population obtain drinking water from groundwater sources. Access to a piped supply of safe drinking water is not equally accessible, and even at places with a piped system, water is not necessarily clean. Storage of water in reservoirs, community ponds, and large drums for the collection of rainwater for domestic and drinking water is common in rural areas. Groundwater is increasingly being used for drinking water, although concerns are raised whether high concentrations of arsenic and fluoride concentrations in drinking water from natural geology and bedrock can cause severe problems for urban and rural areas. A survey by UNICEF, the Ministry of Health and the Ministry of Border Region Municipal on arsenic contamination in drinking water, "showed arsenic at levels above 10 ppb (parts per billion) – the level set as permissible by the World Health Organisation (WHO) – in the states and divisions of all 12 regions" (Mizzima News, 2010). The highest level of arsenic in water was found in Rakhine State, Ayeyarwaddy and Bago Region.

Myanmar drinking water standard

A draft Myanmar drinking water standard has been produced (Appendix D). This draft version (2014) is a revised version that is currently operational. It includes standards for bacteriological quality, physical quality, chemical quality of health significance, and chemical quality.

The WHO drinking water standard

Water quantity: WHO (2006), has presented guidelines on water intake volumes; adult males require on average 2.9 litres, 2, 2 litres for adult females, and 1 litre per day for children. Note that daily intake increases with temperature - up to 4.5 litres per day, and in addition, specific population groups have particular hydration requirements, including young children, women in pregnancy or lactation, the elderly, terminally ill and athletes (Magara and Tachibana, 2000)

Water Quality: WHO (2006) considers that access to safe drinking water is a basic human right and an essential component of health protection. The guideline's third edition replaces previous editions (1983–1984, 1993–1997 and addenda in 1998, 1999 and 2002) and previous International Standards (1958, 1963 and 1971). The Guidelines are representative of the UN's stance on issues of drinking-water quality and health, such as UN-Water[3]**.** Guidelines for Drinking-Water Quality explains requirements to ensure drinking-water safety including minimum procedures, including for example, source protection, specific guideline values, and includes fact sheets on significant microbial and chemical hazards. This takes into account important developments in microbial risk assessment and its linkages to risk management.

Domestic uses, bathing and washing

The second largest use of water in Myanmar (after agriculture) is domestic usage, including sanitation and drinking water. According to FAO (2014), about 10 % is used for domestic purposes (Table 2.1). No specific guidelines exist in Myanmar on domestic water use, although please refer to the previous paragraph on the drinking water usage and drinking water standards in Myanmar.

WHO guidelines on domestic use of water

WHO defines in its Guideline for Drinking-Water Quality, domestic water as being "water used for all usual domestic purposes including consumption, bathing and food preparation" (WHO, 1993; 2002). This implies that adequate water requirements apply across all uses and not solely in relation to drinking water.

Water quantity. A minimum of 7.5 litres per capita per day will meet the requirements of most people under most conditions. This volume does not account for health and well-being-related demands outside of normal domestic use, such as water use in health care facilities, food production, economic activity, or amenity use.

The need for domestic water supplies for basic health protection exceeds the minimum required for consumption (drinking and cooking) and additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry. Poor hygiene may in part be caused by a lack of sufficient quantity of domestic water - a situation that may cause diarrhoeal and other diseases (Prüss-Ustün et al. 2014).

Water quality. Water provided for direct consumption and ingestion via food should be of a quality that does not represent a significant risk to human health. A 'zero-risk' scenario for public supplies is not achievable and evidence points to the need to define tolerable risks, commonly based on estimates of

[3] UN-Water coordinates amongst the 24 UN agencies and programmes concerned with water

numbers of excess cases per defined population size. This approach underpins much risk assessment thinking within the water sector for both microbial and chemical contaminants (Fewtrell and Bartram, 2001; WHO, 1996).

Irrigation of agriculture

In Myanmar, the largest water use category is irrigation (Table 2.1). A total area of ca. 18 400 km^2 is irrigated in Myanmar, mainly in the central dry zone which consists of large parts of Mandalay, Magway and lower Sagaing divisions, along with Rakhine Region and Shan State. Irrigation is usually supplied by water diversion with weirs, dams and tanks and in recent years the substantial infrastructure development of water pumps has occurred. In the central dry areas, approximately 31 % of irrigation water is supplied by canals, 11 % by tanks, 4 % by tube wells and 8 % by other irrigation methods. The seasonal rainfall pattern and accompanying river flow largely determines the annual irrigation budget. In the water-scarce central dry zone, 546 km^2 of the total irrigated landscape is based on groundwater. Groundwater withdrawal is done with diesel pumps (77%), electric pumps (15%) and artesian wells (8%). To estimate the pressure of irrigation on the available water resources, an assessment must be made of both the water requirement of irrigation, and the actual withdrawal of irrigation water. Irrigation water requirement depends on the crop water requirement and the water naturally available to the crops (effective precipitation, soil moisture, etc.).

During the dry season when the demand for irrigation is at its highest, saltwater intrusion is a problem in coastal areas causing severe issues for water security. For irrigation water quality criteria Myanmar authorities refer to the FAO guideline 'Water Quality for Agriculture' (FAO 1985).

<u>The FAO Water quality for agriculture</u>

The FAO guideline for evaluation of water quality is presented as a field guide for evaluating the suitability of water for irrigation[4]. The field guide includes suggestions for obtaining maximum utilisation of an existing or potential water supply. The Guideline identify possible restrictions in use related to values of: 1) salinity, 2) rate of water infiltration into the soil, 3) a specific ion toxicity, or 4) to some other miscellaneous effects (see Appendix C). The guidelines emphasise the long-term influence of water quality on crop production, soil conditions and farm management. Discussions and examples are given along with possible management alternatives to deal with these potential problems.

Aquaculture including propagation of fish and shellfish

Aquaculture is a growing industry in Myanmar with fish cultivation, including artificial hatching, requiring large amounts of water. An appropriate level of water quality must be secured in order not to cause any adverse effect on cultivated fish, or any health risk to people who consume the cultivated fish. Present aquaculture includes fish, prawns and shrimps in the freshwater rivers and brackish waters in the coastal areas. During the last decades, the production has increased substantially in inland waters, from c. 3000 tonnes in 1980s to ca. 820 000 tonnes in 2012 (FAO 2016). While the industry is still growing, the negative effects on groundwater and freshwaters mainly refers to an increased level of nutrients.

There are no identified water quality criteria for aquaculture in Myanmar. Several international water quality criteria for aquaculture are available for consideration. Such examples include Source Water Quality for Aquaculture, (World Bank 1999), and South Africa's Water Quality Guidelines for Agricultural Use: Aquaculture (Department of Water Affairs and Forestry, 1996).

Recreational usage of water

Human beings typically enjoy recreational activities in and around the water, such as swimming, fishing and boating. It is increasingly common to identify criteria to protect the public from exposure to harmful

[4] The FAO water quality for agriculture was first published in 1976 as Irrigation and Drainage Paper 29; the 1985 version include the then recent research results.

levels of pathogens in water. No such criteria exist in Myanmar. Several nations have developed recreational water quality criteria, and some examples are the 2012 Recreational Water Quality Criteria (United States Environmental Protection Agency, 2012), South Africa the South African National Water Act (1998), Guidelines for Canadian Recreational Water Quality (Public Health Agency of Canada, 2012), and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council 2000). We briefly describe the EU Bathing Water Directive (EU 2006), which applies to EU member states below.

The EU Bathing Water Directive (76/160/EEC) (2006/7/EC).
The revised Bathing Water Directive (BWD) of 2006 requires Member States to monitor and assess coastal and inland bathing water for at least two parameters of (faecal) bacteria (intestinal enterococci and Escherichia coli). In addition, they must inform the public about bathing water quality and beach management, through bathing water profiles. These profiles contain for instance information on the kind of pollution and sources that affect the quality of the bathing water and are a risk to bathers' health (such as wastewater discharges).

Industrial use
Many industries need water for production. Principal uses of water in industries, are processing, product treatment, cleaning, and cooling. In Myanmar, the two important industries using water are hydropower production companies and mining companies: other types of industries are of minor magnitude (Table 2.2).

Table 2.2. Distribution Registered Private Industrial Enterprises by Commodity Group in Myanmar, 30.6.2015. Source: Ministry of Industry (2015).

No	Industry	Large	Medium	Small	Total	(%)
1.	Food and beverages	2856	4677	19580	27113	60,93
2.	Clothing and apparel	502	616	1140	2258	5,07
3.	Construction material	718	933	1980	3631	8,16
4.	Personal goods	507	456	361	1324	2,90
5.	Consumer goods	140	84	70	294	0,66
6.	Literature and arts	50	145	150	345	0,78
7.	Raw goods production	184	181	182	547	1,23
8.	Metal and mineral production	322	520	1510	2352	5,29
9.	Agriculture machinery	13	25	35	73	0,16
10.	Industrial tools/equipment production	22	35	38	95	0,21
11.	Automobiles	103	38	23	164	0,37
12.	Electrical equipment	55	18	26	99	0,22
13.	General	225	862	5114	6201	13,94

No criteria for industrial water use has been identified in Myanmar, but we refer briefly to the South African Water Quality Guidelines, which include a volume on industrial water use, as an example of regulations that refer to industrial usage of water (regulations of reference to the South African National Water Act (1998) South African Water Quality Guidelines http://waternet.co.za/policy/legi.html). In this volume, industries are defined as systems of water-using processes, in which fitness for use is assessed in terms of:
(i) its potential for causing damage to equipment (e.g. corrosion and abrasion)
(ii) problems it may cause in the manufacturing process (e.g. precipitates and colour changes)
(iii) impairment of product quality (e.g. taste and discolouration)
(iv) complexity of waste handling as a result of using water of the quality available.

Rules for Environmental Impact Assessment (EIAs) of industry and development projects are being developed by the Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation (MONREC) (http://www.burmalibrary.org/docs15/2013-03-

draft_eia_rules-en.pdf). Below we provide information on two main industries with potential impact on water quality and quantity in Myanmar.

Hydropower production; High sedimentation rates in Myanmar complicate management of hydropower dams as sediments can reduce water storage capacity and can damage turbines and cause loss of hydropower production.

Hydropower production provides renewable energy, but there may still be negative environmental and social impacts. Hydroelectric energy is produced by the force of falling water, and the capacity to produce this energy is dependent on available water flow and the height from which it falls. The IPCC compared several technologies for their use of water for electricity production (Sims et al. 2007). The water consumption per unit energy produced was compared considering a life cycle perspective; revealing both the top of a gradient where hydropower consumed more water than any other technologies, to the bottom of the gradient where water consumed was close to 0 m3/MWH. The high value was explained by high evaporation from dams, while the low value was estimated from "run of the river" type of hydropower plants; such hydropower have no water storage at all or a limited amount of storage. Availability of water for hydropower is directly related to irrigation upstream. The degree of regulation can reduce availability of water downstream. Negative environmental impacts of hydropower may typically include; loss of biological diversity, reservoir impoundment, reservoir sedimentation, reduced water quality, modifications of hydrological regimes, barriers for fish migration and river navigation and modification of landscape, and methane, a strong greenhouse gas, may be emitted from some reservoirs from rotting (inundated) vegetation. Negative social impacts can include deprivation of livelihoods by inundation of fields and homes, and a range of challenges associated with relocation.

As part of planning and defining the management regime in regulated rivers, it should be explored if environmental/ecological benefits can be achieved by adjusting the operation of power plants. Furthermore, planned installation of more than 40 MW and projects which may be of significant damage or inconvenience to public interests should undergo an Environmental Impact Assessment (EIA). Several measures however, can be identified to reduce the negative impacts of hydropower regulation and several of these may not reduce energy production. 'Mitigation measures' refers to impact avoidance actions by limiting the extent of flooding, localised vegetation clearing prior to impoundment, and by compensation measures (see Trussart et al., 2002). Most mitigation measures have been directed at ecological conditions in the watercourse, while some have been implemented for the benefit of landscape and other important societal values. The most important environmental mitigation measures include demand for environmental flow or minimum flow, restrictions on regulation heights of dams, release of fish, construction of thresholds, fish ladders and habitat adjustments (Thaulow et al. 2016; Trussart et al. 2002). Demand for mitigation measures however, will vary among and within watercourses. There are various ways of compensating for impacts that are not possible to mitigate, or impacts that can only be mitigated to a limited degree.

The mining industry; Myanmar has a long history of mining in gemstones, gold, silver, amber, antimony, cinnabar and copper sulphate, that can be traced back to the regimes of ancient Kings of Myanmar. According to historical records, some of the above minerals have been produced in Myanmar since the fifteenth century. Myanmar is the largest jade producer in the world, but also rubies, sapphires and diamonds are also found in significant quantities. According to the US Department of State, figures for 2010 show that precious and semi-precious stones accounted for around 10% of the total exports of Myanmar (ref http://www.azomining.com/Article.aspx?ArticleID=20. In addition to mining of precious stones, mining for metals is also an important activity. Nickel, copper, and less common metals are also present in valuable quantities, including tungsten and molybdenum. It is the Department of Mines' (previously the Ministry of Mines) policy objective to increase mining activities to fulfil the growing domestic needs of mineral and metal products and at the same time promote exports, and encourage foreign participation in projects. The magnitude of extraction is difficult to assess, however, the overview of issued permits presented on the website of Department of Mines, Appendix F, gives an indication on the level of mining activities in Myanmar. It is likely that this is an underestimation, as it is known some actors do small-scale mining without a permit (personal communication with Myanmar authorities, 2016, 2017).

The extraction of minerals demands large amounts of water, and mining through discharged mine effluent and seepage from tailings and waste rock impoundments pollute waters downstream. The impact of mining on water quality depends on the sensitivity of local terrain, the composition of minerals being mined, the type of technology employed, the skill, knowledge and environmental commitment of the mining company. Monitoring to enforce compliance with environmental regulations is important. Water pollution from mine waste rock and tailings generally need to be managed for several decades after a mine's closure.

Mining activities impact on water quality in the following ways:

(i) Acid Mine Drainage: When large quantities of rock containing sulphide minerals are excavated from an open pit or opened up in an underground mine, they react with water and oxygen to create sulphuric acid. The acid is carried by rainwater or surface drainage and deposited into nearby streams, rivers, lakes and groundwater.
(ii) Heavy Metal Contamination: Heavy metal pollution is caused when such metals such as arsenic, cobalt, copper, cadmium, lead, silver and zinc contained in excavated rock or exposed in an underground mine come in contact with water.
(iii) Processing Chemicals Pollution: This kind of pollution occurs when chemical agents (such as cyanide or sulphuric acid used by mining companies to separate the target mineral from the ore) spill, leak, or leach from the mine site into nearby water bodies.
(iv) Erosion and Sedimentation: Extraction of ore for minerals disturbs soil and rock. In the absence of adequate prevention and control strategies, erosion of the exposed earth may carry substantial amounts of sediment into streams, rivers and lakes. Ore is mineralised rock containing a valuable metal such as gold or copper, or other mineral substance such as coal.

Risk assessments and abatement measures for responsible mining need to be implemented, see websites such as: Alaskans for Responsible Mining 2004; Environmental Mining Council of BC, 2000.

3. Water quality criteria to determine ecological status according to EU WFD

3.1 Introduction

As an addition to the water *use* criteria described in chapter 2, this chapter focuses on criteria for determining ecological status of waters. Ecological status refers to the status of the biological elements living in water, both freshwater and marine areas. Ecological criteria have been determined for the protection of water resources and water ecosystems. It was the increasing understanding worldwide of ecosystems and environmental problems during the 1990s that led to the development of several agreements and conventions: the European Water Framework Directive (WFD) was adopted in 2000, inspired by the US Clean Water Act (CWA) of 1972 (see Hering et al. 2010).

Similar approaches are the UNESCO IWRM guidelines (IHP and NARBO, 2009), the Network of Asian River Basin Organizations (NARBO) launched in 2004 (Asian Development Bank 2015), and the IWRM Framework of the Mekong River Commission (Mekong IWRM Project 2010), see Nesheim & Platjouw (2016).

The National Water Resources Committee (Myanmar) adopted the National Water Framework Directive (NWFD) in 2014 (see Annex B), inspired by the EU WFD. The NWFD is a policy framework with three main goals: 1) making Myanmar rivers healthier, waters cleaner and more beneficial for all purposes; 2) getting citizens involved in a peaceful way; and 3) increasing Green Economy momentum quickly and achieving rapid Green Growth. The NWFD presents seven principles for achieving good ecological status of Myanmar water bodies and river basins, and indicates four water quality elements.

The purpose of the EU Water Framework Directive (WFD) is to establish a framework for the protection of surface waters (including rivers, lakes, transitional and coastal waters) and ground waters throughout the EU territory (European Commission 2000). The main environmental objectives are to achieve and maintain 'good status' for all surface waters and ground waters by the target date of 2015, to prevent deterioration, and ensure the conservation of high water quality where it still exists. The WFD thus aims to protect and improve the status of aquatic ecosystems and groundwater and to promote sustainable water use based on long-term protection of available water resources by applying an integrated river basin management process. The directive was developed in response to an increasingly fragmented legislation and mounting concerns among EU citizens regarding the increased water pollution problems. The Directive calls for a single system of water management based on the river basin; a natural geographical and hydrological unit, instead of according to administrative or political boundaries.
The EU WFD and the National Water Framework Directive (NWFD) in Myanmar have similar goals and approaches. Testing the processes established within the EU WFD for lakes and rivers in Myanmar are assumed to be a valuable experience for developing operational rules and guidelines reflecting the National Water Framework Directive.

A detailed description of the EU WFD and all processes can be found at the internet site: http://ec.europa.eu/environment/water/index_en.htm, and in the different guidance documents; for instance, WFD (2003, 2005). In addition, Nesheim & Platjouw (2016) give a detailed description of the EU Water Framework Directive, including the main principles and an overview of the Common Implementation Strategy.

This chapter includes a short overview of the process for characterisation, classification and monitoring of water bodies, according to EUs Water Framework Directive (WFD).

3.2 Characterisation

According to the EU WFD, ecological assessment must be ‘type specific’, i.e. water bodies should be grouped according to their physical and morphological attributes, such as salinity, alkalinity, catchment size or altitude/depth. Such fundamental ecological drivers explain most of the variation among reference conditions (unimpacted sites). It is generally understood that the use of “water body types” is a simple and appropriate tool for water managers and the general public to better understand the natural differences in aquatic communities and consequently differences in restoration targets (Hering et al. 2010).

A characterisation process that includes preliminary identification and description of water bodies based upon existing geographical information, biological quality, chemical and physical, physical-morphological quality elements, and sometime expert judgement, is the basis for assigning water body types. In addition, characterisation needs to include identification of the main pressures, a preliminary classification and risk analysis.

