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# TVET SKILLS FOR RENEWABLE ENERGY AND GREEN HYDROGEN IN NAMIBIA

## Annexure 6: Water Treatment and Desalination

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Registered offices
Bonn and Eschborn, Germany

Friedrich-Ebert-Allee 36+40
3113 Bonn, Germany
Phone +49 228 44 60-0
Fax +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
Phone +49 61 96 79-0
Fax +49 61 96 79-17 66

Namibia

Promotion of Technical Vocational Education and Training (ProTVET) Project
10 Rand Street, Khomasdal, Windhoek, Namibia
Phone +264 61 222 447
Email jerry.beukes@giz.de
www.giz.de/en/worldwide/323.html

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Design
Joyce Kondo
Windhoek, Namibia
joycekondojk.wixsite.com/mysite

Photo credits
Desley Hitiraukunga, ProTVET: cover
NamWater HRDC: pages 5, 9, 14 and 20
Rodney Seibeb at Daures: page 12

**Responsible**
Sybil Ferris (GfA), Emil Spieler and Rodney Seibeb (GIZ ProTVET)

**Researchers**
Samuel Haraseb and Yulia Titova

On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ)



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# ACRONYMS

| | |
|---|---|
| ATEX | Atmosphères Explosibles (EU directive on equipment in explosive atmospheres) |
| ASTM | American Society for Testing and Materials |
| CBET | Competency-Based Education and Training |
| CHIETA | Chemical Industries Education and Training Authority (South Africa) |
| CIP | Clean-In-Place (membrane cleaning) |
| CP | Cathodic Protection |
| CPD | Continuous Professional Development |
| CPUT | Cape Peninsula University of Technology |
| CSIR | Council for Scientific and Industrial Research (South Africa) |
| CSR | Corporate Social Responsibility |
| $\Delta$P | Delta-Pressure (pressure differential) |
| DEWA | Dubai Electricity and Water Authority |
| DIN | Deutsches Institut für Normung (German Standards Body) |
| DIT | Directorate of Industrial Training (Uganda) |
| DWS | Department of Water and Sanitation (South Africa) |
| EC | Electrical Conductivity |
| EIA | Environmental Impact Assessment |
| EPC | Engineering, Procurement and Construction |
| ERD | Energy Recovery Device |
| ESG | Environmental, Social and Governance |
| EWEC | Emirates Water and Electricity Company |
| EWSETA | Energy & Water Sector Education and Training Authority (SA) |
| FRP | Fibre-Reinforced Plastic |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| $GH_2$ | Green Hydrogen |
| GSM | Global System for Mobile communications |
| GVTC | Gobabis Vocational Training Centre |
| HDPE | High-Density Polyethylene |
| HDF | Hydrogen de France (project developer) |
| HRDC | Human Resource Development Centre (NamWater) |
| HSE | Health, Safety and Environment |
| $H_2$ | Molecular hydrogen |
| HySA | Hydrogen South Africa (research centre) |
| IFMEREE | Institut de Formation aux Métiers des Énergies Renouvelables et de l'Efficacité Énergétique (Morocco) |
| ISO | International Organization for Standardization |
| KEWI | Kenya Water Institute |
| KPI | Key Performance Indicator |
| KSA | Kingdom of Saudi Arabia |
| LCOH | Levelised Cost of Hydrogen |
| LOTO | Lock-Out / Tag-Out (safety procedure) |
| LSI | Langelier Saturation Index |
| MAWFLR | Ministry of Agriculture, Water, Fisheries and Land Reform (Namibia) |
| MBO | Middelbaar Beroepsonderwijs (Dutch secondary VET level) |
| $Mm^3$ | Million cubic metres |
| MoU | Memorandum of Understanding |
| MPPT | Maximum Power Point Tracking (solar) |
| NDP 6 | National Development Plan 6 (Namibia) |
| NGH2P | Namibia Green Hydrogen Programme |
| NIMT | Namibia Institute of Mining and Technology |
| NQF | National Qualifications Framework |
| NSI | Namibian Standards Institution |
| NTA | Namibia Training Authority |
| NUST | Namibia University of Science and Technology |
| NVC | National Vocational Certificate |
| O&M | Operations & Maintenance |
| OFPPT | Office de la Formation Professionnelle et de la Promotion du Travail (Morocco) |
| OEM | Original Equipment Manufacturer |

| | |
|---|---|
| OHS | Occupational Health and Safety |
| ORP | Oxidation-Reduction Potential |
| PIRB | Plumbing Industry Registration Board (South Africa) |
| PtX | Power-to-X (renewable-energy-to-fuels) |
| PVC | Polyvinyl Chloride |
| PV | Photovoltaic |
| QCTO | Quality Council for Trades and Occupations (South Africa) |
| RE | Renewable Energy |
| RES4Africa | Renewable Energy Solutions for Africa Foundation |
| RINA | RINA Consulting (engineering firm) |
| R&D | Research and Development |
| RPL | Recognition of Prior Learning |
| RO | Reverse Osmosis |
| SANS | South African National Standards |
| SARETEC | South African Renewable Energy Technology Centre |
| SCADA | Supervisory Control and Data Acquisition |
| SDI | Silt Density Index |
| SDP | Skills Development Provider |
| SOC | State of Charge (battery) |
| SPADNS | Sodium 2-(p-sulfophenylazo)-1,8-dihydroxynaphthalene-3,6-disulfonate (fluoride test reagent) |
| SWCC | Saline Water Conversion Corporation (Saudi Arabia) |
| SWRO | Seawater Reverse Osmosis |
| TDS | Total Dissolved Solids |
| ToR | Terms of Reference |
| TVET | Technical & Vocational Education and Training |
| TVTC | Technical and Vocational Training Corporation (Saudi Arabia) |
| UAE | United Arab Emirates |
| UNAM | University of Namibia |
| UV | Ultraviolet |
| VTC | Vocational Training Centre |
| WISA | Water Institute of South Africa |
| ZLD | Zero Liquid Discharge |

# 1

# ANALYTICAL REPORT

## 1.1 Status quo – overview of existing training measures and training providers

Namibia's Sixth National Development Plan (NDP6) sets a 2030 target of raising bulk-water capacity from 1.608 Mm³ to 2.100 Mm³ and expanding the number of desalination plants from three to four, under a "diversification of water sources" priority intervention that explicitly identifies seawater and brackish-water desalination as future supply options. Two solar- and wind-powered micro-purification plants have already been constructed as proof of concept under this initiative. The same plan calls for investments in green-technology skills.