A short overview of the main elements in the characterisation process for **lakes and rivers** follows:

3.2.1 Identification of water bodies

The first step in the characterisation process should be to identify and group all water bodies into type: a) Lake: body of standing inland surface water, b) River: body of inland water flowing for the most part on the surface of the land, c) Groundwater: all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil, d) Transitional waters: bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater, e) Coastal water: surface water on the landward side of coastline, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters, f) Artificial water body: body of surface water created by human activity, or g) Heavily modified water body: body of surface water which as a result of physical alterations, e.g. such as by irrigation, drinking water supply, power generation, and navigation, has to be created. The WFD recognises that in some cases the benefits of such uses need to be retained.

3.2.2 Typology - identification of surface body types

For each surface water category (lake, river, etc.), the relevant surface water bodies within the River Basin Area shall be differentiated according to type. Several factors for identifying types have been used in the different European countries, and it is always a trade-off between having all environmental factors included and having a manageable typology system.

In Table 3.1a-b, we have listed the most commonly used type factors for lakes and rivers in the EU WFD. These are used to characterise the lakes and river stretches into different types, e.g. lowland, large, calcareous, clear lake.

Table 3.1a. Numeric ranges applied for the most commonly used type factors for **lakes** in the EU WFD (ETC/ICM, 2015).

Type factor	Categories	Numeric ranges for Europe
Altitude	lowland mid-altitude highland	<200 masl 200-800 masl >800 masl
Surface area	very small small medium large very large	<0,5 km^2 0,5-1 km^2 1-10 km^2 10-100 km^2 >100 km^2
Mean water depth	very shallow shallow deep	<3 m 3-15 m >15 m
Geology	siliceous calcareous organic/humic mixed	alkalinity: <1 mEq/l, calcium: <20 mg Ca/l and colour: <30 mg Pt/l alkalinity: >1 mEq/l, calcium: >20 mg Ca/l and colour: <30 mg Pt/l colour: >30 mg Pt/l any

Table 3.1b. Numeric ranges applied for the most commonly used type factors for **rivers** in the EU WFD (ETC/ICM, 2015).

Type factor	Categories	Numeric ranges for Europe
Altitude	lowland mid-altitude highland	<200 masl 200-800 masl >800 masl
Catchment size (upstream area)	very small small medium large very large	<10 km^2 10-100 km^2 100-1000 km^2 1000-10 000 km^2 >10 000 km^2
Geology	siliceous calcareous organic/humic mixed	alkalinity: <1 mEq/l, calcium: <20 mg Ca/l and colour: <30 mg Pt/l alkalinity: >1 mEq/l, calcium: >20 mg Ca/l and colour: <30 mg Pt/l colour: >30 mg Pt/l any

3.2.1 Identification of pressures

The main pressures to the different water bodies must be identified. This identification is essential for later monitoring and selection of monitoring sites. Detecting pressures from e.g. eutrophication or heavy metals require different sets of quality elements, both biological and chemical (see explanation in chapter 3.3). According to the EU WFD, the following pressure categories shall be identified: point source pollution, diffuse source pollution, abstraction and flow regulation, morphological alterations and alien species (See, Table 3.2 for examples and Project report on Characterisation of the Bago Sub-basin).

Table 3.2. Pressures – examples and possible effects on the water bodies.

Pressures
Air pollution causing acidification and increased heavy metal concentrations
Nutrient enrichment from agriculture and urban areas, causing eutrophication
Organic enrichment, O_2-consuming substances from urban areas
Hydromorphological pressures, e.g. embankment, flood defence, power generation including hydropower, inland water navigation, straightening, and land drainage, increased erosion
Forestry/deforestation; increased sediment transport/turbidity
Biological pressures; invasive species, decreasing abundance of native species
Mining; heavy metals, effecting drinking water and fisheries
Climate changes, causing salinization

3.2.2 Register of protected water bodies

A register for protected areas must be created, including areas designated for the abstraction of drinking water, areas for protection of economically significant aquatic species, water bodies designated as recreational waters, areas designated as vulnerable zones or for protection of habitats (e.g. Ramsar areas).

3.2.3 Preliminary assessment of reference conditions

WFD (2003) define reference conditions: "For any surface water body type, reference conditions or high ecological status is a state in the present or in the past where there are no, or only very minor, changes to the values of the hydromorphological, physico-chemical, and biological quality elements which would be found in the absence of anthropogenic disturbance. Reference conditions should be represented by values of the biological quality elements in calculation of ecological quality ratios and the subsequent classification of ecological status."

Reference conditions represent the condition of a water body in a relatively pristine or unimpacted state and provide a calibration point against which other water bodies' quality can be measured. A first assessment of reference sites should be based on available data. If reference sites are not available other approaches such as modelling, historic data or paleolimnological studies may be used to provide the range of variability for the reference biological data (e.g. Johnson et al 2013).

The selection of reference sites can be based on factors such as catchment use, population density, absence of major point sources and other pressures in the catchment (Poikane et al. 2011). Some suggested criteria may be <10 % agriculture and <10 % urban areas in total catchment area, and no major point sources (e.g. Pardo et al 2012).

3.2.4 Preliminary classification

The first classification of ecological status for most lakes and rivers should be based on available data and expert judgement.

This allows a first identification of water bodies that are: **at risk** - significant alteration in the ecological quality as a result of human pressures; **possibly at risk** - lack of sufficient information to decide or moderate alteration, and **not at risk** - no or slight alteration.

3.3 Classification of ecological status

The WFD classification scheme for water quality aims to describe the biological response due to specific pressures, e.g. elevated nutrients or hydromorphological alteration.

The ecological status is evaluated by biological assessment methods using selected biological quality elements. Physico-chemical and/or hydromorphologial parameters are included as supporting elements.

The classification scheme includes five status classes: high, good, moderate, poor and bad. 'High status' is defined as the biological, chemical and morphological conditions associated with no or very low human pressure. This condition is the same as or close to the 'reference condition', i.e. the best status achievable. The reference conditions are type-specific, so they differ for different types of rivers, lakes or coastal waters. Due to ecological variability, no absolute standards for biological quality apply to all EU member states. Assessment of quality is based on the extent of deviation from these reference conditions, following the normative definitions in the Directive (see Appendix A). 'Good status' means 'slight' deviation, 'moderate status' means 'moderate' deviation, and so on (Appendix A). The definition of ecological status takes into account specific aspects of the biological quality elements, for example 'composition and abundance of aquatic flora' or 'composition, abundance and age structure of fish fauna'.

The Water Framework Directive uses the 'one-out, all-out' principle in assessing water bodies (i.e., the worst status of the biological elements used in the assessment determines the final status of the water body). Class boundary values have been developed for these supporting elements. In classification, however, supporting elements can only influence the status, down to moderate, while only biological elements can determine poor or bad status.

All *reference water bodies* should be classified as having high or good ecological status, and good chemical status. The boundary between good and moderate status is the most important basis for the assessment of ecological status for natural water bodies.

To determine class boundary values for ecological status assessment, the following steps are needed:

a. Establishment of normative definitions of high, good and moderate status (see Appendix A)
b. Suggest indices for all biological elements, physical-chemical elements and hydromorphological elements
c. Suggest boundaries, especially the good/moderate boundary
d. Define reference conditions

For heavily modified and artificial water bodies, the WFD uses "Good ecological potential" for these specific water bodies. Good ecological potential is identified as good status for the chemical quality element, while for the biological quality element and the hydro-morphological elements the objective is simply to achieve the best possible situation.

Typology, reference conditions and classification systems for river and lakes are discussed in WFD (2003), and the process for classifying ecological status is illustrated in Figure 3.1.

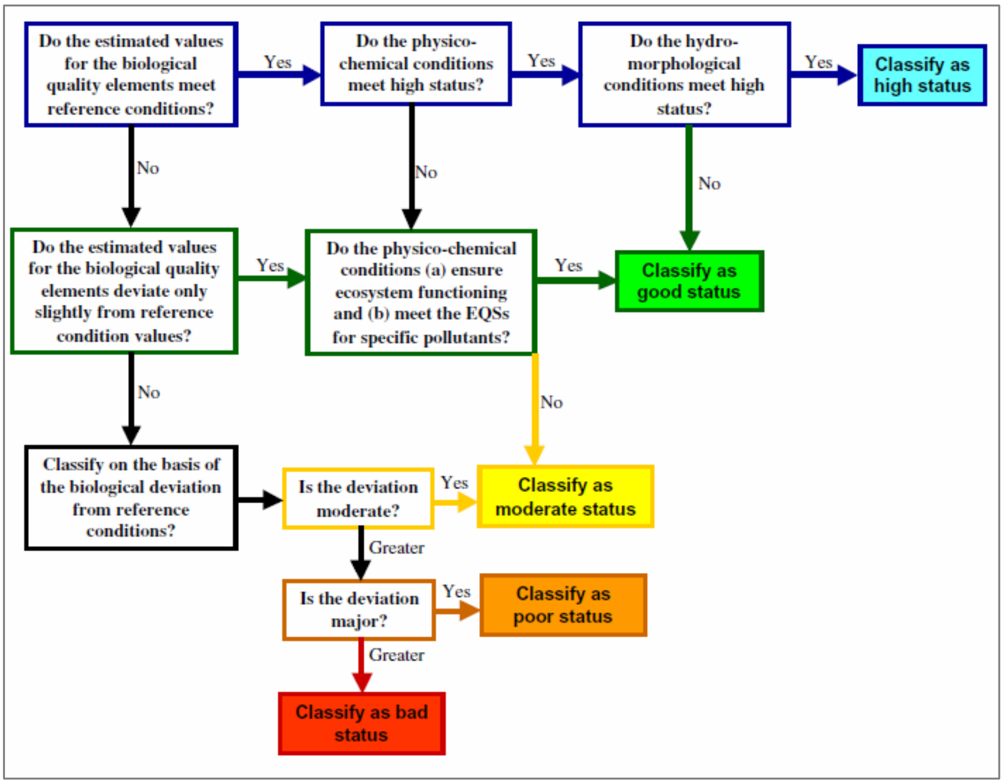

Figure 3.1. Indication of the relative roles of biological, hydromorphological and physico-chemical quality elements in ecological status classification according the normative definitions in WFD (WFD 2003).

The WFD provides biological and chemical water quality criteria to assess ecological status of standing water bodies and rivers in Europe; the criteria are listed in Table 3.3.

Biological water quality elements
All together five biological elements are included in the classification discussion in the EU WFD; phytoplankton, aquatic macrophytes, phytobenthos, bentic invertebrates and fish.

The phytoplankton community is formed by primary producers that respond sensitively to changes in water quality. Changes in phytoplankton composition in lakes along the eutrophication gradient have been well-known for several decades in Europe and North-America. For instance, as nutrient concentrations increase, the dominance and abundance of cyanobacteria generally increase, often resulting in dense mono-specific blooms. This makes phytoplankton one of the most relevant biological elements for assessment of eutrophication in lakes (Poikane et al. 2011, and references herein), and large, very slow-flowing rivers. Within the WFD, numerous indices and systems have been developed for using phytoplankton biomass metrics in assessments of nutrient loading in Europe (e.g. Carvalho et al. 2012, Phillips et al. 2012).

Aquatic macrophytes are primary producers and considered to be excellent indicators for ecological status assessment of lake ecosystem and slow-flowing rivers because they respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, and water level change (Poikane et al. 2011, and references herein). This makes aquatic macrophytes the most relevant biological element for assessment of eutrophication, acidification, salinisation and hydromorphological changes.

The phytobenthos is one of the biological quality elements required in the WFD, and most member states have chosen to consider phytobenthos apart from macrophytes, and often using diatoms as a proxy for the phytobenthos (Kelly 2006), however, also other phytobenthos groups have been used (Schneider & Lindstrøm 2011). Phytobenthos has been widely used to support decision-making in freshwater management over the past two decades, indicating acidification, eutrophication and 'general water quality' (Kelly 2006, and references herein). Phytobenthos is the group with the most relevant primary producers in rivers, especially in fast-flowing sites, however some countries include this element also in lakes.

Benthic macroinvertebrates (bottom fauna) refer to organisms that inhabit the bottom substrates of freshwater habitats, for at least part of their life cycle. Benthic macroinvertebrates constitute important links between primary producers, detrital deposits and higher trophic levels in aquatic ecosystems and are an integral part within food chains, as well as playing an important role in productivity, nutrient cycling and decomposition. Having such an integral part, aquatic macroinvertebrates have been used worldwide for more than a century to detect a wide range of stressors in their ecosystems (Cairns and Pratt 1993). Benthic macroinvertebrates are one of the recommended WFR biological elements for rivers, but also in lakes. The benthic macroinvertebrates are sensitive to organic enrichment, pollution by toxic chemicals, acidification, and abstraction of water.

Fish are a recommended element for both rivers and lakes, and are primarily sensitive to abstraction of water and morphological alterations.

The physico-chemical water quality element
The main focus in the EU WFR is the status of the biological elements. However, the physico-chemical elements are supporting quality elements and assigned to detect the main pressures for rivers and lakes; secchi depth, oxygen and nutrients indicates eutrophication pressures, pH, ANC and LAL indicates acidification.

Chemical status and hydro-morphological elements
Heavy metals indicate pollution from mining etc., while hydromorphological elements indicate water flow and water level regulations.

Table 3.3. Water quality criteria to assess the ecological status in European lakes and rivers.

	LAKES	RIVERS
Biological quality elements		
Phytoplankton: - chlorophyll a (µg/l) - Total algal biomass (mg/l) - Species composition - Cyanobacterial biomass (mg/l)	+ + + + +	- - - - -
Aquatic macrophytes: - abundance - species composition	 + +	 (+) (+)
Periphyton: - abundance - species composition	 (+) (+)	 + +
Macroinvertebrates (bottom fauna) - abundance - species composition - Indicator organisms:	 (+) (+) Amphipod *Gammarus lacustris*, Tadpole shrimps, noble crayfish	 + + Freshwater pearl mussel, noble crayfish
Fish - Abundance	 +	 +
Physico-chemical quality elements		
Secchi depth (m)	+	-
Oxygen (close to bottom) (mg/l)	+	+
Total phosphorous (µg/l)	+	+
Ammonium (NH4 + NH3) (mg/l)	+	+
Total nitrogen (µg/l)	+	+
pH	+	+
ANC acid neutralizing capacity(µekv/l)	+	+
LAL (labile aluminium) (µg/l)	+	+
Hydro-morphological elements		
Hydromorphology: - Water level variations - Water flow regulations	 + 	 + +
Chemical status		
Concentration of quantitative significant micropollutants (heavy metals and organic micropollutants)	+	+

3.4 Monitoring programme

According to WFD, all member states are required to design monitoring programs. The WFD distinguishes among three types of monitoring (e.g. Allen et al. 2006, Johnsen et al. 2013, Hering et al. 2010), see Figure 3.2: **surveillance monitoring** aims to assess long-term changes resulting from widespread anthropogenic activity, reveal long-time trends and provide baseline data; **operational monitoring** aims to provide status of those water bodies identified as being at risk (see chapter 3.2.4) of failing to meet their environmental objectives; and **investigative monitoring** aims to find the reason for such a failure, or to ascertain the magnitude and impacts of 'accidental' pollution.

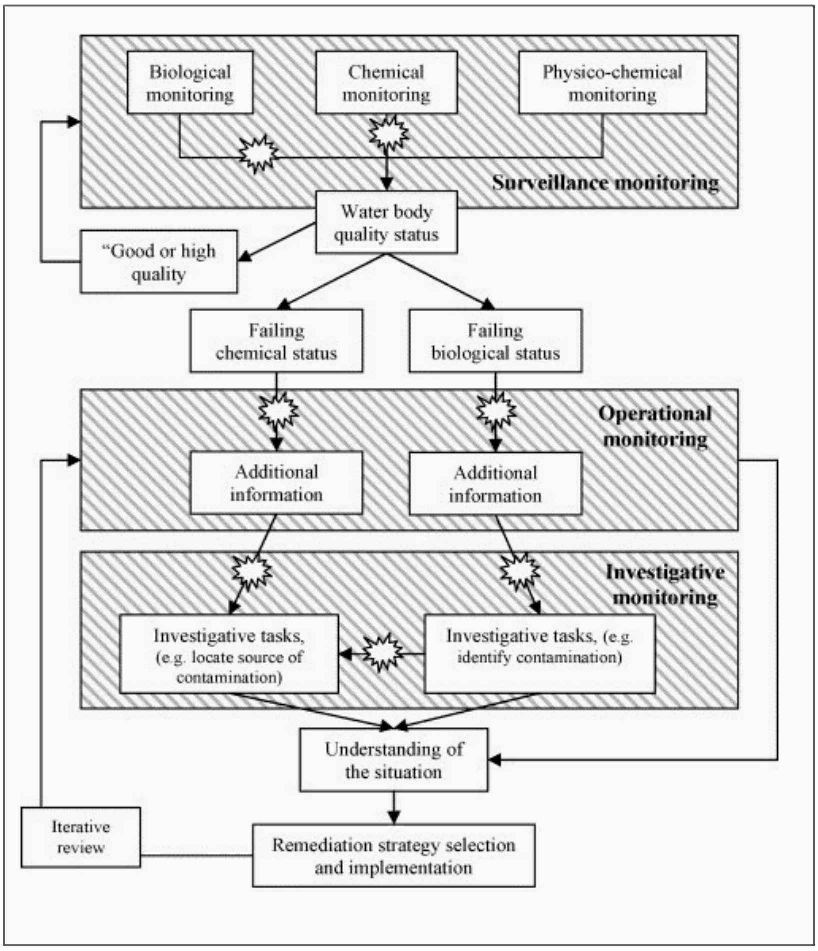

Figure 3.2. Simplified scheme for the three types of monitoring in the WFD: surveillance, operational and investigative monitoring (figure from Allen et al 2006).

Based on the results of monitoring, the water body characterisation might be refined and status assessment carried out by considering biological, chemical and hydro-morphological quality elements. Status assessment is necessary to classify the status of the water body as required by the Water Framework Directive. Depending on the risk assessed within the inventory, water bodies are under targeted control. The directive contains detailed provisions for different types of monitoring and a complex system of inter-calibration to enable comparisons of data across member states.

3.4.1 Additional monitoring

Drinking water
Bodies of surface water which provide more than 100 m^3 drinking water per day shall be designated as monitoring sites and shall be subject to such additional monitoring.

Habitat and species protection areas
Monitoring shall be carried out to assess the magnitude and impact of all relevant significant pressures on such bodies and, where necessary, to assess changes in the status of such bodies resulting from the programmes of measures.

4. Suggested characterisation and classification of ecological status of surface water in Myanmar

4.1 Introduction

In this chapter, the EU's Water Framework Directive (WFD) is used as a conceptual guide for characterisation, classification and monitoring of water bodies in Myanmar. However, the classification system and boundaries discussed in this chapter have to be evaluated and adjusted to Myanmar conditions. A workshop will be organised for the discussion of characterisation and classification procedures and elements mentioned here.

The suggested typology factors are based on commonly used typology factors for European water bodies (see previous chapter), with some adjustments for Myanmar.

In this chapter, we present the official and intercalibrated Norwegian indices and boundaries (Direktorats-gruppa 2015). These indices and boundaries will be the baseline for the forthcoming preliminary characterisation and classification of ecological status of Inlay Lake and Bago River in Myanmar (Ballot et al., 2017; Eriksen et al., in prep), and based on biological and physico-chemical data sampled during the project period. In Europe, different indices and boundaries have been developed in different geographical regions; Alpine, Atlantic, Central/Baltic, Mediterranean and Northern regions (see Poikane 2009). It is important to notice that the indices and boundaries differ among these regions, and for some water types, quite extensively. An intercalibration process within each geographic region, ensure that the Norwegian indices and boundaries are comparable throughout the northern geographical region. There is no reason to believe that indices and boundaries developed for one of the other geographical regions in Europe would be more suitable for conditions in Myanmar. We refer to the Norwegian indices and boundaries because the system is well known to the authors, and in order to demonstrate how the conceptual approach of the EU WFD could be treated in Myanmar. The boundaries and indices however, are an example and should not be referred to or considered as otherwise, as they solely serve as demonstrations for the concep. In addition, available literature and previous data from Inlay Lake, Bago River, and other Myanmar lakes and rivers, and interviews with Myanmar experts will be used as input for these first adaptive recommendations. *The final classification system of ecological status in Myanmar lakes and rivers should include indices and boundaries developed exclusively for Myanmar, based on a larger dataset from Myanmar water bodies.*

4.2 Characterisation of water bodies

4.2.1 Identification

The first step is to identify and give coordinates for all lakes and rivers, appearing at a map with scale e.g. 1:50 000. Both natural and modified lakes and rivers are to be included. The catchment areas, the largest input rivers and the main pollutants must be estimated. In addition, heavily modified water bodies and protected areas should be identified. The data should be included in a database.

4.2.2 Suggested typology factors

The second step will be to collect all available geographical, geological, physico-chemical and biological data from rivers and lakes (from literature, universities, departments, etc.), and store them in the database. The project, of which this report is part of, has provided a database for storing of water quality data (see Selvik 2016). These data will be an important basis for establishing/adjusting main lake and river types in Myanmar and enable the first steps in classification of the ecological status.

For a preliminary assessment for lakes and rivers in Myanmar, we recommend to start with the type factors suggested in the EU WFD (see Table 4.1 and 4.2).

The type factors and categories should reflect natural conditions in Myanmar. Several categories may differ from the categories established in Europe. For instance, the altitude categories should reflect natural changes, changes that are expected to be reflected in the aquatic flora and fauna. The European categories reflect the area covered by marine clay (<200 masl.), areas mainly covered with forest (200 masl. - timberline), and mountain areas (> timberline). The timberline in the Northern part of Europe typically exceed c. 1000 masl., while the timberline in Myanmar exceed 3000 masl. So, when establishing/adjusting the typology factors in Myanmar we recommend discussing all these factors, but also other factors and categories that may be important determining the aquatic flora and fauna.

In addition to the suggested type factors, we suggest considering and discussing also other factors, e.g. latitude and longitude, turbidity, climatic zone (tropic– subtropics – temperate) and salinity. The suggested type factors, categories and ranges will be adjusted and revised when sufficient data from lakes and rivers are available in the frame of this project.

Table 4.1. Recommended type factors and ranges for a preliminary assessment of **lakes** in Myanmar. These factors should be considered for revision.

Type factor	Categories	Suggested for Myanmar
Altitude	lowland mid-altitude highland	<200 masl 200 masl. - timberline >timberline (i.e. > 3000m?)
surface area	very small small medium large very large	<0,5 km^2 0,5-1 km^2 1-10 km^2 10-100 km^2 >100km^2
Mean water depth	very shallow shallow deep	<3 m 3-15 m >15 m
Geology	siliceous calcareous organic/humic	Alkalinity <1 mEq/l, Calcium <20 mg Ca/l, Colour <30 mg Pt/l Alkalinity >1 mEq/l, Calcium >20 mg Ca/l, Colour <30 mg Pt/l Colour >30 mg Pt/l

Table 4.2. Recommended type factors and ranges for a preliminary assessment of **rivers** in Myanmar. These factors should be considered for revision.

Type factor	Categories	Numeric ranges for Europe
Altitude	lowland mid-altitude highland	<200 masl 200 masl. - timberline >timberline (i.e. > 3000m?)
Catchment size (upstream area)	very small small medium large very large	<10 km^2 10-100 km^2 100-1000 km^2 1000-10 000 km^2 >10 000 km^2
Geology	siliceous calcareous organic/humic	Alkalinity <1 mEq/l, Calcium <20 mg Ca/l, Colour <30 mg Pt/l Alkalinity >1 mEq/l, Calcium >20 mg Ca/l, Colour <30 mg Pt/l Colour >30 mg Pt/l

4.2.3 Reference conditions and preliminary classification

All available biological and chemistry data from lakes and rivers in Myanmar, in addition to information from Myanmar experts and from different literature, should be collected and included in a database.
A preliminary identification of reference sites should be based on these available data and information. Identification of reference sites can be based on factors as catchment use, population density, absence of major point sources and other pressures in the catchment (Poikane et al. 2011). Some suggested criteria may be <10 % agriculture and <10 % urban areas in total catchment area, and no major point sources

(e.g. Pardo et al. 2012). In addition, based on the collected information, main pollution pressures will be identified and a register of protected water bodies should be established.

The preliminary classification and risk assessment should be done, based on these available data. Data from further monitoring programmes will gradually increase and improve the data availability, and accordingly improve the risk assessment, the reference conditions and assessment of ecological status of the individual water bodies.

4.3 Suggested quality elements in lakes and rivers

Presently, no for ecological classification of water exist in Myanmar. Suggested water quality elements for assessing ecological status in lakes in Myanmar are presented in Table 4.3. The discussion about water quality elements in this chapter assessing ecological status in **lakes and rivers**, will focus on two pollution pressures: nutrient enrichment from agriculture and urban areas (causing eutrophication), and pollution from heavy metals and pesticides, associated with chemical status. Criteria for other important pressures in Myanmar, such as hydro-morphological pressures, deforestation and invasive species, must be addressed later. For drinking water and irrigation water, separate standards are available, see chapter 2.

Table 4.3. Suggested water quality elements for assessing ecological status of lakes and rivers in Myanmar in **the first phase (indicated by +)**; need to be considered for revision.

	LAKES	RIVERS
Biological quality elements		
Phytoplankton:		
- chlorophyll a (µg/l)	+	-
- total algal biomass (mg/l)	+	-
- species composition	+	-
- cyanobacterial biomass (mg/l)	+	-
Aquatic macrophytes:		
- abundance	+	-
- species composition	+	-
Phytobenthos:		
- abundance	-	-
- species composition	-	-
Macroinvertebrates (bottom fauna)		
- abundance	-	+
- species composition	-	+
Fish		
- abundance	-	-
- species composition	-	-
Physico-chemical quality elements		
Secchi depth (m)	+	-
Oxygen (close to bottom) (mg/l)	+	-
Total phosphorous (µg/l)	+	+
Ammonium (NH4 + NH3) (mg/l)	+	+
Total nitrogen (µg/l)	+	+
pH	+	+
ANC acid neutralizing capacity(µekv/l)	-	-
LAL (labile aluminium) (µg/l)	-	-
Hydro-morphological elements		
Hydro-morphology:		
- water level variations	+	-
- water flow variations	-	+
Chemical status		
Concentration of quantitative significant micro-pollutants (heavy metals and organic micropollutants)	+	+

4.4 Physico-chemical status in lakes

4.4.1 Eutrophication pressure

The physico-chemical elements are supporting quality elements and assigned to detect the main pressures for rivers and lakes. The most important physico-chemical parameters for tracking eutrophication pollution in lakes are secchi-depth, total-phosphorous, total-nitrogen, and ammonium-ammonia.

As an example, we present the official Norwegian boundaries for all these parameters (Direktoratsgruppa 2015), see Table 4.4-4.8. The Norwegian boundaries and indices however, is an example and should not be referred to, or considered as otherwise. In this preliminary classification exercise, we suggest using these boundaries for lakes in Myanmar. However, the boundaries must be evaluated and suitable boundaries will be suggested based on feedback from Myanmar experts.

Table 4.4. Boundaries for Secchi depth in different lake types in Norway.

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	>6	4-6	2-4	1-2	<1
Lowland	siliceous, clear, deep	>8	5-8	3-5	1,5-3	<1,5
Lowland	siliceous, humus-rich	>4	3-4	1,5-3	0,7-1,5	<0,7
Lowland	calcareous, clear	>4	3-4	1,5-3	0,7-1,5	<0,7
Lowland	calcareous, humus-rich	>3	2-3	1-2	0,5-1	<0,5
Forest	siliceous, clear	>8	6-8	3-6	1,5-3	<1,5
Forest	siliceous, humus-rich	>5	3,5-5	1,7-3,5	0,8-1,7	<0,8
Mountains	siliceous, humus-rich	>9	7-9	3,5-7	1,7-3,5	<1,7

Table 4.5. Boundaries for total phosphorous (TP) in different lake types in Norway.

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	1-7	7-11	11-20	20-40	>40
Lowland	siliceous, clear, deep	1-4	4-9	9-16	16-38	>38
Lowland	siliceous, humus-rich	1-11	11-16	16-30	30-55	>55
Lowland	calcareous, clear	1-10	10-17	17-26	26-42	>42
Lowland	calcareous, humus-rich	1-13	13-20	20-39	39-65	>65
Forest	siliceous, clear	1-5	5-10	10-17	17-36	>36
Forest	siliceous, humus-rich	1-9	9-13	13-24	24-45	>45
Forest	calcareous clear	1-7	7-11	11-20	20-40	>83
Mountains	siliceous, clear	1-3	3-5	5-11	11-20	>40
Mountains	siliceous, humus-rich	1-5	5-10	10-17	17-36	>36

Table 4.6. Boundaries for total nitrogen (TN) in different lake and river types in Norway.

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	1-325	325-475	475-775	775-1350	>1350
Lowland	siliceous, clear, deep	1-200	200-400	400-650	650-1300	>1300
Lowland	siliceous, humus-rich	1-475	475-650	650-1075	1075-1755	>1755
Lowland	calcareous, clear	1-425	425-675	675-950	950-1425	>1425
Lowland	calcareous, humus-rich	1-550	550-775	775-1325	1325-2025	>2025
Forest	siliceous, clear	1-250	250-425	425-675	675-1250	>1250
Forest	siliceous humus-rich	1-400	400-550	550-900	900-1500	>1500
Forest	calcareous humus -rich	1-475	475-650	650-1075	1075-1755	>1755
Mountains	siliceous, clear	1-175	175-250	250-475	475-775	>775
Mountains	siliceous humus-rich	1-250	250-425	425-675	675-1250	>1250

Table 4.7. Boundaries for total phosphorous (TP) in different rivers types in Norway.

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	1-11	11-17	17-30	30-60	>60
Lowland	siliceous, humus-rich	1-17	17-24	24-45	45-83	>83
Lowland	calcareous, clear	1-15	15-25	25-38	38-65	>65
Lowland	calcareous, humus-rich	1-20	20-29	29-58	58-98	>98
Forest	siliceous, clear	1-8	8-15	15-25	25-55	>55
Forest	siliceous, humus-rich	1-14	14-20	20-36	36-68	>68
Forest	calcareous humus -rich	1-17	17-24	24-45	45-83	>83
Mountains	siliceous, clear	1-5	5-8	8-17	17-30	>30
Mountains	siliceous humus-rich	1-8	8-15	15-25	25-55	>55

Table 4.8. Boundaries for ammonium (NH_4+NH_3) and free ammonia (NH_3) in lakes and rivers in Norway.

Watertype	Parameter	high	good	moderate	poor	bad
All types	free ammoniac (NH_3)	1-5	5-10	10-15	15-25	>25
All types	Total ammonium (NH_3+NH_4)	10-30	30-60	60-100	100-160	>160

* only valid for pH > 8 and temp. > 25 ^{0}C.

4.4.2 Pressures from heavy metal and pesticides – chemical status

A list of environmental quality standards for priority substances and certain other pollutants is included in Annex I, in EU (2008). Among these are several substances that may be relevant for lakes and rivers in Myanmar, i.e. cadmium, mercury, lead etc. According to the laboratory analysis within this project, traces of lead and cadmium in drinking water samples, taken from around Inlay Lake in November, were well above safety standards set by the World Health Organization (WHO) and the European Union. National newspapers describe risks of heavy metals and pesticides in Myanmar: *The Irrawaddy*, (December 2015); “the amount of lead in the samples was 60-110 times higher than the WHO maximum of 0,01 mg per litre”; *The Myanmar Times* (April 2014), “In Myanmar, the gold mining industry is dumping an estimated 16,3 kilograms (36 pounds) of mercury into Myanmar’s waterways per day”; *The Irrawaddy*, (April 2017), “Especially at Inlay lake pesticides are used by farmers in the extended floating gardens threatening the Inlay lake ecosystem and people living in the area”.

Table 4.9. Class boundaries for Norway (Miljødirektoratet 2016) for some selected parameters defining chemical status. AA: annual average; MAC: maximum allowable concentration. Unit: µg/l.

Parameter	Class I Background	Class II AA-EQS	Class III MAC-EQS	Class IV acute toxic	Class V extensive acute toxic effect
Cadmium	0,003	*Note 1*	*Note 2*	*Note 3*	*Note 3*
Lead	0,02	1,2	14	57	>57
Mercury	0,001	0,047	0,07	0,14	>0,14
Nickel	0,5	4	34	67	>67

Notes:
1) class II Cd value depends on water alkalinity: ≤ 0.08 (< 40 mg CaCO3/L); 0.08 (40 - <50 mg CaCO3/L); 0.09 (50 - <100 mg CaCO3/L); 0.15 (100 -<200 mg CaCO3/L); 0.25 (≥200 mg CaCO3/L)
2) class III Cd value depends on water alkalinity: ≤ 0.45 (< 40 mg CaCO3/L); 0.45 (40 - <50 mg CaCO3/L); 0.60 (50 - <100 mg CaCO3/L); 0.9 (100 -<200 mg CaCO3/L); 1.5 (≥200 mg CaCO3/L)
3) class IV Cd value depends on water alkalinity: ≤ 4.5 (< 40 mg CaCO3/L); 4.5 (40 - <50 mg CaCO3/L); 6.0 (50 - <100 mg CaCO3/L); 9.0 (100 -<200 mg CaCO3/L); 15 (≥200 mg CaCO3/L). Higher values: class V.

Cadmium

According to EEA (2011), cadmium is mainly produced as a by-product from the extraction, smelting and refining of non-ferrous metals like e.g. zinc and others. Cadmium is also used in the production of pigments, coatings and platings. Cadmium is also found in phosphate rock, which is used for manufacturing fertilisers. It is also found in animal feeds and hence in cattle fodder and manure.

Cadmium was mainly used in rechargeable nickel-cadmium batteries; this type of battery has now been banned in Europe, although with some exceptions. Emissions of cadmium arise primarily from combustion processes in power plants and industry, and are ultimately deposited onto land or directly into fresh and marine waters. Emissions to water arise also from the chemical and metalworking industry, the transport sector and wastewater. Deposition in urban areas from the atmosphere will typically result in cadmium being washed from impervious surfaces, collected and discharged to a receiving water, either directly or via a wastewater treatment plant. The combined wet and dry deposition of cadmium is variable, generally ranging between 10 and 50 $g/km^2/year$, but reaching in excess of 100 $g/km^2/year$ in parts of central and south-eastern Europe (EEA 2011).

Lead

Lead is an element which naturally occurs in the environment (NEA 2017). It is primarily used in lead-acid batteries. Other important uses include lead roofing and flashing, lead solders in electronic equipment, in radiation shielding and in pigments. Lead is used in lead shots and fishing equipment., and also used to be added to petrol. The majority of lead used today is produced from minerals containing lead and from recycling of lead from lead-acid batteries and other old lead scraps. Current major sources of emission of lead to the environment are iron and steel industry, disposal of lead containing products and the energy and chemical industry. Another significant emission source to surface waters are sewage treatment plants. Historical use of lead in paint, petrol and water pipes contributes to releases to land and water. Lead is toxic to plants, animals and aquatic life. Excessive exposure to lead and some of its compounds may cause effects on the nervous system and have an impact on learning abilities and behaviour. However, hazards depend on the form and bioavailability of lead. Lead and its compounds are listed as priority hazardous substances (PH)S in the EU Water Framework Directive, in the OSPAR convention for protection of the Marine Environment, and in the Basel Convention controlling the transboundary movements of hazardous wastes (NEA 2017)

Mercury

Mercury and most of its compounds are extremely toxic to both humans and the environment and, as a result, are classified as priority hazardous substances (PHSs) (EEA 2011). Mercury is a persistent pollutant and subject to long-range transport. This has contributed to the building of a global pool of mercury in the environment. For example, around 40 % of annual mercury deposition to Europe originates from outside the continent. The concentrations of mercury in ambient air are generally too low to present a risk to human health. However, the concern over mercury relates to the fact that the deposited mercury can be taken up by biota and subsequently enter the food chain. Ingestion via seafood is of particular concern. The uptake in biota is facilitated by the conversion of inorganic mercury to organic methyl mercury. Methyl mercury is lipid soluble and 10 to 100 times more biologically available than inorganic mercury. In the human body, it has a tendency to accumulate in the nerve tissue. Methylation in the environment is effected by bacteria and other microorganisms in the soil and in lake and coastal sediments. Through this mechanism, historical deposition of mercury continues to affect biota. This explains why there is no obvious reduction in methyl mercury levels in lake fish in some areas of Europe (e.g. Scandinavia). Recent findings show that atmospheric mercury deposition to the sea is methylated by algae or bacteria. This is a likely reason for the surprisingly high concentrations of methyl mercury found in long-lived fish like tuna, swordfish and sharks. In Europe, all mining of mercury has now ceased and the majority of production results from the recycling of products and wastes containing mercury. Mercury is used in the chloro-alkali industry, in electrical control and switching devices, measuring and control instruments, lighting, batteries and dental amalgams (EEA 2011).