Additionally, the Ministry of Agriculture, Water, Fisheries and Land Reform (MAWFLR) owns approximately twelve borehole-based mini-reverse osmosis (RO) units in the regions of Oshikoto, Zambezi, Kavango, Kunene and Karas, and is targeting nine more units if drought-response funds materialise.

Handover training is currently limited to a single briefing day, without standard operating procedures. Contractors are frequently recalled for filter replacement, creating a distributed yet under-skilled Operations and Maintenance (O&M) cohort that Technical and Vocational Education and Training (TVET) providers could serve more effectively through targeted short courses.

Namibia's vocational system does provide an educational pathway for water treatment and plant operations, primarily through the National Vocational Certificate (NVC) in Water Supply and Sanitation (WSS) (formerly Water Care) under the Namibia Training Authority (NTA). This three-level, competency-based programme focuses on water quality, conventional treatment processes and basic plant-operation theory.

Training is delivered in classrooms and at operational facilities. Notably, the NamWater Human Resource Development Centre (HRDC) – a dedicated training facility located at the Von Bach Water Treatment Plant near Okahandja – is a key provider. HRDC is a registered vocational training centre that offers full-time training in WSS alongside other trades.

Trainees benefit from close proximity to a working water plant, gaining hands-on experience in standard treatment techniques (e.g. coagulation, filtration, chlorination) as part of their three-year programme.

Beyond NamWater's in-house centre, a few state-owned Vocational Training Centres (VTCs) are considering offering water-related qualifications. For instance, Gobabis VTC (GVTC) in the Omaheke Region has conducted a feasibility study on offering the NVC in Water Supply and Sanitation up to National Qualifications Framework (NQF) Level 3.

The study, however, deemed it unfeasible due to inadequate campus space, despite upcoming mining operations potentially requiring qualified water and wastewater treatment specialists. Therefore, additional campuses offering these qualifications should be considered, whether stand-alone or hybrid, in partnership with NamWater's HRDC.

Comparable programmes are not yet widespread. Most other VTCs continue to focus on trades such as Plumbing and Pipefitting, Electrical Engineering, or other construction-related occupations, without dedicated streams for desalination or advanced water plant operations. Training for water treatment operators in Namibia is thus relatively niche and centralised, with NamWater's HRDC producing the bulk of qualified graduates, typically in cohorts of around 20 trainees per intake.

**Several systemic challenges constrain the capacity of training providers in Namibia to deliver programmes on desalination and water plant operations:**

- **Limited access to specialised infrastructure:** While Namibia's water training institutions, such as NamWater's HRDC, provide valuable hands-on exposure to operational water treatment facilities, there is a gap in access to advanced infrastructure. For instance, specialised installations such as seawater RO systems, high-pressure pumps, multi-stage membrane units, and automation laboratories tailored to modern desalination and water reuse processes are not yet widely available. As a result, trainees struggle to gain familiarity with relevant technologies for large-scale, future-oriented projects.
- **Need for enhanced trainer capacity:** Recruiting and upskilling trainers with recent, hands-on experience in emerging water technologies remains a challenge. Many current trainers come from strong municipal or general water backgrounds but may have limited exposure to newer systems such as ultrafiltration, ultraviolet (UV) disinfection, or hybrid renewable-powered treatment solutions. Continuous professional development (CPD) – including exposure to international best practices in digital control systems, energy-efficient desalination, and hydrogen-integrated water management – is essential to ensure that training remains aligned with sectoral innovation.
- **Curriculum modernisation opportunities:** The existing qualifications in Water Supply and Sanitation (WSS) cover essential foundational skills in conventional treatment processes. However, there is scope to expand coverage into specialised areas such as seawater desalination, water reuse, and hydrogen-ready infrastructure. For example, while trainees are well-versed in traditional treatment methods, topics such as brackish-water treatment, brine management, and ultra-pure water for electrolysis are insufficiently covered at the theoretical level.

- **Dispersed delivery:** The current delivery model for water operator training remains relatively centralised, with most structured training concentrated at NamWater's HRDC. Trainees often need to relocate or rely on informal, on-the-job training to gain relevant experience.

**Strengths:** Namibia has a solid foundation to build on. A national water treatment training pipeline exists, ensuring the availability of a basic workforce for water supply operations.

The presence of NamWater's HRDC as a dedicated centre is a notable advantage, producing graduates with practical, hands-on experience in water treatment and strong links to industry. As part of the national water utility, HRDC can also facilitate on-site practical learning. NDP6 further opens a direct funding channel for the rollout of NQF Level 4 programmes, RO pilot rigs, and hydrogen-grade water quality modules.

**Implications for the forthcoming gap analysis and benchmarking study:** The Terms of Reference (ToR) for the "Water – Plumbing / Plant Operation & Desalination" assignment under the ProTVET III programme explicitly call for benchmarking Namibia's training against international standards and exploring fast-tracked short-course solutions to address the green hydrogen ($GH_2$) skills gap.