Pesticides

Pesticides are any substances used to kill, repel, or control certain forms of plant or animal life that are considered to be pests. Pesticides include herbicides for destroying weeds and other unwanted vegetation, insecticides for controlling a wide variety of insects, fungicides used to prevent the growth of mould and mildew, disinfectants for preventing the spread of bacteria, and compounds used to control mice and rats. Because of the widespread use of agricultural chemicals in food production, people are exposed to low levels of pesticide residues through their diets.

4.5 Ecological status of phytoplankton in lakes

4.5.1 General

The abundance and composition of phytoplankton are important indicators for the ecological status of standing water bodies. The group of phytoplankton comprises microscopic prokaryotic cyanobacteria and eukaryotic algae. They are freely floating organisms, which mainly move with water currents. The highest biodiversity of phytoplankton organisms is often observed under lower nutrient concentrations. Increasing nutrient concentrations often lead to a decrease in phytoplankton biodiversity and an increase in biomass of some adapted phytoplankton taxa. At eutrophic conditions very often blooms of one or a few phytoplankton taxa can be observed.

In lakes and reservoirs, the spatial variation of phytoplankton can be very variable vertically and horizontally. In many cases the vertical variation is higher than the horizontal variation. However, a higher variability in horizontal distribution of phytoplankton taxa and their biomasses has been also often observed (patchiness).

Knowledge about phytoplankton in Asia and especially in Myanmar is scarce. However, several phytoplankton organisms are found both in tropical and temperate regions. This allows a determination of many species, with standard literature from Europe and North America (e.g. Büdel et al. 1978-2015, Croasdale 1983, Huber-Pestalozzi 1969, Komárek et al. 1983, Prescott et al 1977, 1981, 1982, Skuja 1949). Several taxa, however, can only be determined to genus or family level so far.

4.5.2 Field method

When possible, phytoplankton samples should be taken from the open water. In lakes and reservoirs with a homogenous bathymetry, samples should be taken from surface water above the deepest point. For lakes with several basins and bays and for elongated lakes and reservoirs a higher number of sampling stations is recommended. The sampling should be conducted as integrated samples or discrete samples at known intervals, covering the whole euphotic zone. Monthly sampling covering the entire growing season is recommended. For a lake not investigated before regular investigation, the sampling period should cover several years.

4.5.3 Analysis method

For quantitative sampling, samples from the euphotic zone are taken at 1 m steps and mixed. An aliquot will be then taken and fixed with acidic Lugol's solution, stored in the dark and later analysed using an inverted microscope. For qualitative sampling, samples are concentrated with a plankton net covering the euphotic zone and fixed with formaldehyde (4% end concentration) and analysed using compound microscopy.

4.5.4 Trophic indices

Several parameters are used to characterise the ecological status of lakes with phytoplankton: chlorophyll-a, total biovolume of phytoplankton, Phytoplankton Trophic Index (PTI) and biomass of cyanobacteria. Phytoplankton composition and biomass react very sensitively against an increase in nutrients, especially nitrogen and phosphorous. In a weak eutrophication process the phytoplankton biomass increases and the phytoplankton composition changes. During substantial eutrophication process, the phytoplankton diversity will be reduced to some species, which often develop blooms. In many cases cyanobacteria are responsible for such blooms. A number of cyanobacterial species are also known to be able produce toxic compounds that pose a risk for the health of humans and animals. The four indices developed for phytoplankton combine all of the changes and are well correlated to total phosphorous in lakes. Chlorophyll a is the most important pigment involved in the photosynthesis of phytoplankton and can be used as a proxy for phytoplankton biomass.

The phytoplankton Trophic index (PTI) describes the increase of tolerant species (often nuisance algae or cyanobacteria) and the reduction of sensitive taxa along the phosphorus gradient. The index is based on a modification of Ptacnik et al. (2009). It sums up the indicator value for each taxon in a sample in relation to the proportion of each taxon in the sample. The indicator value for each taxon can vary from 1 to 5. The index value for lakes can vary between 1.5 and 4.0.

$$\mathrm{PTI}=\frac{\sum_{j=1}^{n} a_j s_j}{\sum_{j=1}^{n} a_j}$$

The class boundaries of chlorophyll- a, total biovolume and PTI are calculated by using response curves for each index along total phosphorous gradient.

The maximum volume for cyanobacteria (Cyanomax) describes the presence of unwanted cyanobacteria. Cyanobacteria are associated with eutrophication in lakes. They can produce high biomasses and are potential toxin producers. Their presence can limit the use of lakes as drinking water source for recreation and other purposes. This index reflects an unwanted disturbance of the phytoplankton community and is linked to risk levels of WHO (1999).

WHO defines different risk levels. The thresholds are 4 000, 20 000 and 100 000 cells ml^{-1} (WHO 1999). These values are converted to biovolume thresholds of 0.2, 1 and 5 $mm^3\ l^{-1}$ (or mg/l) and multiplied with a cell volume (based on spherical cells like those from *Microcystis* with a cell diameter of 4.5 µm (Hillebrand et al. 1999).

Definition of reference conditions and indices for phytoplankton in Northern Europe are described by Lyche-Solheim et al. (2014), while the Norwegian indices are described in Direktoratsgruppa (2015). As an example, the class boundaries for phytoplankton-indices in Norwegian lakes are presented in Table 4.11. See also Poikane et al. (2011) for boundaries in different geographic regions in Europe. Similar boundaries should be achieved for lakes and slow floating rivers in Myanamar.

Table 4.10. Class boundaries for phytoplankton-indices in Norwegian lakes. H=high, G=good, M=moderate, P=poor, B=bad

Type	Class	chlorophyll µg/l	Biovolume mg/l	PTI	Cyanomax mg/l
Lowland, calcareous, clear, shallow	H	<6	<0,64	<2,26	<0,16
	G	6-9	0,64-1,04	2,26-2,43	1,00
	M	9-18	1,04-2,35	2,43-2,60	1,00-2,00
	P	18-36	2,35-5,33	2,60-2,86	2,00-5,00
	B	>36	>5,33	2,86-4,0	>5,00
Lowland, siliceous, clear, shallow or Forest, calcareous, clear, shallow	H	<4	<0,40	<2.17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-13	0,64-1,60	2,34-2,51	1,00-2,00
	P	13-27	1,60-3,79	2,51-2,69	2,00-5,00
	B	>27	>3,79	2,69-4,0	>5,00
Lowland, siliceous, clear, deep	H	<2	<0,18	<2,09	<0,16
	G	2-4	0,18-0,40	2,09-2,26	0,16-1,00
	M	4-7	0,40-0,77	2,26-2,43	1,00-2,00
	P	7-15	0,77-1,90	2,43-2,60	2,00-5,00
	B	>15	>1,90	2,60-4,0	>5,00
Lowland, siliceous, humus-rich, shallow or Forest, calcareous, humus-rich, shallow	H	<5,4	<0,60	<2,26	<0,16
	G	5,4-9	0,60-1,00	2,26-2,43	0,16-1,00
	M	9-16	1,00-2,00	2,43-2,60	1,00-2,00
	P	16-32	2,00-4,60	2,60-2,86	2,00-5,00
	B	>32	>4,60	2,86-4,0	>5,00
Lowland, siliceous, clear, shallow or deep or Forest, siliceous, clear, shallow or deep	H	<2	<0,18	<2,00	<0-0,16
	G	2-4	0,18-0,40	2,00-2,17	0,16-1,00
	M	4-7	0,40-0,77	2,17-2,34	1,00-2,00
	P	7-15	0,77-1,90	2,34-2,51	2,00-5,00
	B	>15	>1,90	2,51-4,0	>5,00
Lowland or forest, siliceous, humus-rich, shallow	H	<4	<0,40	<2,17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-12	0,64-1,46	2,34-2,51	1,00-2,00
	P	12-25	1,46-3,46	2,51-2,69	2,00-5,00
	B	>25	>3,46	2,69-4,0	>5,00
Lowland, calcareous, humus-rich, shallow	H	<7	<0,77	<2,39	<0,16
	G	7-10,5	0,77-1,24	2,39-2,56	0,16-1,00
	M	10,5-20	1,24-2,66	2,56-2,73	1,00-2,00
	P	20-40	2,66-6,03	2,73-3,07	2,00-5,00
	B	>40	>6,03	3,07-4,0	>5,00

4.6 Ecological status of aquatic macrophytes in lakes

4.6.1 Definition

A simple definition of macrophytes is aquatic plants growing in or close to the water. They can be divided into semi-aquatic plants (i.e. emergent plants, helophytes) and aquatic macrophytes (hydrophytes), i.e. submerged plants or plants with floating leaves.

In this study, we only include aquatic macrophytes (hydrophytes). These are the species used in the EU Water Framework Directive, intercalibration process in the Northern Group (Hellsten et al. 2014), including Norway (Mjelde, in prep.).

The aquatic macrophytes can be divided into growth form groups (see Figure 4.1); isoetids (2), elodeids (3), nymphaeids (4), lemnids (5). In addition, the charophytes (large macro-algae) are included. Some macrophyte species can occur in both helophyte and true aquatic forms, e.g. *Sagittaria sagittifolia.* These are also included. Helophytes (emergent aquatic plants) (1) are not included in the definition, neither are the aquatic bryophytes or filamentous algae.

4.6.2 Sampling method

In this initial study of ecological status of aquatic macrophytes in lakes in Myanmar, we suggest testing the Norwegian field method for aquatic macrophytes (Direktoratsgruppa 2015).

The purpose of the field survey is to get an overview of most aquatic macrophytes species in a lake.
In temperate areas, the macrophyte sampling takes place once a year, during the period of maximum biomass. However, in tropical areas, where macrophyte biomass remains high throughout the year, two surveys per year are necessary to catch the yearly variations in species frequency and abundance.

The survey should include different localities in the lake (with different erosion conditions, outlet, inlet, shallow and deep area etc.), and cover all main habitats in the lake. For large lakes at least 20 localities should be visited.

At each locality the plants should be recorded using an aqua scope and collected by dredging from the boat (casting rake and rake). The abundance of the species should be scored by a semi-quantitative scale, where 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant.

A few specimens of each species should be collected and dried. This herbarium collection of species will be important if identification using microscope or genetic analysis is necessary.

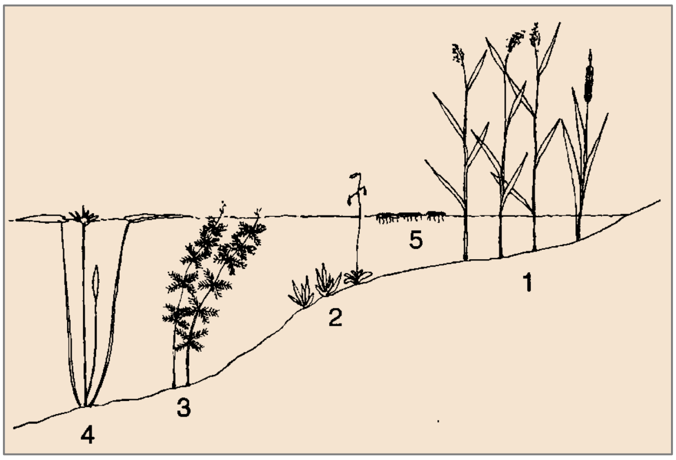

Figure 4.1. Growth forms of aquatic macrophytes

Additionally, for deeper lakes we recommend to assess the maximum depth distribution of aquatic macrophytes, using a casting rake, or preferably, underwater-camera or diving.

4.6.3 Flora and identification keys

In the Asian region, some aquatic macrophyte genera are very variable without satisfactory taxonomic treatment. In addition, several genera have been cultivated for a long time, e.g. among the *Nymphaea* species, which may confuse the taxonomic identification.

For identification, we suggest using the keys in standard flora for the region, i.e. Cook (1996), in addition to updated or more specialised taxonomic work, e.g. Wiegleb (1990), Wiegleb & Kaplan (1998), Ito et al. (2014), Triest (1988), La-Ongsri (2008). When updated taxonomic work does not exist, different internet-sites like Flora of China (http//www.efloras.org) and Encyclopedia of Life (http//eol.org) may be used. The *Chara*-species can be identified using Wood & Imahori (1965). However, for some difficult genera, genetic analysis is needed as an identification supplement.

4.6.4 Testing indices

Coverage and species richness of macrophytes decrease with increasing enrichment of lakes (Phillips, et al., 1978, Rørslett, 1991). The enrichment causes a change from the submerged isoetids or charophytes, via elodeids, to floating leaved or free-floating species, and in the end to phytoplankton. The decrease in submerged macrophyte cover and species diversity are mainly due to shading by phytoplankton, or epiphytic algae, or competition for nutrients (see Mjelde and Faafeng, 1997, with references).

Assessing ecological status of aquatic macrophytes in lakes in Myanmar in this first phase, we suggest starting with testing a trophic index, similar to the Norwegian index, which was developed and intercalibrated within the Northern Geographic group in the EU WFD (Hellsten et al. 2014). We also suggest testing a relative abundance index and a submerged macrophyte coverage index, similar to indices used in shallow lakes in Central Europe (Portielje 2014).

Trophic index
Assessing ecological status of aquatic macrophytes in lakes in Myanmar, we suggest starting with testing a trophic index, similar to the Norwegian index.

The trophic index is based on the relationship between species sensitive to eutrophication and species that are tolerant to this impact.

$$TI_C = \frac{N_S - N_T}{N} \times 100$$

N_S is the number of sensitive species in the lake, while N_T is the number of tolerant species. N is the total number of all aquatic macrophyte species.

The index-value can vary between +100, if all present species are sensitive, and -100, if they are tolerant. The index calculates one value for each lake, however, for larger lakes index-values for different parts of the lake should be considered.

All lifeform groups of aquatic macrophytes (isoetids, elodeids, nymphaeids, lemnids and charophytes) are included in the index, while aquatic mosses, filamental algae and helphytes are excluded.

The different species of aquatic macrophytes have various distribution patterns, and most of the species found in temperate regions in Northern Europe are rare or non-existing in the tropical regions, and vice versa. Therefore, the list of sensitive and tolerant species has to be developed for each country, or at least for each region. The list is an important basis for calculating the trophic index. Creation of such a list requires macrophyte data from different lake types with different eutrophication levels.

As an example, Table 4.11 shows the class boundaries for TIc-index in Norwegian lakes. The boundaries are set, based on different analysis of changes in the macrophyte community along the phosphorous gradient.

Definition of reference conditions and indices for aquatic macrophytes in Northern Europe is described in Hellsten et al. (2014), while the Norwegian indices are described in Direktoratsgruppa (2015).

Table 4.11. Class boundaries for the aquatic macrophyte TIc-index in Norwegian lakes. H=high, G=good, M=moderate, P=poor, B=bad.

Lake type		Calcium mg Ca/l	Colour mg Pt/l	Reference value	H/G	G/M	M/P	P/B
001	Very low alkalinity, clear	<1	<30	95	92	55	40	15
002	Very low alkalinity, humic	<1	>30	78	71	55	40	15
101	Low alkalinity, clear	1-4	<30	79	75	55	40	15
102	Low alkalinity, humic	1-4	>30	78	71	55	40	15
201	Moderate alkalinity, clear	4-20	<30	74	66	30	5	-35
202	Moderate alkalinity, humic	4-20	>30	69	67	30	5	-35
301	High alkalinity, clear	>20	<30	75	63	30	5	-35
302	High alkalinity, humic	>20	>30	73	63	30	5	-35

Species sensitivity from literature

As pointed out earlier in this report, assessing ecological status using a trophic index require creation of lists of sensitive and tolerant macrophyte species in Myanmar. We have little information about the distribution of aquatic macrophytes in different lake types in Myanmar. Therefore, as an initial step, we have gathered information from available literature, both from temperate and tropical areas (Table 4.12). Based on these data and information, we have suggested preliminary sensitivities for aquatic macrophytes in Myanmar (Table 4.13).

Table 4.12. Species sensitivity information from literature, covering temperate and tropical areas. Background for suggested species sensitivity for Myanmar species (Table 4.13).

No.	Reference	Country	Description
1	Mjelde et al. (in prep)	Norway	T=tolerant, S=sensitive, (S?) = not registered, but all *Chara*-species in Norway are sensitive
2	Willby et al. (2009)	United Kingdom	including macrophyte nutrient index scores, where score approx. >6 may be called tolerant. () = not registered in UK, but the scores from other *Azolla*-species are used
3	Lacoul & Freedman (2006)	?	o=oligotraphent species, e=eutraphent species, (e)=prefer nutrient-rich sediments, gen=generalists, I=invasive species which causes serious ecological problems in Asia,
4	Schaumburg et al (2004)	Germany	a=reference species, b=indifferent species, c=disturbance species. Differ from lake type to lake type
5	Portielje et al. (2014)	Lithuania	a=reference species, b=indifferent species, c=disturbance species.
6	Pereira et al. (2012)	Brazil	o=oligotrophic conditions, i=intermediate conditions,
7	Penning et al. (2008)		T=tolerant, S=sensitive.
8	Kolada et al (2012)	Europe	N score, modified from Ellenbergs index, 1= extreme nutrient-poor, 9= extreme nutrient-rich. We choose to call species with 1-3 score as sensitive, N score 4-6 as indifferent and 7-9 as tolerant.

Information about sensitivity or general ecology is not available for all species. For such species, we use more general information (see column 9 in the table), e.g. the giant *Euryale ferox*, which grow in meso-eutrophic waters, showed a marked decline and total disappearance when increasing eutrophication (Kadono & Schneider 1987). *Vallisneria spiralis* is indicated as an indifferent species since it is growing in meso-eutrophic water, but also in oligotrophic water (Bolpagni et al. 2014). According to Albert et al. (2010) the carnivorous plants inhabit nutrient-poor environments. We therefore suggest all *Utricularia*-species as sensitive to eutrophication. Suggesting *Nelumbo nucifera* as an indifferent species is based on Sharip et al. (2012). *Limnophila sessiliflora* is a perennial plant, forming dense stands in the water, and reproduces asexually (regrows from plant fragments). Dwivedi et al. (2014) report large stands of the species in a eutrophic pond in India, together with other eutrophic species. Unlike most other aquatic plants, *Ottelia alismoides* lacks specialised organs for vegetative reproduction and the recruitment and expansion of its population solely depends on the sexual reproduction (Chen et al 2008). *O. alismoides*, once widely distributed in the mid-lower reaches of the Yangtze River, is now at risk of extinction, and therefore, listed as threatened aquatic plant species of China (Yu et al., 1998); referred in (Chen et al.

2008). Because of this information, we indicate *Ottelia alismoides* and *O. ovalifolia* as indifferent species, however we do not know whether the decrease of the species is due to eutrophication or other impacts.

Table 4.13. Eutrophication sensitivity information from the literature, for aquatic macrophytes recorded in Myanmar lakes 2014-2017 (Ballot et al 2017, Mjelde & Ballot 2016, Mjelde & Wathne 2015). Preliminary sensitivity for aquatic macrophytes in Myanmar is suggested, where T=tolerant species, I=indifferent species and S=sensitive species.