In addition, mini-desalination offers a distributed training-lab network, well-suited for short rural attachments and artisan upskilling programmes. Accordingly, the benchmarking scope should cover **both large-scale seawater reverse osmosis (SWRO)** operations and the fast-growing mini-desalination fleet, ensuring that curricula address both high-pressure industrial systems and simplified rural skids.

## 1.2 Stakeholder mapping and analysis in the RE and $GH_2$ sector in Desalination/Plant Operations

Namibia's push towards a global hydrogen economy has spotlighted the critical role of water in hydrogen production. $GH_2$ (produced via electrolysis) requires large volumes of ultra-pure water. Ensuring a reliable water supply via desalination within Namibia's emerging $GH_2$ industry has become a critical piece of the puzzle.

This introduces a network of stakeholders intersecting with desalination plant operations.

**Project developers** such as Hyphen Hydrogen Energy and HDF Energy plan to build large electrolyser facilities that will depend on seawater desalination for process water. These developers may establish dedicated desalination plants (for example, Hyphen has proposed an oversized unit to also augment supply to local towns). NamWater, the national water utility, is a key player – it already operates in partnership with industry on coastal desalination (e.g. managing supply from Orano's Erongo desalination plant) and is co-developing a new 25 million m³/yr desalination facility with Chinese investors.

**The Namibian government's** Namibia Green Hydrogen Programme (NGH2P) coordinates policy across ministries, ensuring that water infrastructure for hydrogen projects aligns with national water strategies.

**This involves regulators and standards bodies:** the Ministry of Agriculture, Water, Fisheries and Land Reform (MAWFLR) oversees water resource allocation and quality, while the Namibian Standards Institution (NSI) may work with international bodies (such as ISO/DIN) on standards for desalination technology and safety.

**Training authorities** are also pivotal. The Namibia Training Authority (NTA) and Namibia Qualifications Authority (NQA) oversee vocational programmes and will need to adapt curricula to produce desalination plant operators and technicians. For instance, NamWater's HRDC runs a "Water Care" vocational programme (NQF Level 3) that covers water treatment and plant operations, but new modules on seawater RO, high-pressure pump maintenance, and automation will be needed for hydrogen-related desalination.

**Educational institutions** such as the Namibia University of Science and Technology (NUST) and the University of Namibia (UNAM), along with regional VTCs, can contribute research and tailored courses on desalination processes, water chemistry, and membrane technology through their engineering and environmental science faculties.

**Industry and contractors –** ranging from engineering firms that design and build desalination plants to maintenance contractors – all share a stake in ensuring a competent workforce for installation and O&M of these complex systems. They will push for upskilling in areas such as Supervisory Control and Data Acquisition (SCADA) system operation, pump and valve servicing, and water quality testing.

**Regional linkages** also influence Namibia's approach. South Africa, for example, has been developing green hydrogen skills programmes at NQF Level 4 (focused on hydrogen production, storage, etc.), and it has long-established qualifications for water plant operators. Namibia can draw on this neighbouring expertise to integrate desalination operations into its vocational training framework.

In summary, the stakeholder map spans government, industry, and education sectors – all collaborating to ensure that as Namibia pursues $GH_2$, the supporting desalination infrastructure is managed by well-trained professionals equipped with both traditional water treatment expertise and new "hydrogen era" competencies.

## 1.3 International Benchmarking in relation to Desalination/Plant Operations

### Namibia

Namibia's current vocational training in water management produces technicians versed in conventional water and wastewater treatment. The flagship qualification is the NVC in Water Supply and Sanitation (WSS) – offered through NamWater – a multi-year programme covering water quality control, treatment processes, and basic plant operation.

The training is suited to municipal waterworks and mines but lacks specialised content on seawater desalination or the high-purity water requirements of hydrogen electrolysis. With few existing desalination plants in the country (the Orano Erongo plant being the primary supplier to coastal industries), hands-on experience with RO membranes, anti-scaling chemistry, and high-pressure pumps is limited – even though it is plant technicians, rather than university engineers, who replace and clean RO membranes, mix and dose antiscalant, and inspect or retune 60-bar high-pressure pumps.

A recent skills assessment recommended updating Namibia's water curricula to fill these gaps, for example by adding modules on seawater intake systems, reverse osmosis operation, and brine handling. The strength of Namibia's system lies in a solid foundation in water treatment principles and safety standards, but gaps remain in advanced technical and digital skills relevant to large-scale desalination. As new hydrogen projects drive plans for large desalination plants, Namibia will need to introduce certifiable training on desalination technology (possibly at NQF Level 4–5) and offer apprenticeships in partnership with operating plants to build practical expertise.

### Germany

In Germany, water plant operation is a well-established trade specialisation, although large-scale desalination is not common domestically. German vocational pathways include the Fachkraft für Wasserversorgungstechnik (Water Supply Engineering Technician) and related certifications overseen by the Chambers of Crafts and water associations. These programmes place strong emphasis on drinking-water purification, distribution networks, pump systems, and water quality in line with DIN standards. German trainees learn to operate treatment processes (filtration, chemical dosing, etc.), with close attention to safety and automation, in alignment with Germany's high water-quality regulations.

A major strength of the German system is its comprehensiveness and dual-training model, in which operators are schooled in basic chemistry, machinery maintenance, and control systems, often completing apprenticeships at utilities or water companies. Many of these skills are transferable to desalination (e.g. understanding pressure vessels and water chemistry).

Additionally, German engineering firms are highly advanced in water technology (including developing RO membranes and control software), so knowledge of the latest equipment often filters into training.
However, explicit desalination content is typically absent from standard curricula, as Germany's climate provides ample freshwater and thus little domestic desalination deployment. German technicians required for desalination projects (for instance, in overseas hydrogen ventures) usually receive on-the-job training or pursue specialised short courses.