Latin names	1	2	3	4	5	6	7	8	9	Preliminary sensitivity Myanmar species
ELODEIDS										
Ceratophyllum demersum	T	7,99	e/I	b-c	b		T	8		T
Hydrilla verticillata			e		b-a			3		S
Limnophila sessiflora									T?	T
Myriophyllum spicatum	T	6,23	e	b	b			7		T
Myriophyllum verticillatum	T	5,32		a-b	b		T	8		T
Najas indica								5-6*		I
Najas minor								5-6*		I
Nechamandra alternifolia									T?	T
Potamogeton crispus	T	7,50	I	c-b	c-b		T	5		I
Potamogeton lucens	T	4,37		b-a	b-a			7		S
Potamogeton nodosus			e	c-b				5		I
Potamogeton pusillus	T	7,54			b		T	6		I
Potamogeton nodosus-hybrid?										
Potamogeton sp.										
Stuckenia pectinata	T	7,19	gen	b-a	b		T	8		T
Utricularia aurea	S*							1-3*		S
Utricularia australis	S*						S	1-3*		S
Utricularia punctata	S*							1-3*		S
Utricularia stellaris	S*							1-3*		S
Utricularia sp	S*							1-3*		S
Vallisneria spiralis				c					I	I
NYMPHAEIDS										
Euryale ferox									S	S
Nelumbo nucifera			(e)						??	I
Nymphaea cyanea								3-5*		I
Nymphaea nouchali								3-5*		I
Nymphaea pubescens								3-5*		I
Nymphaea rubra								3-5*		I
Nymphoides indica			e					7*		T
Nymphoides hydrophylla								7*		T
Nymphoides cordata								7*		T
Ottelia alismoides										I
Ottelia ovalifolia										I
Trapa natans v. bispinosa			(e?)/I	b			T			T
Trapa natans v. natans			(e?)/I	b			T			T
LEMNIDS										
Azolla pinnata		(7,25)	I							T
Eichornia crassipes			I							T
Lemna trisulca	T	7,96	e	c	c-b		T	5		I
Pistia stratiotes			I			i				T
Spirodela polyrhizza	T		e		c-b		T	6		I
Salvinia cucullata						(i)				T
Salvinia natans						(i)				T
CHAROPHYTES										
Chara sp. zeylandica	(S?)					(o)	(S)	3-6*		S

*: values for other species in the same family

Information about the habitat of *Nechamandra alternifolia* is sparse. Because of the large stands in Inlay lake, we suggest it is a tolerant species. If no available information, we also suggest that all free-floating species are tolerant species, especially those with vegetative growth (column 8 in the table). Similarly, all *Chara*-species are sensitive.

4.6.5 Relative abundance index and submerged coverage index

Trophic indices based on the relationship between sensitive and tolerant species seem to be less useful for assessing ecological status in very shallow European lakes (e.g. Portielje 2014). For such lakes in Myanmar, it may be important to test other indices.

In several countries in Central Europe, relative abundance of important life forms or species have been used as metrics in very shallow lakes (Portielje 2014). In most regions, the charophytes are recognised as sensitive species, while the free-floating lemnids are tolerant species. Most of the lemnids utilise CO_2 from the air and have nutrient uptake directly from the water. They are not affected by bad light conditions caused by increased phytoplankton biomass. We therefore suggest including the relative abundance of the lifeform groups charophytes and lemnids, and the relative abundance of the sensitive elodeid *Potamogeton lucens* (used as a metric in Estonia) (Table 4.14). The average of all metrics and localities gives a number 1-5, where 5= high status, 4= good status, 3= moderate status, 2=poor status and 1= bad status. The boundaries are examples, and have to be tested with available data from Myanmar lakes.

In addition, high coverage of submerged macrophytes are considered important as they deplete the phytoplankton biomass and maintain the clear-water stage. Based on this statement, we suggest considering metrics or indices based on macrophyte coverage or abundance.

Table 4.14. Suggested abundance index, with possible metrics for assessing ecological status for aquatic macrophytes.

metric	High (5)	Good (4)	Moderate (3)	Poor (2)	Bad (1)
RA: *Potamogeton lucens* [2]	3	4-5	2	1	0
RA: charophytes [2]	4-5	3	2	1	0
RA: lemnids [2]	0	1-2	3	4	5
Submerged macrophyte coverage [1]	5	3-4	2	1	0

RA: relative abundance, 1: one or more species at each locality with given semi-quantitative score,
2: semi-quantitative score

4.7 Ecological status of macroinvertebrates in rivers

4.7.1 Definition

Aquatic, benthic macroinvertebrates is a diverse group of bottom-dwelling organisms that inhabit most surface waters, including rivers, streams, ditches, ponds and lakes. They lack a backbone (invertebrate) and are usually visible with the naked eye (macro). Their differentiated responses to many types of perturbation, in addition to low mobility, has made them excellent indicators of water quality. Because they have wide distributions and are easy to collect and identify to an operational level, benthic macroinvertebrates are used indicators of water quality worldwide.

4.7.2 Sampling and analysis method

Macroinvertebrates should be sampled with a hand net, and by disturbing the river bottom with a person's feet. Animals that live on the bottom will then drift into the net (Figure 4.2). The community composition will tell us how much pollution there is.

The macroinvertebrate sample method is called the "kick sampling method" (CEN standard protocol, no. (NS-EN-16150:2012; NS-EN-ISO-10870:2012), and uses a hand net with a frame opening of 25 x 25 cm and a mesh size of 0.25 mm. The net is held in the direction of flow while 1 m of substratum is stirred using one foot for a total of 20 seconds. This procedure should be repeated 9 times, which leads to a total sampling time of 3 minutes, and the total area covered is approximately 2.25 m^2.

All 9 subsamples should be pooled and preserved in 96 % ethanol, and later analysed using magnification in a laboratory for species composition.

4.7.3 Identification keys

The taxonomic literature for macroinvertebrates inhabiting Tropical Asian streams is generally not well developed. For taxa identifications we suggest mainly Sangpradub and Boonsoong (2006) and Dudgeon (1999), but also Braasch and Boonsoong (2010), Boonsoong and Braasch (2013), Boonsoong and Sartori (2015), Sivaramakrishnan et al. (2009), Bauernfeind and Soldán (2012), Gattolliat (2012), Tungpairojwong and Bae (2015), Shi and Tong (2014), Tubtimon et al. (2014), Cai and Ng (2002), Phone and Suzuki (2004), Molineri et al. (2015), Corbet et al. (1974), Zhou and Zheng (2004), Tungpairojwong and Boonsoong (2011), Shi and Tong (2013), Bojkova and Soldan (2015), Yam (2015), Balachandran et al. (2016), Genoni and Fazzone (2008), Madsen and Hung (2015), Taylor (2003), Jorgensen et al. (2004), Davie and Ng (2013), Ng et al. (2008), and Peumwarunyoo and Prommi (2013).

Figure 4.2. Sampling of macroinvertebrates in rivers: the samples are collected by kicking the substratum so that macroinvertebrates flow into the net (left). The sample is emptied into a plastic box (right) and transferred to a plastic bottle with ethanol.

4.7.4 Ecological status assessment

To assess ecological status, biological data is usually presented as a numeric value that is relative to environmental perturbation (called index or metric). The evaluation systems applied to Europe and elsewhere have traditionally been based on single metrics that are primarily sensitive to one stressor, e.g. oxygen content of the water, with metric values changing along the stressor gradient in a predictable manner (De Pauw et al. 2006; Friberg et al. 2006). However, recently there has been an increased use of multi-metric approaches, in which simple metrics are combined to improve sensitivity and diagnostic capabilities (Buffagni et al. 2006; Hering et al. 2006; Baptista et al. 2007; Damanik-Ambarita et al. 2016).

Another, and fundamentally different way of assessing impact is using a modelling methodology, in which the biotic community composition for a given site with no impacts (reference sites) can be predicted using environmental variables and then compared with the biotic communities actually observed, such as the British RIVPACS – river invertebrate prediction and classification system (Wright et al. 2000). Both singular and multi-metric approaches have been applied successfully to detect perturbation to Asian streams (Mustow 2002; Boonsoong et al. 2009). However, no such systems have yet been tested for Myanmar.

For a preliminary classification of Myanmar rivers, the data can be evaluated qualitatively based on expected pollution tolerances at the family level (Armitage et al. 1983; Mustow 2002) (see Figure 4.3).

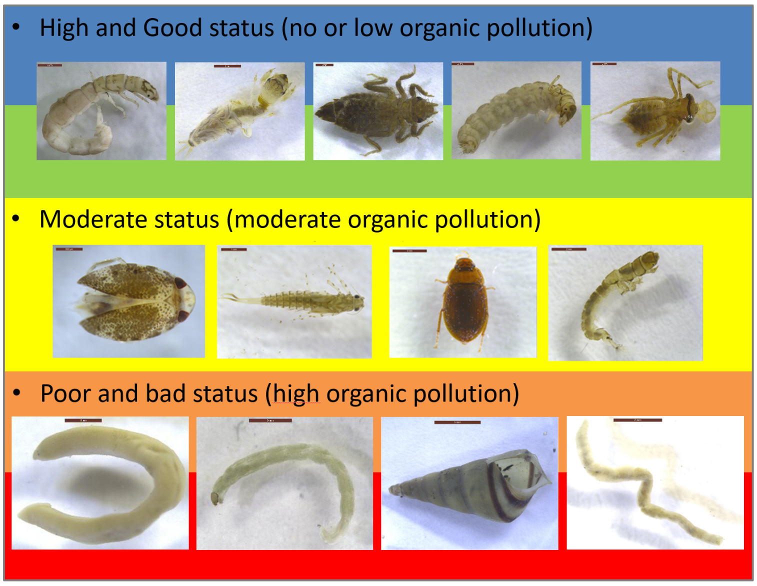

Figure 4.3. The shift in community composition can be used to assess ecological status. But such a system needs more work before it can be adapted to conditions in Myanmar**.**

More data is required to study quantitative relationships and to propose class boundaries. In this phase, assessment is only done qualitatively based on dominance of tolerant versus intolerant species from other parts of the world (see Figure 4.4).

Figure 4.4. Community composition of macroinvertebrates from the Bago region in relation to organic pollution: no (top), moderate (middle) and high pollution (bottom).

4.8 Recommended monitoring in lakes and rivers

4.8.1 Surveillance monitoring

The surveillance monitoring programme shall provide information for the efficient and effective design of future monitoring programmes, the assessment of long-term changes in natural conditions, and the assessment of long-term changes resulting from widespread anthropogenic activity. The monitoring must contain a representative number of monitoring sites for each water type and must be designed to provide a representative overview of all water types and human impacts.

Available data on aquatic flora and fauna, and important physico-chemical parameter, are rare or incomplete in Myanmar. We therefore recommend that the first phase of monitoring in lakes and rivers in Myanmar should focus on surveillance monitoring.

The surveillance monitoring programme in lakes in Myanmar should include all biological quality elements. In this first phase we suggest to include phytoplankton and aquatic macrophytes, all hydro-morphological quality elements, all general physio-chemical quality elements, some important priority substances, and list of pollutants.

Table 4.12. Recommended frequency for the different elements in surveillance monitoring of lakes in Myanmar.

Quality elements	Frequency	Repetition
Phytoplankton	Every month in a 2-year period	after 3 years
Aquatic macrophytes	Twice a year in a two-year period	after 3 years
Fish	in a later phase	-
Hydrology morphology: -water level -bathymetric map	 Every month in a 2-year period Once	 after 3 years -
Physical-chemical elements	Every month in a 2-year period	after 3 years
Priority substances	?	?

In addition, water samples for physico-chemical analyses from the main inflowing rivers and lake outlet should be collected every month in a 2-year period.

A surveillance monitoring programme in rivers in Myanmar should also include biological quality elements. In a first monitoring phase, we suggest to only include macro-invertebrates. Monitoring of macro-invertebrates should be conducted during the dry season when most streams are wadable. Smaller streams may however be sampled during the rainy season. Sampling of specific pollutants and physico-chemical water quality should be done monthly (or more often if wanted). Screenings of priority substances should be considered less often.

Table 4.13. Recommended frequency for the different elements in surveillance monitoring of rivers in Myanmar.

Quality elements	Frequency	Repetition
Biology		
Macroinvertebrates	Once a year in a 3-year period	after 3 years
Water flow measurements Morphological surveys	Monthly in a 2-year period Once	after 3-5 years -
Physico-chemical elements	Every month in a 2-year period	after 3 years
Priority substances	?	?

Suggested water chemical parameters are:

Specific pollutants (metals) - mercury (Hg), copper (Cu), nickel (Ni), lead (Pb), chromium (Cr), zinc (Zn), Manganese (Mn), Cadmium (Cd), Iron (Fe) and arsenic (As)

Physico-chemical – pH, turbidity, suspended solids alkalinity, calcium (Ca), potassium (K), chloride (Cl), magnesium (Mg), sodium (Na) and sulfate (So), nitrogen, nitrate, phosphate, phosphorous, ammonia, Chemical and Bio-chemical oxygen demand (COD and BOD), and bacteria

4.9 Additional activities

4.9.1 Taxonomic competence building

Assessing biological status in lakes and rivers are often based on changes in species/taxa diversity, where some species are sensitive and some are tolerant against a certain pollution or impact. Taxonomic competence is essential for these assessments.

Taxonomic training both in the field and in the laboratories, should be initiated as soon as possible.

4.9.2 Overview of aquatic flora and important determinants

Studies about the freshwater flora and fauna in Myanmar may exist in different literature, at universities, and in national and international articles and reports. A literature review and collection of data from different sources should commence as soon as possible. All data should be stored in the database.

Analysis of occurrence of freshwater species combined with water chemistry in the actual water bodies will provide preliminary knowledge about the most important determining factors/parameters for biodiversity variation.

4.9.3 Identification of reference conditions and developing indices

Data collection from chapter 5 and 6 will hopefully give some indication of natural biodiversity in lakes and rivers (i.e. reference conditions). Available data and knowledge from neighbouring countries may be useful.

As a first step in developing indices, already established indices and boundaries for phytoplankton and aquatic macrophytes from other countries should be tested.

4.9.4 Data management and database

Historical data and biological and chemical data achieved through present and future monitoring should be included in a database (see Selvik 2016).

5. Water quality assessment in other Asian countries

5.1 Introduction

In this report we have recommended to use the EU WFD as baseline for the development of Myanmar ecological quality criteria. In addition, the biological and chemical assessment systems developed in other Asian countries should be discussed. The water quality criteria and boundary setting procedure in these systems should be compared and discussed, to determine whether these can be suitable when developing the Myanmar assessment system.

This chapter gives a short presentation of some of the assessment systems and studies in freshwater in the neighbouring countries; India, Thailand, Vietnam, China, and Bangladesh. Systems and studies in other countries in the region will be included later. The presentation and discussion of the boundary setting procedure and the specific boundaries for different biological and the supporting physico-chemical elements in these systems will be included in the final version of the report.

5.2 Short overview of assessment systems in other Asian countries

All information that we discuss in this chapter are based on the literature available from the internet in Myanmar, and therefore we recognise that there are more studies unable to be accessed via Myanmar webpages. While searching published literature using a variety of search engines, it was acknowledged that there could be many articles pertaining to water quality assessment that have been published in local or foreign language other than English, and that local journals cannot be included in this review.

India
Several studies on water quality assessment of freshwater systems have been done in India. Water physico-chemical parameters and algae are used to assess the quality of freshwater systems such as rivers, ponds, lakes, etc. Palmer (1959) used algae as biological indicators of pollution by rating pollution tolerant algae in rivers. Other Indian researchers conducted several studies on the distribution of phytoplankton with availability of light (Singh & Sharma, 2012), and physical, chemical and biological qualities (Zafar, 1967; Munawar, 1974) in freshwater lakes. Ramakrishnan (2003) investigated several biological communities including phytoplankton, periphyton, microphytobenthos and aquatic macrophytes. This was the only paper found electronically that used aquatic macrophytes for assessment of water quality in India.

Physico-chemical assessment of rivers in India were reported by Pardeshi & Sharda (2015), Dey Kallot *et. al.*, (2005) and assessment of lakes are reported by Premlata Vikal (2009) Ramakrishnan (2003) Ramesh & Krishnaiah (2014). The physico-chemical parameters used in India for assessing freshwater quality monitoring are temperature (degree C), colour, turbidity (NTU), conductivity (µS/cm), total dissolved solids (TDS – mg/l), pH, total hardness (mg/l), calcium hardness (mg/l), magnesium hardness (mg/l), alkalinity (mg/L), sulphate (mg/L), itrate (mg/l), Chcloride (mg/l), phosphate (mg/l), fluoride (mg/l), dissolved oxygen (DO – mg/l), biological oxygen demand (BOD – mg/l) and chemical oxygen demand (COD – mg/l). Water quality monitoring was carried out for a month (Ramesh & Krishnaiah, 2004) and for one-year period (monthly assessment) (Ramakrishnan, 2003). To know the status of freshwater system, the results were compared with the desirable limit and permissible limit set by the Bureau of Indian Standard (BIS) and/or World Health Organization (WHO).

Thailand
Several research studies on phytoplankton as a bio-indicator for water quality assessment have been undertaken throughout the country by Khongsang & Wongsai (unknown year); Pongswat *et. al.,* (2004); Khuantrairong & Traichaiyaporn (2008); Sakset & Chankaew (2013); Prasertisin & Peerapornpisal (2015).

The physico-chemical properties measured for the water quality assessment were water temperature, pH, conductivity, dissolved oxygen, alkalinity, BOD, turbidity, ammonium nitrogen, nitrate nitrogen and phosphorous, etc.

Vietnam

In Vietnam, there have been few related studies on algae as a bio-indicator. Instead, physico-chemical parameters have been used as the traditional tool to monitor the surface water. Lan and Long (2011), Hanh *et. al*., (2011) and Cude (2001) (mentioned in Pham, 2016) applied the WQI index in Vietnam, which is commonly used in Canada, for assessing water quality of canals and rivers. Pham (2016) analysed the two different indices WQI, based on physio-chemical variables, and BDI, based on diatom assemblages. Nguyen *et. al* (2014) also demonstrated the suitability of a multi-metric index by using the macro-invertebrates in national monitoring and assessment of water quality of rivers instead of using the traditional physical-chemical analysis. Pham (2013) demonstrated the water quality assessment approach using benthic macro-invertebrates in the Mekong River Basin as a useful method to evaluate and zone the water quality.

According to the report of Hue (2007) at the WEPA Forum, Vietnam has an extensive set of water quality classification and standards for different uses (domestic, irrigation, etc.), like surface water quality standard based on pH, COD, BOD, NO_3, NH_4-N, dissolved oxygen, suspended solid, and coliform; coastal water quality standard based on BOD, oil, coliform, phosphate, nitrate, COD; ground water quality standard based on arsenic, chloride, nitrate, iron, and coliform.