The gap, therefore, lies in the lack of a dedicated module on seawater desalination and its unique challenges (such as membrane fouling by salt/brine) within national qualifications. Given Germany's push for a global hydrogen economy, there are ongoing discussions about updating training for Wassertechniker to include desalination and electrolysis feed-water preparation, thereby ensuring that German experts remain at the forefront of water technology in new contexts.

### Gulf Region (KSA/UAE)

The Gulf countries arguably have the most direct experience with desalination plant operations, as desalinated seawater forms the backbone of municipal and industrial water supply. In Saudi Arabia, for example, the Saline Water Conversion Corporation (SWCC) alone produces about 69% of the country's desalinated water – roughly 20% of global desalination capacity, equivalent to around 11.5 million $m^3$/day. Vocational training in the Gulf is closely tied to these massive infrastructure needs.

Saudi Arabia's Technical and Vocational Training Corporation (TVTC), together with SWCC's own Saudi Water Academy, runs specialised programmes to train operators and technicians for both thermal desalination (multi-stage flash and multi-effect distillation) and RO plants. Trainees learn to manage high-pressure boilers, large turbines, and pumps, while monitoring water quality in real time. The United Arab Emirates (UAE) has similar training initiatives through entities such as Dubai Electricity and Water Authority (DEWA) and Emirates Water and Electricity Company (EWEC), often partnering with international firms to upskill workers on the latest RO technologies.

The strength of Gulf training lies in its decades-long accumulation of expertise and dedicated institutions. Operators from this region are skilled in keeping mega-scale plants running efficiently under harsh conditions, optimising energy use, and implementing strict safety and maintenance schedules. They are also familiar with integrated power-and-water co-generation, which is common in the Gulf's desalination plants.

With the advent of $GH_2$ projects (for example, NEOM's planned hydrogen–ammonia plant in the Kingdom of Saudi Arabia, which includes a large renewable-powered RO facility), these countries are beginning to factor in new requirements. For instance, running desalination on variable renewable energy (RE) or directly coupling with electrolysers may require more flexible operational skills and advanced control algorithms.

Currently, hydrogen-specific content (such as dynamically adjusting desalination output to match intermittent solar/wind power or ultra-pure water production for fuel cells) is not yet standard in curricula. Bridging that gap will be the next step – and efforts are already underway, as Gulf governments invest in pilot projects and send engineers abroad for training in green desalination.

Overall, the Gulf's vocational systems in water serve as a benchmark for scale and specialisation, requiring only incremental adaptations to align with RE-powered hydrogen production.

### Kenya

Kenya's vocational education in water and plant operations is centred on the country's diverse water supply challenges, with relatively little emphasis on desalination. Kenya's coastline is comparatively short, and while small desalination units have been introduced for some arid coastal communities and hotels, large-scale desalination is not yet widespread.
The Kenya Water Institute (KEWI) offers diploma- and certificate-level programmes in Water Engineering and Wastewater Technology, preparing technicians for roles in municipal waterworks, borehole management, and wastewater treatment.

These curricula cover water supply design, pump installation, and treatment of river or groundwater, and increasingly integrate sustainable practices such as rainwater harvesting and solar-powered pumping. A notable strength is the inclusion of RE concepts; for instance, Kenyan training often features solar water heating and pumping modules in line with national regulations promoting solar hot-water systems. This gives graduates a holistic view of the water–energy nexus and resource conservation.

However, content on desalination or high-salinity water treatment is minimal or absent – reflecting Kenya's historical reliance on freshwater resources. As $GH_2$ initiatives emerge in Africa, Kenya may consider coastal $GH_2$projects (leveraging wind or solar in places such as Lamu); this would necessitate desalination skills that the current system does not explicitly provide. The gap includes knowledge of RO systems, sea-water intake and pre-treatment (for removing salt and marine organisms), and managing brine waste. Moreover, handling high-purity water for electrolysers – which is more demanding than typical drinking-water treatment – represents a new challenge for Kenyan technicians.

Kenya's strong foundation in water engineering education means it could adapt by developing short courses or adding modules on desalination. Partnerships with countries experienced in desalination (such as Israel or the UAE), as well as international development projects, could help fast-track the transfer of these skills into Kenya's TVET institutions.

### Zambia

Zambia's technical training for plant operations in the water sector remains focused on conventional water treatment and distribution, as the country is landlocked and has abundant freshwater bodies. The traditional vocational pathway related to water in Zambia has been through programmes such as the Craft Certificate or Diploma in Water Operations, along with general engineering tracks. Historically, many Zambian technicians in utilities have been trained through on-the-job experience or broad technical college courses in plumbing and sheet metal, which included basic pipework and pump maintenance.

The strength in Zambia's context is very much its hands-on skill set: technicians are adept at improvising solutions for rural water supply, maintaining boreholes, and repairing pumps or treatment units with limited resources. This practical ingenuity is highly valuable. There is, however, a significant gap in exposure to advanced or specialised processes such as desalination. Since Zambia is landlocked and has not needed to desalinate water, its vocational syllabus does not cover RO membranes, seawater intake systems, or related chemistry.

Additionally, any hydrogen production in Zambia (for example, using hydroelectric power for electrolysis) would likely rely on freshwater, meaning desalination may not even be featured in future hydrogen plans. Nonetheless, if Zambia were to engage in Power-to-X (PtX) projects requiring ultrapure water (such as producing ammonia for fertiliser or export), current training would require upgrading. Topics like ion exchange, demineralisation, and modern water purification technologies would have to be introduced.

In summary, Zambia's vocational training excels in foundational plumbing and basic water treatment, but modern RE/$GH_2$-linked water processing technologies remain outside the curriculum. Collaboration with international programmes or neighbouring countries will be key if these skills become necessary, ensuring Zambian technicians can participate in regional hydrogen supply chains that involve complex water treatment.

### Uganda

Uganda's water sector training, while diverse, is geared towards its local context of freshwater usage. Through bodies such as the Directorate of Industrial Training (DIT) and technical colleges, Uganda offers a National Certificate in Water Operations and related qualifications under its competence-based education framework. Trainees learn about pumping, water storage, treatment of lake and river water, and distribution maintenance.

Uganda's programmes often incorporate multiple skills areas – for example, a trainee in a plumbing or water certificate might also gain basics in electrical controls and even refrigeration, since many courses are multidisciplinary. This produces versatile technicians who can adapt to various roles (plumbing, pipefitting, pump operation, etc.).

A strength of the Ugandan approach is this comprehensive cross-training, which is valuable in rural and small-town water schemes where a single operator may be responsible for mechanical, electrical, and water-quality tasks.

That said, Uganda's curricula do not yet include desalination or other advanced treatments specific to saline or brackish water, as inland water resources have historically made such technologies unnecessary. Even for RE integration, Ugandan TVET has primarily emphasised solar pumping for village water supply, but not the large-scale linkage of water treatment with megawatt-scale power. If Uganda were to venture into $GH_2$ (there have been discussions of using its hydro or geothermal potential for hydrogen), the water for electrolysis would likely be sourced from freshwater.

Thus, the immediate gap is less about desalination and more about ultra-pure water production and industrial water recycling knowledge. Current training may briefly touch on filtration and distillation in theory, but practical skills in operating demineralisation units or understanding corrosion control in high-purity water systems still need to be developed. Uganda could benchmark against international best practices, or draw on its own oil-refining sector (where water treatment processes are applied), to begin introducing these new topics into training.

Overall, Uganda's vocational system is adaptable, but incorporating $GH_2$-related water skills will require deliberate curriculum enhancements, since these areas fall outside traditional water-supply training.

### Japan

Japan's approach to vocational training in water and plant operations is characterised by high technical standards and rigorous certification, though not specifically centred on desalination. Municipal water treatment and industrial plant operators are required to be licensed through national exams and training programmes. Typically, a Class-2 or Class-1 Water Treatment Technician licence is needed to supervise water facilities, administered by the Ministry of Health, Labour and Welfare or related agencies.

Japanese training emphasises precision, automation, and resilience – for example, operators are taught to manage treatment systems that can withstand earthquakes and to integrate advanced technologies (sensors, automated controls) for efficiency. They are also familiar with handling gas chlorination and on-demand water heaters, reflecting a blend of plumbing and plant-operation skills.

In terms of RE and hydrogen, Japan is a global proponent of a "hydrogen society" (fuel cells in homes, hydrogen fuelling stations, etc.), but water supply for hydrogen has not become a bottleneck given Japan's rainfall. Desalination exists in limited niches (such as remote islands or emergency backup systems), making desalination content non-standard in vocational curricula.

The strengths of Japan's system – strong foundations in science, a culture of continuous improvement, and manufacturer-led skill updates – mean that if hydrogen production via seawater electrolysis were to expand domestically, or if Japanese companies were to engage in overseas hydrogen projects, the workforce could be upskilled relatively quickly. Currently, any specialised training for desalination or high-purity water is likely delivered through on-site training by equipment suppliers or short courses offered by bodies such as the Japan Water Works Association.

A potential gap in the context of RE/$GH_2$ is the lack of formal inclusion of hydrogen-specific water processes; for example, operating a desalination plant in tandem with an offshore wind farm may be a scenario Japanese operators have not yet encountered. Nevertheless, given Japan's proactive stance on hydrogen and its advanced research and development in membranes (Japanese firms are leading producers of RO membranes), vocational programmes are expected to evolve. In the near future, Japan may introduce modules on hydrogen-related utilities (including water electrolysis systems) through its polytechnic universities or professional development courses, ensuring that its technicians remain at the cutting edge.

### Israel

Israel stands out as a country that has successfully bridged vocational skills with a national-scale desalination rollout. With over half of its domestic water supplied through seawater desalination, Israel has built a workforce capable of operating some of the world's largest and most efficient RO plants, such as the Sorek and Ashkelon facilities.

Historically, Israel's formal plumbing and mechanical trades had a multi-tier certification system (five levels of plumber, with higher levels covering gas and heating systems).

However, enforcement of these certifications has been inconsistent, meaning that many technicians acquired skills through apprenticeships or technical military experience. In practice, the expertise for desalination plant operations in Israel often comes from a mix of academic engineers and experienced technicians trained on the job by companies such as IDE Technologies or Mekorot, the national water company.

Strengths of the Israeli system include its culture of innovation and problem-solving born of necessity. Technicians are accustomed to optimising operations, improving energy efficiency, and addressing challenges such as membrane biofouling.

Training is often continuous and project-based: for example, when new technologies (energy-recovery devices, advanced filtration systems) were introduced, Israeli teams underwent manufacturer-led training and in-house workshops. Israel also benefits from extensive R&D through institutions such as the Zuckerberg Institute for Water Research, which indirectly enhances vocational training as cutting-edge practices filter down to operational staff.

Currently, there is no specific vocational qualification labelled for "hydrogen desalination" in Israel, since hydrogen remains an emerging sector. Gaps in the Israeli context are therefore less about desalination knowledge, which is strong, and more about integrating this expertise with hydrogen production processes.

Should Israel invest in PtX projects (for example, using solar power to produce hydrogen or ammonia), existing water professionals would require orientation on the stringent purity requirements of electrolysers and on coupling desalination output with variable power input.