China

Zhao *et. al*., (2012) focused on twenty-one physico-chemical parameters of water samples collected monthly over a two-year period from 13 different sites in and around the Baiyangdian Lake. The parameters were water temperature, pH, electrical conductivity, total suspended solids, calcium, magnesium, potassium, sodium, chloride, sulphate, total hardness, total alkalinity, dissolved oxygen, ammonium-nitrogen, nitrite-nitrogen, nitrate-nitrogen, permanganate index, biochemical oxygen demand, arsenic, chromium, lead, total phosphorus, total nitrogen. Different multivariate statistical techniques were used to evaluate variation in surface water quality of Baiyangdian Lake. Based on information obtained from their study, the possibility of designing an optimal sampling strategy was concluded. They also illustrated the usefulness of multivariate statistical techniques in the analysis and interpretation of complex data sets, in identifying pollutant sources, and in understanding variations in water quality for effective lake water management.

Zhang & Zang (2015) used phytoplankton as a bio-indicator to assess the water quality of Zhalong Wetland in China. They also measured physico-chemical parameters such as chemical oxygen demand, total nitrogen, total phosphorous, and chlorophyll a. A total of 410 phytoplankton taxa was obtained.

Bangladesh

Chowdhury *et. al*., (2015) developed and tested the first Bangladesh Lake Biotic Index (BLBI). The index is based on macroinvertebrates and assess the ecological status of lakes, in order to support effective lake management in Bangladesh. They found that the BLBI was positively related to traditional structural metrics including species diversity and richness, evenness, and presence of taxa sensitive to pollution. This study provides the basic information on the ecological status of lakes in Bangladesh, and encourage the use and development of biomonitoring methods for the assessment and conservation of lakes in developing Asian countries.

5.3 Conclusions

According to the literature available so far, some Asian countries have already practiced water quality monitoring system for freshwater lakes and rivers using physico-chemical or biological parameters. To assess the status of freshwater system, the physico-chemical results were compared with the desirable limit and permissible limit set by the Bureau of Indian Standard (BIS), World Health Organization (WHO), State Environmental Protection Administration of China (SEPA) etc. Species identification was conducted according to Meneghini (1840), Prescott (1970, 1978), Huber-Pestalozzi (1982), Croasdale *et al.* (1994), Chang and Mi (1997), Komarek and Jankovska (2001), John *et al.* (2011), Kowalska and Wolowski (2010), Wongrat (1999), Cox (1996), Desikachary (1959), Krammer and Lange-Bertalot (1991), Prescott (1978) and Smith (1950).

Water quality monitoring was done during the growing season of phytoplankton or monthly assessment for one- or two-year period. Biological assessment is based on phytoplankton in most of Asian countries, aquatic macrophytes, periphyton, macroinvertebrates, etc. are limited used.

The following table shows the water quality criteria used for lakes and rivers in the Asian countries mentioned in this chapter.

Table 5.1. Water quality criteria to assess the ecological status in some Asian Countries' lakes and rivers.

	LAKES	RIVERS
Biological quality elements		
Phytoplankton: (chlorophyll a; Total algal biomass; Species composition; Cyanobacterial biomass)	□	-
Aquatic macrophytes: (abundance, species composition)	(□)	(+)
Periphyton: (Abundance, Species Composition)	(□)	-
Macroinvertebrates (abundance, species composition)	(□)	+
Fish (Abundance)	n.a	n.a
Physico-chemical quality elements		
Secchi depth (m)	□	-
Dissolved Oxygen	□	□
Total phosphorous	□	□
Ammonium (NH4 + NH3)	□	□
Total nitrogen	□	□
pH	□	□
Concentration of quantitative significant micropollutants (heavy metals and organic micropollutants)	□	□
Hydromorphology: (Water level, Water flow)	n.a	n.a

n.a.: not available

6. References

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Appendix A. EU WFD normative definitions

Normative definitions for high, good and moderate status for phytoplankton and macrophytes in lakes.
From: DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000: Establishing a framework for Community action in the field of water policy

Status	Phytoplankton	Aquatic macrophytes
High	The taxonomic composition of phytoplankton corresponds totally or nearly totally to undisturbed conditions. The average phytoplankton abundance is wholly consistent with the type-specific physio-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type-specific physicochemical conditions	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in the average macrophyte abundance.
Good	There are slight changes in the composition and abundance of planktonic taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbances to the balance of organisms present in the water body or to the physio-chemical quality of the water or sediment. A slight increase in the frequency and intensity of the type-specific planktonic blooms may occur.	There are slight changes in the composition and abundance of macrophyte taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth resulting in undesirable disturbances to the balance of organisms present in the water body or to the physio-chemical quality of the water or sediment.
Moderate	The composition of planktonic taxa differs moderately from the type-specific communities. Abundance is moderately disturbed and may be such as to produce a significant undesirable disturbance in the values of other biological and physio-chemical quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.	The composition of macrophyte taxa differs moderately from the type-specific community and is significantly more distorted than at good status. Moderate changes in the average macrophyte abundance are evident.

Appendix B. Myanmar National Water Framework Directive, English language

Proposed Myanmar Water Framework Directive

Introduction

Sustainable Water Resources Development Standing Committee (SWRDSC) was established by the Presidential order on 29 Nov 2012. It is chaired by the Vice President Two U Nyan Tun and has 18 members in total at the start. Later on few selected internationally and locally outstanding, water experts in their respective fields of expertise were invited to the join SWRDSC. Since then SWRDSC has consulted the wider audience of Myanmar professionals, international and local experts, fellow citizens, civil society organizations and government officials as well as global water leaders occasionally and informally. All of them expressed their concerns and stressed the need for a single piece of water framework legislation to resolve current and potential water problems, which includes water shortage, water-related disasters and water pollution in Myanmar. In response to this, SWRDSC presented a concept proposal for a Water Framework Directive with the following key purposes:

- to ensure water security, water-related disaster risks reduction, good water governance, sustainable development and acceleration of the promotion of Green Economy and Green Growth through Integrated Water Resources Management practices;
- consequently expanding the scope of SWRDSC from 'water resources development for Special Economic Zones focus' to 'protection, management and economic use of all waters, i.e. surface waters and groundwater' in Myanmar
- achieving the status of clean and sufficient water for all purposes by a set deadline
- water management based on proper spatial unit called basin-wide approach
- combined approach of green practices and quality standards
- getting the pro-poor prices to respect the human rights as well as economically viable prices for commercial uses
- getting right perspective and priorities in relation to water-energy-food nexus and Climate Change
- getting the citizen involved more closely and hands-on projects to achieve dire need for Peace and Prosperity
- formulating a continuum of water legislation in Myanmar to ensure the direct and indirect revenues from water resources

The below concept explains what elements should be stated in the Directive and need to begin the process as soon as possible.

The Water Framework Directive

The proposed **"Water Framework Directive"** of the Republic of the Union of Myanmar (Zero Draft) aims to establish **"a framework for all walks of life in field of water policy"**, which commits all local governments (States and Divisional Governments) to achieve good qualitative and quantitative status of all Water Bodies within Myanmar (including marine waters up to one nautical mile from shore) by 2015. It is a framework in the sense that it prescribes steps to reach the common goals rather than adopting the pretext by top down approach.

Goals

Three main goals of this proposed Water Framework Directive are:-

1. getting Myanmar rivers healthier, waters cleaner and more beneficial for all purposes;
2. getting the citizens involved in a peaceful way; and
3. getting Green Economy momentum quickly and achieve Green Growth shortly.

Objectives of the Directive

There are seven objectives as listed below.

Objective (1): Good status for all ground water and surface water

The Directive aims for 'good status, i.e. clean and sufficiently stored' for all ground water and surface water (rivers, lakes, transitional waters, and coastal waters) in Myanmar.

Objective (2): National Water Budget

The Water Framework Directive stipulates that National Water Budget must be estimated under the current hydrological and meteorological conditions taking into consideration of the Climate Change impacts already visible. The groundwater must achieve "good quantitative status" and "good chemical status" (i.e. not polluted) by 2020. Classification of groundwater bodies, "good" or "poor" according to the current status, should be examined.

Objective (3): The ecological and chemical status

The ecological and chemical status of surface waters should be assessed according to the following criteria:

- Biological quality (fish, benthic invertebrates, aquatic flora);
- Hydro-morphological quality such as status of river banks, river bank structures, river training works, river continuity or substrate of the river bed;
- Physical-chemical quality such as temperature, oxygenation and nutrient conditions;
- Chemical quality that refers to environmental quality standards for river basin specific pollutants. These standards specify maximum concentrations for specific water pollutants. If even one such concentration is exceeded, the water body will not be classed as having a "good ecological status".

Objective (4): Cooperation between the Union Government and the States and Divisional Governments

The proposed Directive requires local governments (States and Divisional Governments) "to encourage the active involvement of interested parties" in the implementation of the Directive. This is generally acknowledged the requirement of frequent consultative and coordinating meetings yielded by capacity building workshops across the country. It also emphasizes the need to have clear mandate sharing between the Union and Local Governments.

Objective (5): Spatial management of river basins

One important aspect of the Water Framework Directive is the introduction of River Basin Management approach. These basin areas have to be designated, not according to administrative or political boundaries, but rather according to the river basin (the spatial catchment area of the river) as a natural geographical and hydrological unit. As our main rivers cross many administrative boundaries, i.e. States and Divisional Administrative Boundaries, the Local Governments have to cooperate and work together for the management of the river basin (so-called national basins) such as Ayeyarwady, Sttaung, Chindwin , etc.

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and international basin such as Thanlwin River. All major basins in Myanmar need River Basin Development Plans, which provide a clear indication of the way the objectives set for those river basins, are to be reached within the required timescale. They should be updated every ten years.

Objective (6): Transgressions
The River Water Transfer projects are very popular due to water scarcity around the world and heavily criticized as being contrary to the principles of Sustainable Water Resources Management of River Basin. Therefore this topic should be addressed in a proper manner. Thus it needs a section in the proposed Water Framework Directive.

Objective (7) Restructuring Process
Citizens of Myanmar expressed their concerns over water scarcity, safety and water pollution issues through media and various workshops as well as direct communication to the President's office. This is one of the main reasons to draft this Water Framework Directive. New Water Policies will be formulated and proposed along the line after holding a number of public consultations at the regional and community levels. In achieving three goals and seven objectives, the changing role of the Government and that of citizens and civil society groups will be crucial. This is why a new Myanmar Water Policy has to get citizens more involved in order to achieve Peace and Prosperity. That means a serious restructuring process is necessary!

Key issues to be addressed in the Directive

1. Water Pollution
2. Environmental Flow
3. Water Allocation
4. Water Pricing
5. Mandate Sharing between authorities
6. Effective use of Integrated Water Resources Management
7. Water use Efficiency for economic development towards Green Economy and Green Growth
8. Phase by phase tackling of "water legislation" – water law, policies and procedures, regulations and Acts, etc.
9. Efficient communication mechanism by the SWRDSC to up and down channels; the Union Government, States and Divisional Governments, Ministries, Line Agencies and Citizens of Myanmar – setting up an open process
10. Coordination of objectives to achieve a good status for all waters by a set deadline
11. Coordination of measures
12. The river basin management plans
13. Public Private Participation (PPP) for secure investments
14. Water-related Data Bank (i.e., not only limited to hydrological, meteorological, geotechnical, environmental and climate change data but also including economy, market, trade, product, innovative technologies, societal, cultural, research and investment opportunities as well as financial aid data)
15. Water-related disaster risk reduction and early warning systems
16. Water for peoples, water for food, water for energy and water for industries
17. Water projects for social inclusion and good governance
18. Water, sanitation and hygiene programmes
19. Water and Peace
20. Streamlining legislation to abolish the outdated ones and to enact the suitable ones with present time. This is extremely important for the revenue creation.

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21. Getting the appropriate prices for the business and for the peoples
22. More topics can be added . . . .

Conclusion

In reality, it is a political process!

Let us share the momentum from the President led national reform process.

We can begin by:-

- Water protection in each and every state and division and also tackling significant problems at the Union level. For example Food Security and Energy Security issues, water for Industries and Special Economic Zones SEZs);
- To keep our waters clean, we need water legislation. What we meant by 'water legislation' is a complete set of legal instruments that includes water law, regulations, Acts, standards and procedures, and water policies enforced by law enforcement bodies, neighbor watch system, citizen's active participation and properly budgeted by both internal and external financing mechanisms as a continuum of water legislation. Parliament has approved the motion on drafting of the water law since Sept 2011, however, it is just the very beginning;
- scientific community and other experts need to join forces with water professionals in capacity building; and
- We should take up the challenge of water protection as one of the most important tasks in achieving Green Economy and Green Growth.

Appendix C. Myanmar National Water Framework Directive, Myanmar language

အမျိုးသားအဆင့် ရေအရင်းအမြစ် ကော်မတီမှ ပြုစုတင်သွင်းသော
မြန်မာနိုင်ငံလုံးဆိုင်ရာ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မူဘောင်
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Myanmar National Water Framework Directive (MNWFD)
by the National Water Resources Committee (NWRC)
May, 2015

နိဒါန်း

ပြည်ထောင်စု သမ္မတ မြန်မာနိုင်ငံတော်၏ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မူဘောင်သည် မြန်မာနိုင်ငံသူ နိုင်ငံသားများအားလုံးအတွက် အဆင့်အတန်း မခွဲခြားသော ရေမူဝါဒ ဆိုင်ရာ နယ်ပယ် အတွင်းမှ မူဘောင်တစ်ခု ဖြစ်လာပြီး တိုင်းဒေသကြီးနှင့် ပြည်နယ် အစိုးရများအနေဖြင့် မိမိတို့ အုပ်ချုပ်မှု ပိုင်နက်အတွင်းရှိ ရေအရင်း အမြစ်များ၏ ပိုင်ဆိုင်မှု ရေပမာဏနှင့် ရေအရည်အသွေးတို့ကို ကောင်းမွန်သော အဆင့်အတန်းတွင် ထိန်းသိမ်းထားနိုင်စေရန်အတွက် အထောက်အကူပြု ကိရိယာ တစ်ခုအဖြစ် အသုံးချနိုင်ရန် ရည်ရွယ်ပါသည်။ ဤမူဘောင်သည် အထက်မှအောက်သို့ ကိစ္စရပ်များကို ညွှန်ကြားစေခိုင်းသော နည်းမဟုတ်ပဲ လုပ်ဆောင်ရန် လိုအပ်သော လုပ်ငန်းဆောင်တာများကို တစ်ဆင့်စီ ရှင်းလင်း တင်ပြသွားခြင်းအားဖြင့် တာဝန်ရှိသူများအားလုံး၏ ကိုယ်စားပြု တူညီသော ပန်းတိုင်တစ်ခုကို မြင်လာပြီး အသီးသီး ကိုယ်တိုင်ကိုယ်ကျ မိမိတို့ဘာသာ တာဝန်ခံယူ၍ အကောင် အထည်ဖော်သော နည်းလမ်းဖြစ်ပါသည်။ အောက်ဖော်ပြပါ အတွေးအမြင်အယူအဆများသည် မြန်မာနိုင်ငံလုံးဆိုင်ရာ အမျိုးသားအဆင့် ရေဥပဒေ လမ်းညွှန်မူဘောင် Myanmar National Water Framework Directive (MNWFD) တွင်ပါဝင်သည့် အချက်များကိုဖေါ်ညွှန်းပြီး လုပ်ငန်းစဉ်များကို အမြန်ဆုံး အကောင်အထည်ဖော် ဆောင်ရွက်ရန်လိုအပ်ကြောင်း တိုက်တွန်း၊ ရှင်းလင်း၊ တင်ပြထား ပါသည်။

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ရည်မှန်းချက်ပန်းတိုင်

ဤမူဘောင်တွင် ရည်မှန်းချက်ပန်းတိုင် သုံးခုရှိပါသည်။

- ❖ ရေကိုဘက်စုံအသုံးချရာတွင် မြန်မာ့ရေအရင်းအမြစ်များ ဖြစ်ကြသော၊ မြစ်၊ ချောင်း၊ အင်း၊ အိုင် နှင့် မြေအောက်ရေကြောများ ဖွံ့ဖြိုးရှင်သန် အရှည်တည်တံ့ရန်၊ သန့်ရှင်းစင်ကြယ်သော ရေရရှိနိုင်ရန်နှင့် ရေကိုအကျိုးရှိစွာ အသုံးချနိုင်စေရန်

- ❖ နိုင်ငံသူ၊ နိုင်ငံသားများအားလုံး တက်တက်ကြွကြွနှင့် ငြိမ်းချမ်းစွာ၊ ပူးပေါင်းပါဝင် ဆောင်ရွက်နိုင်ရန်

- ❖ အစိမ်းရောင် စီးပွားရေးစနစ်ကို လျှင်မြန်စွာ အရှိန်အဟုန် မြှင့်တင်ပေးပြီး၊ အစိမ်းရောင် ဖွံ့ဖြိုးတိုးတက်ရေးကို အချိန်တိုတိုအတွင်း အထမြောက်စေရန်

<u>အဓိကရည်ရွယ်ချက်များ</u>

- ❖ နိုင်ငံတော်အတွင်း ရေဖူလုံစေရေး၊ ရေနှင့်နီးနွယ်သော သဘာဝဘေးအန္တရာယ်များ လျှော့ချရေး၊ **ကောင်းမွန်သော ရေစီမံခန့်ခွဲခြင်း** (Good Water Governance) နှင့် **ရေရှည်တည်တံ့သောဖွံ့ဖြိုးတိုးတက်မှု** (Sustainable Development) တို့ ဖြစ်ပေါ်လာရန် အတွက်အာမခံချက်ပေးနိုင်ရန်နှင့် **အစိမ်းရောင်စီးပွားရေးနှင့် အစိမ်းရောင်ဖွံ့ဖြိုးတိုးတက်ရေး** (Green Economy and Green Growth) ကို အရှိန်အဟုန် မြှင့်တင်နိုင်ရန်တို့အတွက် ၊ **ရေအရင်းအမြစ် ဘက်စုံစီမံခန့်ခွဲခြင်း** (Integrated Water Resources Management) နည်းစနစ်ကို အသုံးပြုရန်၊
- ❖ အမျိုးသားအဆင့် ရေအရင်းအမြစ် ကော်မတီ National Water Resources Committee (NWRC) အနေဖြင့် အထူးစီးပွားရေးဇုံများအတွက် ရေပေးဝေနိုင်ရေး အပါအဝင် မြန်မာ့ မြေပေါ်မြေအောက် ရေသယံဇာတများကို ရေရှည် အရှည်အသွေး ကောင်းမွန်စွာဖြင့် လုံလုံလောက်လောက်အသုံးချနိုင်အောင် ထိန်းသိမ်း ကာကွယ်ခြင်း၊ စီမံခန့်ခွဲခြင်းနှင့် အလေအလွင့်နည်းပါး၍ ကျိုးအမြတ်ရှိစွာ သုံးစွဲခြင်း စသည့် လုပ်ငန်းများကို ပိုမိုကျယ်ပြန့်စွာ ဦးဆောင်လမ်းညွှန် ဆောင်ရွက်နိုင်ရန်၊