Given Israel's track record, it is likely to develop short-term specialised courses, perhaps through its technical colleges or via international partnerships, once demand arises. According to the International Water Association, Israel's vocational landscape for water is highly competent in desalination and reuse, with the country recycling approximately 90% of its wastewater for agriculture – the highest rate globally.

Nonetheless, expansion is needed to accommodate $GH_2$ systems – a challenge it is likely to handle due to an innovative workforce and support from both industry and government.

### Netherlands

The Netherlands has a strong reputation in water management and a forward-looking vocational education system, although desalination has not been a core domestic focus. Dutch secondary vocational programmes (MBO) in the installation and environmental sectors produce "All-round Operation Technicians" for water treatment and distribution, under frameworks set by organisations such as SBB (Cooperation Organisation for Vocational Education, Training and the Labour Market). These programmes emphasise modern skills including process automation, water-quality monitoring, and energy-efficient operations.

A notable emphasis in recent years has been sustainability: Dutch curricula often integrate modules on climate adaptation (for example, managing heavy rainfall or drought impacts) and circular water use (such as wastewater recycling and nutrient recovery). When it comes to hydrogen and desalination, the Netherlands occupies a more nuanced position. Domestically, the country is phasing out natural gas for heating, which shifts training priorities towards heat pumps and other low-carbon technologies rather than new gas infrastructure.

At the same time, freshwater availability is generally sufficient, making large-scale desalination for drinking water unnecessary in the Netherlands, where rainfall ensures an adequate supply. Thus, traditional training does not cover seawater desalination technology in depth.

However, the Netherlands is a key player in Europe's $GH_2$ plans, often in partnership with countries where desalination is integral (for example, importing $GH_2$ or ammonia from Middle Eastern and North African countries). Dutch companies and ports, such as Rotterdam, are actively involved in these international hydrogen supply chains, prompting Dutch institutions to give increasing attention to desalination know-how.

The strength of the Dutch system lies in its adaptability and close industry alignment. Sector committees have already begun identifying emerging hydrogen skills – from electrolysis operation to pipeline conversion – and update curricula on a five-year cycle to keep pace. There are early indications of hydrogen topics being included in technical education (for instance, lessons introducing hydrogen production and conversion as future trends).

The main gap remains the absence of detailed desalination training as a standard component for Dutch technicians, since it is not considered a domestic necessity. To address this, the Netherlands is leveraging its international outlook: vocational exchanges and collaborations – such as supporting training in Morocco's hydrogen programme – help Dutch institutions acquire relevant knowledge. Over time, Dutch vocational courses in process technology and water management may add electives on desalination and water for hydrogen, ensuring that graduates are equipped to contribute to global projects.

In summary, Dutch vocational education excels in modern, sustainable water skills. While desalination is a minor gap, the system's proactive evolution and international cooperation are likely to fill it as the hydrogen economy grows.

### Morocco

Morocco's vocational training landscape for water and plant operations is undergoing rapid development in line with the country's ambitious RE and $GH_2$ goals. Traditionally, Morocco – through the OFPPT (Office of Professional Training and Job Promotion) – offered programmes in Industrial Maintenance, Water Treatment, and Electromechanical Trades, providing a foundation for roles in conventional water plants and irrigation systems. Basic desalination knowledge was historically confined to a niche within water treatment courses, as Morocco had few desalination facilities until recently (for example, the Agadir plant for drinking water and agriculture).

The strengths of the Moroccan system lie in its solid fundamental training – trainees acquire core skills such as pump operation, piping, and electrical controls – and in the presence of specialised institutes such as IFMEREE (Institute for Renewable Energy and Energy Efficiency), which focus on energy–water nexus topics.

However, with Morocco positioning itself as a future $GH_2$ powerhouse, it recognises the shortfall in specialised skills for large-scale desalination and complex plant operations. Planned $GH_2$ projects (such as hydrogen/ammonia plants in coastal deserts) will rely on large desalination units to provide pure water, yet current vocational programmes have not fully integrated subjects such as RO desalination engineering, high-pressure system safety, or brine management.

This gap has been acknowledged at the highest levels: the government and training bodies are actively reforming curricula, launching train-the-trainer initiatives, and partnering with international experts – including from the Netherlands and Germany – to create hydrogen-ready training programmes.

There is also a strong focus on scale, with efforts to increase the number of skilled workers. For example, new short courses on desalination technology and maintenance are being rolled out with support from development agencies, while existing water technicians are being offered upskilling opportunities in areas such as membrane replacement, water pre-treatment for electrolysis, and chemical safety.

Morocco's vocational reform is still a work in progress, but its ability to supply the necessary workforce – both in numbers and expertise – will significantly influence the success of its $GH_2$ and desalination projects.

In essence, Morocco's current training provides a solid baseline of plumbing and mechanical skills; its key challenge and opportunity lie in rapidly incorporating advanced desalination operations into that framework – a transformation already under way with strong government backing and international cooperation.

### South Africa - New Green Hydrogen Vocational Qualifications

In South Africa, vocational training for water treatment specialists (including desalination plant operators) is governed by the Quality Council for Trades and Occupations (QCTO) and the relevant Sector Education and Training Authorities, notably the Energy and Water SETA (EWSETA).

Until recently, training for water treatment was based on unit-standard qualifications (e.g. the Water and Wastewater Treatment Process Control certificates at NQF Levels 1–3). These have now been replaced by integrated occupational programmes.
For example, the Occupational Certificate: Water Process Controller (NQF Level 3), registered in 2020, prepares artisans to operate water services works producing potable water and treating wastewater.