- သတ်မှတ်ထားသော အချိန်ကာလအတွင်း၊ ဖြစ်နိုင်ချေရှိသော **ရေအရင်းအမြစ် ဘက်စုံစီမံခန့်ခွဲခြင်း** နည်းနာများအတိုင်း၊ သန့်ရှင်းသောရေကို ပြည်သူပြည်သားတိုင်း မျှတစွာ အချိုးကျ ရရှိစေရန်နှင့် တိုင်းဒေသကြီးနှင့် ပြည်နယ်များအကြား ရေနှင့် ပတ်သက်သော ပူးပေါင်းဆောင်ရွက်မှုများတိုးပွားလာပြီး မြန်မာနိုင်ငံသူနိုင်ငံသားများ အချင်းချင်း နားလည်မှုနှင့် ခင်မင်ရင်းနှီးမှုများ တိုးပွားလာစေရန်၊
- ရေကိုဘက်စုံစီမံခန့်ခွဲရာတွင် သင့်တင့်လျောက်ပတ်သော အကျယ်အဝန်းယူနစ်များ အပေါ်အခြေခံ၍ လုပ်ဆောင်ရန်၊ ဥပမာ- မြစ်ဝှမ်းအခြေပြု ရေစီမံခန့်ခွဲရေးစနစ် (basin-wide approach) ကို အသုံးပြုရန် လိုအပ်ပါသည်။
- ရေနှင့်ဆိုင်သော စီးပွားရေးနှင့်ဖွံ့ဖြိုးရေးလုပ်ငန်းများကို အစိမ်းရောင်စီးပွားရေးအသွင်ဖြင့် ဖော်ဆောင်လုပ်ကိုင်ခြင်းနှင့် သောက်သုံးရေ၊ မြစ်ရေ၊ ကန်ရေ၊ မြေအောက်ရေ၊ စိုက်ပျိုးရေနှင့် စွန့်ပစ်ရေအပါအဝင်၊ ရေနှင့်ဆိုင်သော စံချိန်စံညွှန်း သတ်မှတ်ချက်များအား လေးစားလိုက်နာတတ်သော အလေ့အကျင့်ကောင်းများကို တပါတည်းပေါင်းစပ် လေ့ကျင့် ပေးသွားရန်၊
- ဆင်းရဲသားများအကျိုးကို ရှေးရှုသော၊ လူ့အခွင့်အရေးကို လေးစားလိုက်နာသော၊ သင့်တော်သော ရေဈေးနှုန်းများကို သတ်မှတ်ဖော်ဆောင်ပေးရမည် ဖြစ်သကဲ့သို့၊ စီးပွားရေးဆိုင်ရာ ရေအသုံးချမှုများအတွက်ကိုမူ နိုင်ငံတော်နှင့် စီးပွားရေးလုပ်ငန်းရှင်တို့နှစ်ဦးနှစ်ဘက် စီးပွားရေးတွက်ခြေကိုက်စေမည့် သီးခြားနှုန်းထားများဖြင့် တွက်ချက်၍၊ ရေအရင်းအမြစ်များရရှိနိုင်မှုနှင့် ပြန်လည်ဖြည့်ဆည်းနိုင်မှု အနေအထားအလိုက်၊ နေရာအလိုက်၊ သင့်တော်သလောက်သာ ထုတ်ယူသုံးစွဲခွင့် စည်းမျဉ်း၊ စည်းကမ်းများ ပြဋ္ဌာန်းပေးရန်၊
- ရာသီဥတုပြောင်းလဲခြင်း Climate Change) နှင့် ရေ၊ စွမ်းအင်နှင့် အစားအစာ ဖူလုံမှု၊ ဤသုံးခု တို့အကြား အချင်းချင်း အပြန်အလှန် ဆက်စပ်ပတ်သက်မှု (water-energy-food nexus) များအပေါ် မှန်ကန်သောအမြင်နှင့် ခံယူချက်များ ထားရှိလာစေရန်၊
- နိုင်ငံတော်ငြိမ်းချမ်းရေးနှင့် စီးပွားရေးဖွံ့ဖြိုးတိုးတက်၊ ကြွယ်ဝလာစေရေးတို့အတွက် နိုင်ငံသူ၊ နိုင်ငံသားများအနေဖြင့် အစိမ်းရောင်ဖွံ့ဖြိုး တိုးတက်ရေး စီမံကိန်းများတွင် ပိုမိုတက်ကြွစွာ ပူးပေါင်းပါဝင်လာမှုရရှိနိုင်စေရန်နှင့် ဂေဟစံနစ်ကြီး အရှည်တည်တံ့ပြီး ကောင်းမွန်စွာလည်ပတ်နိုင်ရေးအတွက် စီးပွားရေးလုပ်ငန်းရှင်များအနေဖြင့် ဥပဒေ

စည်းမျဉ်း၊ စည်းကမ်းများကို လိုက်နာယုံမျှသာမက၊ ရေနှင့် ပတ်ဝန်းကျင်ထိန်းသိမ်း စောင့်ရှောက်ရေး လုပ်ငန်းများတွင် လိုက်လှဲစွာ ပူးပေါင်းပါဝင်ဆောင်ရွက်ရန်၊

❖ မြန်မာနိုင်ငံတွင် မှီတင်းနေထိုင်ကြသော ပြည်သူများအားလုံးအတွက် ရေအရင်းအမြစ်များ၊ ရေလုပ်ငန်းနှင့် ရေဆိုင်ရာဝန်ဆောင်မှုလုပ်ငန်းများမှ တိုက်ရိုက်သော်လည်းကောင်း သွယ်ဝိုက်၍သော်လည်းကောင်း၊ အခွန်အခ၊ ဝန်ဆောင်ခနှင့် ရေအရင်းအမြစ် သုံးစွဲမှုတို့မှ ဝင်ငွေအစုစုတို့ကို ရရှိစေရန် တို့ဖြစ်ကြပါသည်။

<u>ပြဋ္ဌာန်းချက် (၇) ရပ်</u>

ပြဋ္ဌာန်းချက် (၁) မြန်မာနိုင်ငံရှိ မြေပေါ်ရေနှင့် မြေအောက်ရေများသည် စဉ်ဆက်မပြတ် **<u>ကောင်းမွန်သော အခြေအနေ</u>**တစ်ရပ်တွင် ရှိရမည်ဆိုသည့် အခြေအနေသစ်တစ်ရပ်ကို ဖော်ဆောင်ရန် လမ်းညွှန်ပါသည်။

ဤ ရေဥပဒေလမ်းညွှန်မူဘောင်ပါ **ကောင်းမွန်သော အခြေအနေ** ဆိုသည်မှာ ရေ အရည်အသွေးကောင်းမွန်သော၊ သန့်ရှင်းသော၊ လုံလောက်သော ပမာဏတစ်ခုထိ စုဆောင်းထားသော မြေအောက်ရေနှင့် မြေပေါ်ရေ တို့ကို ဆိုလိုပါသည်။ မြေပေါ်ရေတို့တွင် မြန်မာနိုင်ငံ တစ်ဝှမ်းလုံးရှိ မြစ်၊ ချောင်း၊ အင်း၊ အိုင်၊ ကန်များ၊ ကမ်းရိုးတန်းများနှင့် ရေတိမ်ဒေသများ အားလုံး ပါဝင်ပါသည်။

ပြဋ္ဌာန်းချက် (၂) ဤရေဥပဒေလမ်းညွှန်မူဘောင်တွင် အဆိုပြုသည့် ပထမဆုံးလုပ်ဆောင်ရမည့် အချက်မှာ မြန်မာနိုင်ငံတစ်ခုလုံးအနေဖြင့် စုစုပေါင်း ရေရရှိနိုင်မှုပမာဏ (**နိုင်ငံတော်၏ ရေဘတ်ဂျက်**) ကို အချိန်ကာလအလိုက်တွက်ချက်ပြီး စဉ်ဆက်မပြတ် သုံးသပ်နေရန်လိုပါသည်။

ဤသို့တွက်ချက်ရာတွင်လက်ရှိမိုးလေဝသနှင့်ဇလဗေဒအချက်အလက်များအပြင်သိသာထင်ရှားသော ရာသီဥတုပြောင်းလဲခြင်း၊ ကမ္ဘာကြီးပူနွေးလာခြင်းတို့၏ သက်ရောက်မှုများကြောင့် ဖြစ်နိုင်ခြေ ပြောင်းလဲနိုင်မှုနှင့် သဘာဝရေဘေးအန္တရာယ် ကြိုတင်ကာကွယ်ရန် ပြင်ဆင်နိုင်မှုများကိုပါ ထည့်သွင်းစဉ်းစားရပါမည်။ မြေအောက်ရေထုတ်ယူရာတွင်လည်း နစ်ရှည်စီမံကိန်းချမှတ်၍ အချိန်တစ်ခုတွင် အရည်အသွေးကောင်းသော ပမာဏတစ်ခုကို စုဆောင်းပြီး ဖြစ်နေရန်လိုအပ်ပါသည်။ မြေပေါ်၊ မြေအောက်ရေ ထုထည်အစုစုတို့၏ အနေအထားနှင့်အရည်အသွေးကို တိုင်းတာစစ်ဆေး၊ ဆန်းစစ်

လေ့လာပြီး အကောင်းအဆိုးအလိုက် အဆင့်များခွဲခြားသတ်မှတ်သင့် ပါသည်။ ထို့နောက်တွင် ပြုပြင်ထိန်းသိမ်း ဆောင်ရွက်ရန် အစီအစဉ်များကို အဆောတလျင် ချမှတ်လုပ်ဆောင်ရမည်။

[ရှင်းလင်းတင်ပြချက်။ နိုင်ငံတစ်ခု၏ ရေ ဘတ်ဂျက်သည် ငွေ ဘတ်ဂျက်ထက် ပို၍ အရေးလည်းကြီး၊ အရေးလည်းပါ ပါသည်။ ငွေမရှိလျှင်ချေးလို့ရပါသည်။ ရေမရှိလျှင် ချေးဘို့တောင် မလွယ်ပါ။ ထို့ကြောင့် အရေးကြီးပါသည်။ ရေ လုပ်ငန်းများမှ စစ်ပွဲတွေ ဖြစ်လေ့ ရှိပြီး၊ ရေကို အကြောင်းပြု၍လည်း ငြိမ်းချမ်းရေး ဖော်ဆောင်နိုင်ရန် ယုံကြည်မှုတည် ဆောက်ရာတွင် အဓိက ကြားခံနယ် အဖြစ် အသုံးပြုလေ့ရှိပါသည်။ ထို့ကြောင့် အရေးပါ ခြင်းဖြစ်သည်။]

ပြဋ္ဌာန်းချက် (၃) ဂေဟစနစ်ဆိုင်ရာ အခြေအနေနှင့် မြစ်၊ ချောင်း၊ အင်းအိုင်နှင့် မြေအောက်ရေ ထဲတွင် ဓာတုပစ္စည်းများ ပျော်ဝင်လာမှု အခြေအနေကို စဉ်ဆက်မပြတ် စောင့်ကြည့် လေ့လာ ကြပ်မတ် ရမည်။

နိုင်ငံတော်၏ မြေပေါ်၊ မြေအောက် ရေတို့နှင့်ဆိုင်သော ဂေဟစနစ်၏အခြေအနေနှင့် ရေထဲတွင် ဓာတုပစ္စည်းများ ပျော်ဝင်လာမှု အခြေအနေတို့ကို လေ့လာစမ်းစစ်ရာတွင် အောက်ပါအချက်များကို မှတည်၍ အကဲဖြတ်သင့်ကြောင်း ဤရေဥပဒေလမ်းညွှန်မှုဘောင်မှ အကြံပြုပါသည်။

၁. ရေ ၏ ဇီဝဆိုင်ရာ အထောက်အပံ့ပေးနိုင်မှု အရည်အသွေး (ငါးများ၊ ကျောရိုးမဲ့သတ္တဝါများ၊ ရေနေ အပင်များ ရှင်သန်မှုအခြေအနေ)

၂. မြစ်၏ ကျန်းမာရေး အရည်အသွေး၊ မြစ်ကြမ်းပြင်နှင့် မြစ်ပြင် အနေအထား၊ မြစ်ကမ်းပါးများ၊ ကမ်းထိမ်း တမံများ၊ မြစ်ကြောင်း၏ တစ်ဆက်တစ်စပ်တည်းဖြစ်တည်မှု၊ ရေကြောင်း ပြတ်တောက်မှု အစရှိသည်။

၃. ရေ၏ ရူပ-ဓါတု အရည်အသွေးများ (အပူချိန်၊ အောက်ဆီဂျင်ပျော်ဝင်မှုနှင့် ရေနေအပင်နှင့် သတ္တဝါ များအတွက် အာဟာရပါဝင်မှု)

၄ ပတ်ဝန်းကျင် အရည်အသွေး စံနှုန်းများအရ မြစ်ဝှမ်းကိုညစ်ညမ်းစေသော သီးသန့် ဓာတု ဓာတ်ပျော်ဝင်မှု ရာခိုင်နှုန်း ပမာဏနှင့် အရည်အသွေးကို တိုင်းတာရန်လိုအပ်ပါသည်။

[မြစ်ရေထဲတွင် အများဆုံးခွင့်ပြုနိုင်သော စွန့်ပစ်ရေနှင့် အညစ်အကြေးပမာဏ စံချိန်၊ စံညွှန်းကို အတိအကျ ကန့်သတ်ထားနိုင်ပါသည်။ ထိုသတ်မှတ်စံချိန်၊စံညွှန်းထက် ပိုမများစေရပါ။ ဂေဟစနစ်တစ်ခုတွင် ဓာတုဓာတ်များပျော်ဝင်မှုသည် အများဆုံး ခွင့်ပြုနိုင်သော ပမာဏထက် ပိုနေပါက ကောင်းသော ဂေစနစ်ဟု မယူဆနိုင်ပါ။]

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ပြဋ္ဌာန်းချက် (၄) ပြည်ထောင်စုအစိုးရအဖွဲ့နှင့် တိုင်းဒေသကြီး/ ပြည်နယ် အစိုးရအဖွဲ့များအကြား ပူးပေါင်းဆောင်ရွက်ခြင်းကို ထိရောက်မှုရှိစေရန်၊ တိကျသော လုပ်ပိုင်ခွင့်များကို ရေးဆွဲသတ်မှတ်ရမည်။

တိုင်းဒေသကြီးနှင့် ပြည်နယ်အစိုးရများအနေဖြင့် ဤရေပေဒေလမ်းညွှန်မူဘောင်ကို အကောင်အထည်ဖော်ရာတွင် မိမိတို့သက်ဆိုင်ရာ ဒေသအတွင်းရှိ စိတ်ပါဝင်စားသည့် ဒေသအသင်းအဖွဲ့များအနေဖြင့် ရေဆိုင်ရာလုပ်ငန်းများတွင် တက်ကြွစွာပါဝင်ဆောင်ရွက်နိုင်ရေးကို အားပေးရန်လိုအပ်ပါသည်။ နိုင်ငံတဝှမ်းလုံးရှိ ပြည်သူလူထု၏ စွမ်းဆောင်ရည် မြင့်မားတိုးတက်လာစေရန် အလုပ်ရုံဆွေးနွေးပွဲများ၊ လူထုအကြံပြု အစည်းအဝေးများ၊ ညှိနှိုင်းဆောင်ရွက်ခြင်း အစည်းအဝေးများကို မကြာခဏကျင်းပပြုလုပ်ရန် လိုအပ်ပါသည်။ ထို့ကြောင့် ပြည်ထောင်စုအစိုးရအဖွဲ့နှင့် တိုင်းဒေသကြီးနှင့် ပြည်နယ် အစိုးရများကြားတွင် တိကျသော လုပ်ပိုင်ခွင့်ရရှိရန် လိုအပ်နေကြောင်း အလေးပေးဖော်ပြထားပါသည်။

ပြဋ္ဌာန်းချက် (၅) ရေဘက်စုံစီမံခန့်ခွဲခြင်းကို အကောင်အထည်ဖော်ရာတွင် မြစ်ဝှမ်းဒေသကို အခြေခံယူနစ်အဖြစ် သတ်မှတ်၍လုပ်ဆောင်ရမည်။ မြစ်ဝှမ်းဒေသဆိုင်ရာ စီမံကိန်းရေးဆွဲခြင်းနှင့် စီမံအုပ်ချုပ်ခြင်း လုပ်ငန်းသည် ရေပေဒေလမ်းညွှန်မူဘောင် အတွက်အရေးပါသောလုပ်ငန်း တစ်ခုဖြစ်သည်။
ရေကို ဘက်စုံ စီမံခန့်ခွဲရာတွင် ဒေသအုပ်ချုပ်ရေး (သို့မဟုတ်) စီရင်စုများဖြင့် မသတ်မှတ်နိုင်ပါ။ မြစ်ကြောင်းဒေသရှိ သဘာဝပထဝီဝင်အနေအထားနှင့် ရေသယံဇာတဆိုင်ရာ ကိန်းဂဏန်းများဖြင့်သာ တွက်ချက်ရပါသည်။ မြန်မာနိုင်ငံတွင် အဓိက မြစ်ကြီးများသည် နိုင်ငံ၏ အစိတ်အပိုင်း အနှံ့အပြားသို့ ဖြန့်ကျက် စီးဆင်းနေပါသည်။ သက်ဆိုင်ရာ အစိုးရအဖွဲ့များသည် နိုင်ငံအတွင်းရှိ မြစ်ဝှမ်းဒေသများ (ဧရာဝတီမြစ်၊ ချင်းတွင်းမြစ်၊ စစ်တောင်းမြစ် စသည်) သာမက အပြည်ပြည်ဆိုင်ရာ မြစ်ဝှမ်းဒေသ (သံလွင်မြစ်) ကိုပါ စီမံခန့်ခွဲရန် လုပ်ငန်းများကို အတူညှိနှိုင်း လုပ်ဆောင်ရပါမည်။ မြန်မာနိုင်ငံရှိ အရေးပါသော မြစ်ဝှမ်းဒေသများအတွက် မြစ်ဝှမ်းဒေသများဆိုင်ရာ ဖွံ့ဖြိုးမှုစီမံချက်များ လိုအပ်ပါသည်။ ထိုစီမံချက်များတွင် ရည်ရွယ်ချက်အဆင့်များကို အစဉ်လိုက် တိကျစွာ ဖော်ပြထားရမည်ဖြစ်ပြီး လုပ်ငန်းအဆင့်ဆင့်ပြီးစီးဆောင်ရွက်ရန် လိုအပ်သော အချိန်ကာလများကိုပါ ရေးဆွဲရပါမည်။ ၎င်းစီမံချက်များကိုလည်း ဆယ်နှစ်တစ်ကြိမ် (သို့) လိုအပ်သလို ပြန်လည် သုံးသပ်သင့်ပါသည်။

ပြဋ္ဌာန်းချက်(၆) ဇလဗေဒနှင့် သဘာဝ၏သတ်မှတ်ချက်ဘောင်များကို ကျော်လွန်လိုပါက သုတေသနပြုလုပ်ပြီးမှ လုပ်ဆောင်သင့်ပါသည်။

မြစ်တစ်ခုမှ တစ်ခုသို့ ရေလမ်းကြောင်းပြောင်း ရယူခြင်းစီမံကိန်းများသည် ယခုအခါ ခေတ်စားနေပါသည်။ အကြောင်းရင်းမှာ ကမ္ဘာ့အနှံ့အပြားတွင် ရေရရှိမှု နည်းပါးလာပြီး ရေရှားပါးလာခြင်းနှင့် မြစ်ဝှမ်းဒေသဆိုင်ရာ စဉ်ဆက်မပြတ် ရေသယံဇာတ စီမံအုပ်ချုပ်မှု စည်းမျဉ်းများကို ဆန့်ကျင်သောကြောင့် ဖြစ်သည်။ ဤကဲ့သို့ အခြေအနေမျိုးကို သင့်တင့်လျောက်ပတ်စွာ သတိဖြင့်ကိုင်တွယ်ဖြေရှင်းသင့်ပါသည်။ ဤကိစ္စအတွက် အသေးစိတ်လေ့လာသော သုတေသနဌာနတစ်ခု ဖွဲ့စည်းပေးရန် လိုအပ်ပါသည်။

<u>ပြဋ္ဌာန်းချက် (၇)</u> ပိုမို တိကျခိုင်ခံ့သော လုပ်ငန်းစဉ်များနှင့် ယင်းတို့ကို အကောင်အထည်ဖော်ဆောင်မည့် ဌာနများ၊ အဖွဲ့အစည်းများ၊ ရေအာဏာပိုင်များအား စံနစ်တကျ ပြန်လည်တည်ဆောက်ဖွဲ့စည်းရန် လိုအပ်ပါသည်။ ပြန်လည် ဖွဲ့စည်းတည်ဆောက်ခြင်းတွင် အစိုးရ၏ ပြုပြင်ပြောင်းလဲခြင်း၊ နိုင်ငံသားများ လူမှုအဖွဲ့အစည်းများ၏ ပူးပေါင်းပါဝင်ခြင်း အခန်းကဏ္ဍသည်လည်း အဓိကနေရာမှ ပါဝင်သည်။

[မြန်မာနိုင်ငံသားများသည် ရေရှားပါးမှု၊ ရေအရင်းအမြစ်များကို ရေရှည်သုံးစွဲနိုင်ရန်၊ ရေဖူလုံမှု ရေရရှိစေရန် စသည့်အချက်များနှင့် ရေထုညစ်ညမ်းမှုများအကြောင်းတို့နှင့် ပတ်သက်၍ ၎င်းတို့၏ သဘောထားများကို အလုပ်ရုံဆွေးနွေးပွဲများတွင်လည်းကောင်း၊ ရုပ်မြင်သံကြားမှလည်းကောင်း၊ နိုင်ငံတော် သမ္မတရုံးသို့ တိုက်ရိုက်ဆက်သွယ်ခြင်းအားဖြင့်လည်းကောင်း ဖော်ပြခဲ့ပါသည်။ ထိုအချက်သည် ***ရေဥပဒေ လမ်းညွှန်မှုဘောင်နှင့် ရေဥပဒေ ရေးဆွဲခြင်းကို*** *အဓိကဖြစ်စေသော အခြင်းအရာ ဖြစ်လာပါသည်။ အစုအဖွဲ့ အဆင့်ဆင့်လိုက်* ***ရေဥပဒေ ရေးဆွဲရေး*** *လူထုအကြံပြုဆွေးနွေးပွဲများစွာ လုပ်ခဲ့ပြီး အဆိုကိုတင်သွင်းကာ* ***အမျိုးသားအဆင့် ရေဥပဒေ လမ်းညွှန်မှုဘောင်ကို သက်ဆိုင်ရာမှ*** *ပြဋ္ဌာန်းမည် ဖြစ်ပါသည်။ ရည်မှန်းချက် မဏ္ဍိုင် ၃-ရပ်နှင့်* ***ပြဋ္ဌာန်းချက်*** *၇-ချက် ကို ဖော်ဆောင်ရာတွင် အစိုးရ၏ ပြုပြင်ပြောင်းလဲခြင်း၊ နိုင်ငံသားများ၊ လူမှုအဖွဲ့အစည်းများ၏ ပူးပေါင်းပါဝင်ခြင်း အခန်းကဏ္ဍသည်လည်း အဓိကမှ ပါဝင်ပါသည်။* ***မြန်မာ့ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မှုဘောင်သည်*** *မြန်မာနိုင်ငံသားများ အားလုံး တက်ကြွစွာ ပါဝင်ဆောင်ရွက်ခြင်းဖြင့် ငြိမ်းချမ်းမှု၊ ကြွယ်ဝချမ်းသာမှုတို့ကို ပိုမိုရရှိစေမှာ ဖြစ်ပါသည်။ ထို့ကြောင့် ပိုမိုတိကျ ခိုင်ခံ့သော လုပ်ငန်းစဉ်များနှင့်* ***ယင်းတို့ကို အကောင်အထည် ဖော်ဆောင်မည့် ဌာန၊ အဖွဲ့အစည်း၊ ရေအာဏာပိုင်များအား စံနစ်တကျ*** *ပြန်လည်တည်ဆောက် ဖွဲ့စည်းရန် လိုအပ်ပါသည်။]*

Appendix D. FAO Guidelines of water quality for irrigation

Guidelines for evaluation of water quality for irrigation are given in Table 1. They emphasize the long-term influence of water quality on crop production, soil conditions and farm management, 1976 edition, but updated to include recent research results. See more explanation at www.fao.org.

Table 1. GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION[1]

Potential Irrigation Problem				**Units**	**Degree of Restriction on Use**		
					None	**Slight to Moderate**	**Severe**
Salinity *(affects crop water availability)*[2]							
	EC_w			dS/m	< 0,7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450-2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using ECw and SAR toghether)*[3]							
SAR	= 0 - 3	and **EC_w**	=		> 0.7	0.7 - 0.2	< 0.2
	= 3 - 6		=		> 1.2	1.2 - 0.3	< 0.3
	= 6 - 12		=		> 1.9	1.9 - 0.5	< 0.5
	= 12 - 20		=		> 2.9	2.9 - 1.3	< 1.3
	= 20- 40		=		> 5.0	5.0 - 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 - 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl) [4]						
	surface irrigation			me/l	< 4	4 - 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)[5]			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)[6]			mg/l	< 5	5 - 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5
	pH				**Normal Range 6.5 – 8.4**		

[1] Adapted from University of California Committee of Consultants 1974.
[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).
[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure at www.fao.org for the SAR calculation procedure. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw. Adapted from Rhoades 1977, and Oster and Schroer 1979.
[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see additional tables at www.fao.org.
[5] For boron tolerances, see additional tables at www.fao.org
[6] NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

Appendix E. Proposed National Drinking Water Quality Standards (Myanmar)

Proposed by Expert Group, National Water Resources Committee, May 2014:
In formulating the National Drinking Water Quality Standard, Myanmar (2014) consideration and identification of aspects have been made for the classification of categories according to the nature and characteristics of substances and their effects on drinking water quality.

Categories: Table I: Bacteriological quality, Table II: Physical quality, Table III (A): Chemical quality of health significance, Table III (B): Chemical quality not of health significance but may raise complaints by consumers, Table IV: Radioactive Material Quality, and Table V: Pesticides.

Table I - Bacteriological Quality (Microbiological Quality)

Sr. No	Parameter	Maximum Permissible Limit	
	Type of Water Source	E.Coil/ Faecial Coliforms (No/100ml)	Total Coliforms (No/100 ml)
1	Treated Pipe Water	0	0
2	Untreated Pipe Water	0	10*
3	Treated water in Distribution System	0	0
4	Unpiped Water	0	10
5	Bottled Drinking Water	0	0
6	Emergency Water Supply	0	3

Remark: E-Coli=Escherichia Coli/Thermotolerant coliform. Coliform organism= coliform bacteria
*: Total Coliforms should not be successively

Table II - Physical Quality

Sr.	Parameter	Unit	Maximum Permissible Limit
1	TCU (True Colour Unit)	Pt.co scale	15
2	Taste and Odour	-	Acceptable/ No objectionable taste and odour
3	Turbidity (NTU-Nephelometric Turbidity Unit)	NTU	5

Remark: TCU=True Colour Unit. NTU=Nephelometric Turbidity Unit

Table III (A) - Chemical Quality of Health Significance (Inorganic Substance)

Sr.	Parameter	Unit	Maximum Permissible Limit
1	Antimony	mg/L	0.02
2	Arsenic	mg/L	0.05
3	Barium	mg/L	0.7
4	Boron	mg/L	2.4
5	Cadmium	mg/L	0.003
6	Chromium	mg/L	0.05
7	Copper	mg/L	2.0
8	Cyanide	mg/L	0.07
9	Fluoride	mg/L	1.5
10	Lead	mg/L	0.01
11	Manganese	mg/L	0.4
12	Mercury (total)	mg/L	0.001
13	Nickel	mg/L	0.07
14	Nitrate (as NO_3)	mg/L	50
15	Nitrite (as NO_2)	mg/L	3
16	Selenium	mg/L	0.04
17	Uranium	mg/L	0.03

Table III (B) - Chemical Quality not of Health Significance but not raise complaints by Consumers (Inorganic Substance)

Sr.	Parameter	Unit	Maximum Permissible Limit
1	Aluminium	mg/L	0.2
2	Ammonia (Nitrogen)	mg/L	1.5
3	Calcium	mg/L	200
4	Chloride	mg/L	250
5	Total Hardness (as $CaCO_3$)	mg/L	500
6	Hydrogen Sulphide	mg/L	0.05
7	Iron	mg/L	1.0
8	Magnesium	mg/L	150
9	pH	mg/L	6.5-8.5
10	Sodium	mg/L	200
11	Sulphate	mg/L	250
12	Total Dissolved Solid	mg/L	1000
13	Zinc	mg/l	3
14	Electrical Conductivity	µs/cm	1500

Remark: µs/cm=Micro Siemens per centimetre

Table IV - Radioactive Material Quality

Sr.	Parameter	Unit	Myanmar (2014) Expert Group NWRC
1	Gross alpha activity	ßq/l	0.5
2	Gross beta activity	ßq/l	0.5

Table V - Pesticides

Sr.	Parameter	Unit	Maximum Permissible Limit
1	Alachor	(ppm) mg/L	0.02
2	Aldicarb	(ppm) mg/L	0.01
3	Aldrin&Dieldrin	(ppm) mg/L	0.00003
4	Atrazine	(ppm) mg/L	0.1
5	Acephate	(ppm) mg/L	0.01
6	Carbofuran	(ppm) mg/L	0.007
7	Chlorpyrifos	(ppm) mg/L	0.03
8	DDT	(ppm) mg/L	0.01
9	2,4 -Dichloropropane	(ppm) mg/L	0.03
10	Dimethoate	(ppm) mg/L	0.006
11	Endrin	(ppm) mg/L	0.0006
12	Endosulfan	(ppm) mg/L	0.03
13	Imidacloprid	(ppm) mg/L	0.01
14	Lindane	(ppm) mg/L	0.002

Appendix F. Hydropower dams, in operation and planned

These tables include operating and planned hydroelectric dams in Myanmar (www.wikipedia.org). The lists should be updated.

Table 1. Operating hydroelectric dams in Myanmar

Name	#	Impounds	MV rating	Commission	Location
Shweli I Dam	1	Shweli River	600	2008-12	Shan State, near Man Tat village (Palaung)
Zawgyi I Dam	2	Zawgyi River	18	1997-5-31	Shan State, Yaksauk Township
Zawgyi II Dam	3	Zawgyi River	12	1998-11	Shan State
Yeywa Dam	4	Myitnge River	790	2010	
Dapein I	5	Dapein River	168	2005	
Dapein II	6	Dapein River	240	2006	
Upper Paunglaung Dam	7	Paunglaung River	140	2009-12	
Lower Paunglaung Dam	8	Paunglaung River	280	2005	
Zaungtu Dam	9	Bago River	20	2000-3	Bago Region
II	10		48	1960, 1992-8	Karenni State
Sedawgyi	11	Chaungmagyi River	25	1989-6	Mandalay Region, Mogok
Mogok	12		4	yes	Mandalay Region
Zawgyt	13		18	yes	Shan State
Kattalu (Kyunsu)	14		.15	yes	Tanintharyi Region
Hopin Dam	15		1.26	yes	
Kunhing	16		.15	yes	Shan State
Namlat (Kyaington)	17		.48	yes	Shan State
Chinshwehaw Dam	18		0.1	yes	Shan State
Kinda Dam	19	Panlaung river	56	1985	Mandalay Reg. Thazi Township
Selu	20		.024		Shan State
Malikyun (Palaw)	21		.192		Tanintharyi Region
Matupi (Namlaung)	22		.2		Chin State
Maing Lar	23		.06		Shan State
Baluchaung I	24		28		Kayah State
Ching Hkran Dam	25		2.52		Kachin State
Laiva Dam	26		0.96 - 0.6		Chin State
Nam Wop Dam	27		3		Shan State
Nammyao (Lashio) Dam	28		4		Shan State
Chinshwehaw (Extension) Dam	29		.2		Shan State
Kunlon Dam	30	Salween River	0.5		Shan State
Zi Chaung Dam	31		1.26		Sagaing Region
Nam Hkam Hka Dam (Mogaung)	32		5		Kachin State
Nam Suang Ngaung (Kyaukme)	33		4		Shan State
Lahe	34		.05		Sagaing Region
Tui swang (Tonzang)	35		.2		Chin State
Che Chaung (Mindat)	36		.2		
Thapanseik Dam	37		30	2002-6	Sagaing Region
Lawpita Dam	39		192	1992	Kayah state
Monechaung	40		75	2004	Magway Region
Shwegyin Dam	41	Shwegyin River	75	2011	Bago Region
Total	**40**	**Hydro plants**	**3,048.5 MW**	**commission**	**All Myanmar**

Table 2. Planned Hydroelectric Dams in Myanmar

Name	#	Impounds	Capacity (MW)	Commission	Location
Myitsone Dam	1	Irawaddy River	3600	2017 est.	
Chibwe Dam	2	N'Mai River	2000		
Pashe Dam	3	N'Mai River	1600		
Lakin Dam	4	N'Mai River	1400		Lakin
Phizaw Dam	5	N'Mai River	1500		
Kaunglanphu Dam	6	N'Mai River	1700		
Laiza Dam	7	Mali River	1560		
Chibwe Creek Dam	8	N'Mai River (Chibwe Creek)	99		
Shwe Kyin Dam	10	Shwe Kyin Chaung (Stream)	75		
Tarpein I	13	Tarpein River	240		
Tarpein II Dam	14	Tarpein River	168		
Nam Myaw Dam	16		4		
Shweli II Dam	17	Shweli River	460		
Shweli III Dam	18	Shweli River	360		
Upper Thanlwin-Kunlong Dams	19	Salween River	2400		
Mepan (Meipan) Dam	22		1.26		
Kunhein (Kunheng) Dam	23		0.15		
Kyaing Ton (Kengtung) Dam	24		0.48		
TaSang Dam	26	Salween River	7110		
Kengtawng Dam	27		54		
Kyaukme Dam	30		4		
Watwon Dam	31		0.5		
Dattawgyaing Dam	33		36		
Kyeeon Kyeewa Dam	39		75		
Buywa Dam	40		60		
Nancho Dam	41		40		
Paung Laung Dam	44		280		
Thaukyegat I Dam	45		150		Kayin State
Thaukyegat II Dam	46		120		Kayin State
Kapaung Dam	47		30		Bago Region
Kunchaung Dam	48		60		Bago Region
Yenwe Dam	49		25		Bago Region
Kyauk Naga Dam	51		75		
Hatgyi Dam	52	Salween River	1360		
Dagwin dam	53	Salween River	792		
Tamanthi	54	Chindwin River	1200		
Weigyi	56	Salween River	4540		
Mobye Dam	57	Balu Chaung River	168		
Datawcha Dam	58	Balu Chaung River	28		
Tha Htay Chaung	59		111		Thandwe Township
Ann Chaung	60	Ann River	10		Ann Township
Sai Din Dam	61	Sai Din Waterfall	76.5	2014 est.	Buthidaung
Laymro Dam	62	Laymro River	500		
Shwesayay Dam	63	Chindwin River	600		
Taninthayi	65		600		
Htamanthi	66		1200		
Tajan	67				
Nam Kok	68		42,100 to 150		
Bilin	85		280		Mon State
Phyu	87		65		Bago Region
Bawgata	88		160		Kayin State
Ywathit Dam	89		600 to 4,500		Kayah State

Appendix G. Issued permits by Department of Mines

Issued permits, as presented by the department of Mines, Ministry of Natural Resources and Environmental Conservation (http://www.mining.gov.mm/DM/1.DM/Details.asp?submenuID=7&sid=338)

Sr. No.	State & Region	Large Scale	Small Scale	Exploration	Subsistence	Small Scale Processing	Total
1	Kachin	3	110	90	-	-	203
2	Kayar	1	11	11	-	-	23
3	Kayin	11	29	53	20	-	113
4	Chin	-	-	11	-	-	11
5	Sagaing	18	277	18	-	-	313
6	Tanintharyi	17	74	37	-	-	128
7	Nay Pyi Taw	2	-	-	-	-	2
8	Bago	-	11	2	-	-	13
9	Magway	1	20	25	-	-	46
10	Mandalay	41	324	50	-	67	482
11	Mon	7	25	11	-	-	43
12	RaKhine	1	-	-	-	-	1
13	Shan (South)	11	133	90	-	-	234
14	Shan (North)	18	72	56	26	-	172
15	Shan (East)	1	46	116	-	-	163
16	Ayeyarwaddy	3	4	2	-	-	9
Total		135	1136	572	46	67	1956