The curriculum covers inspection and operation of chemical, biological, and physical treatment processes (e.g. coagulation, filtration, disinfection), basic water chemistry, equipment maintenance, and health, safety and environmental regulations. It provides a foundational entry into the water sector, ensuring operators can run unit processes and monitor water quality to meet standards such as South Africa's SANS 241: Drinking Water Specification, under supervision.

The Water Institute of Southern Africa (WISA) and the Department of Water and Sanitation (DWS) played key roles in developing these qualifications. WISA also registers professional Process Controllers who meet the required training and experience. Notably, the plumbing trade – governed by the Plumbing Industry Registration Board – remains separate, focusing on water-supply distribution and installation, whereas water treatment and desalination operations fall under specialised process controller qualifications.

South Africa has more recently begun to integrate desalination and advanced water-treatment technologies into its vocational framework, aligning skills development with emerging water-security needs. In 2018, a new Occupational Certificate: Industrial Water Process Controller (NQF Level 5, 251 credits) was introduced, becoming one of the first nationally recognised qualifications to explicitly include membrane desalination in its scope.

The purpose of this NQF5 programme is to train practitioners to "control, monitor and manage industrial water treatment plants" – encompassing processes such as demineralisation, desalination, condensate polishing, membrane technology, and other advanced treatment methods. The issuing authority is the QCTO (under the Occupational Qualifications Sub-Framework), with EWSETA as the Development Quality Partner and industry stakeholders such as Eskom, Rand Water, and WISA contributing to curriculum design. In addition, South Africa approved a new Water Works Management qualification (NQF Level 6) in 2024–2025.

While this NQF6 qualification is aimed at supervisory and management roles, it reflects the broader shift towards modernising water curricula. South African authorities have also signalled the need for specialised skills in emerging areas – for example, EWSETA has noted that future training must address "biological treatment, smart water grids and desalination" to keep pace with technological advances. Although no stand-alone "desalination technician" trade previously existed, the new qualifications at NQF 5–6 mark the first time that hydraulic and water process curricula explicitly incorporate desalination content, representing a milestone in upskilling for climate-resilient water supply and green economy initiatives.

**Curriculum Content and Focus Areas:** The water treatment and desalination-focused curricula in South Africa cover a broad range of technical competencies, with strong emphasis on water-quality control, process technology, and safety compliance. Key learning areas include:

- **Water Treatment Processes (Conventional and Advanced):** Trainees learn to operate and control all major unit processes in treatment works. This spans conventional methods (e.g. coagulation/flocculation, sedimentation, sand filtration, chlorination) as well as advanced technologies. The Industrial Water Process Controller (NQF5) curriculum explicitly includes membrane-based processes such as reverse osmosis (RO) desalination and ultrafiltration, ion exchange, and other high-purity water treatments. Trainees are taught the underlying science (water chemistry and membrane physics) and optimisation techniques. They must understand pretreatment requirements (e.g. cartridge filtration, antiscalant dosing), monitor pressures and flow rates, and respond to issues such as membrane fouling or salt breakthrough. They also study demineralisation and water reuse techniques, reflecting applications ranging from municipal desalination to industrial recycling.

- **Water Quality Monitoring and Analysis:** A core focus is rigorous water-quality control throughout the treatment cycle. Trainees practice sampling and testing of raw, in-process, and final water, measuring physical, chemical, and microbiological parameters (turbidity, pH, chlorine residuals, conductivity, microbial counts) using both laboratory and online instrumentation. They learn to interpret results against standards such as SANS 241 to ensure compliance. For desalination, additional analytical skills are included (e.g. monitoring salt rejection rates, total dissolved solids in permeate, and contamination checks). Practical modules reinforce skills in sample collection and field analysis.

- **Membrane Desalination Technology and Equipment:** The curricula include detailed modules on membrane technology and RO plant operation. Trainees become familiar with system components – high-pressure pumps, energy recovery devices, membranes, pressure vessels, and flow-control valves – and their maintenance. They study start-up and shutdown procedures, membrane cleaning protocols (CIP), and safe handling of high-pressure systems (50–70 bar). Supporting processes such as pretreatment (e.g. ultrafiltration) and post-treatment (e.g. remineralisation) are also covered. For context, trainees are taught that while only six small desalination plants existed nationwide as of 2017, desalination is now gaining traction as a drought-resilience measure.

- **Plant Automation, Instrumentation and Control:** Modern facilities rely on SCADA systems. Trainees are taught to interpret sensor readings (flow, pressure, quality), calibrate instruments, and adjust control setpoints. They practice using control panels and simulations to respond to alarms, optimise processes, and maintain dosing systems. This competence prepares them to supervise high-tech plants with minimal downtime.

- **Safety, Health and Environmental Standards:** All training stresses occupational health and safety. Modules include safe handling of chemicals (acids, chlorine gas), use of PPE, first aid, fire safety, and emergency response (e.g. chlorine leaks, pipe bursts). Environmental compliance is also emphasised, including responsible disposal of brine and sludge. National frameworks such as the Blue Drop (drinking water quality) and Green Drop (wastewater quality) are incorporated to build awareness of regulatory compliance.

- **Technical Coordination and Operations Management:** Higher-level qualifications (NQF5 and NQF6) include supervisory and coordination skills. Trainees learn to schedule maintenance, manage chemical supplies, oversee junior operators, and optimise processes for efficiency. Case studies of plant upsets or equipment failures develop problem-solving skills. The curriculum is multidisciplinary, blending environmental science, process engineering, mechanical/electrical maintenance, and quality management, to produce well-rounded technicians and operators.

**Rollout Status and Training Delivery:** Integration of desalination into South Africa's vocational training is relatively recent and still being implemented. The Industrial Water Process Controller (NQF5) qualification, first registered in 2018 and re-registered through 2025, is active and available for delivery. Developed collaboratively by EWSETA and major stakeholders, it provides a pathway for experienced operators to upgrade their skills.

As of 2025, several providers have begun offering courses aligned with this qualification. For example, the Southern Africa Youth Project (a skills-development NGO) launched a 10-week online programme to prepare trainees for the NQF5 certificate. This covers water purification processes, industrial treatment operations, and safety requirements, demonstrating the use of blended learning to broaden access.

Public-sector utilities and training centres are also preparing to roll out the new curricula. The Rand Water Academy, for instance, is expected to integrate QCTO's new occupational standards into its programmes. WISA, as the professional body, has partnered with EWSETA (2024–2025) to deliver recognition of prior learning (RPL) programmes and short courses, enabling practicing controllers to attain the new qualifications.

This push is partly driven by regulatory change – notably, the Department of Water and Sanitation's Regulation 3630 (June 2023), which mandates that all treatment works be overseen by qualified, registered process controllers by 2025. In response, a national effort was launched to certify hundreds of existing operators. EWSETA reported a shortfall of about 1,704 qualified process controllers as of 2022, and has since funded "upskilling" projects with WISA and the Local Government SETA. These initiatives include structured candidacy programmes enabling mid-career operators to complete the Water Works Management Practitioner (NQF6) qualification, as well as bursaries and grants for younger trainees to enter at NQF3 or NQF5 levels.

**Institutional Proposals (South Africa)**

Unlike $GH_2$ training – spearheaded by select TVET colleges and universities – water treatment and desalination training in South Africa leverages a mix of water-sector institutions and accredited providers. Several public TVET colleges are beginning to show interest in water and sanitation programmes, particularly in regions facing water scarcity, but historically much of the training has been delivered by water utilities themselves. For example, large water boards (Rand Water, Umgeni Water, Magalies Water, etc.) and metros (e.g. City of Cape Town, eThekwini) maintain in-house training facilities or partnerships for developing their plant operators. These institutions are likely to seek accreditation as Skills Development Providers (SDPs) for QCTO qualifications so that they can formally issue the new Occupational Certificates.

EWSETA has been driving awareness through its partnerships, engaging municipalities and water boards to adopt the curriculum and retrofit their training workshops with updated equipment. International collaboration also plays a role. For instance, the World Water Academy (a Dutch training organisation) recently provided specialised courses to South African water professionals (e.g. a wastewater treatment course for Rand Water staff), indicating knowledge exchange aimed at strengthening local training capacity.

Within academia, some universities of technology and institutes may contribute by offering advanced certificates or acting as assessment sites. The Durban University of Technology and Tshwane University of Technology, for example, have long offered programmes in water and wastewater technology and could align these with the occupational qualifications, especially at NQF6 level. The University of Stellenbosch and University of Pretoria, which conduct desalination research, might also support curriculum development or provide guest lecturers for modules on membrane technology.

Meanwhile, private training providers and non-profit organisations are entering the field. The Southern Africa Youth Project, mentioned above, is one example; others (such as professional training consultants in the water sector) are expected to gain accreditation to deliver short courses on specific skills like RO plant operation or water-quality testing. To support wider reach, EWSETA has also indicated interest in mobile training units (similar to CHIETA's Smart Skill Centres) to bring practical training to remote areas, ensuring even rural water schemes can employ certified operators.

**Pilot Programmes and Future Outlook (South Africa)**

South Africa's push for desalination and advanced water-treatment skills is still at an early stage, but momentum is building. By mid-2025, the first cohorts of trainees were undergoing the updated programmes.

While there is no single large-scale "train-the-trainer" pilot (as seen with hydrogen fuel-cell courses), the sector has leveraged existing frameworks such as the DWS Blue Drop certification process to scale up quickly. For example, many experienced operators participated in EWSETA/WISA's RPL assessments in 2024–2025 to attain the Occupational Certificate: Water Process Controller based on their years of experience, thereby immediately increasing the number of formally qualified desalination-capable operators.

At the same time, new learners are enrolling, and water boards such as Umgeni Water have signalled plans to host apprenticeship and learnership programmes tied to these qualifications, giving students hands-on experience at treatment plants (including pilot desalination units) alongside completing the QCTO curriculum. Looking ahead 1–2 years, multiple training centres and colleges are expected to roll out dedicated desalination modules as part of their water and sanitation courses.

EWSETA has explicitly identified desalination as "critical for the development of the $GH_2$ economy in South Africa" – since $GH_2$ production requires large volumes of purified water, and coastal hydrogen projects may invest in desalination facilities. This cross-sector linkage means graduates of the new programmes could find roles not only in municipal utilities, but also in hydrogen fuel production sites, power plants, and industries requiring high-purity water.

By 2026, South Africa is expected to have a growing cadre of certified water-treatment artisans and technicians competent in operating desalination plants and other modern treatment systems. This capacity-building represents a strategic step toward national water security and provides a valuable model for neighbouring countries such as Namibia.

**Summary**

In summary, South Africa's experience demonstrates how updating vocational curricula – integrating desalination technology, enforcing operator certification, and partnering with industry – can equip the water and sanitation workforce with the skills required to meet the challenges of a water-scarce, climate-stressed future.

## 1.4 Gap analysis within the field of Desalination/Plant Operations

A desalination technician serving a $GH_2$ plant must operate equipment that is more akin to a petrochemical unit than to a municipal works: 80 bar high pressure pumps, energy recovery devices, duplex stainless and FRP pipework, ultralow fouling RO membranes, online conductivity/SDI/ORP sensors tied into a plantwide SCADA, and brine systems that meet stringent environmental discharge permits or ZLD requirements.

In addition to core water treatment know-how, the role demands competence in hydrogen-site safety (ATEX zoning, $O_2$ management), rapid load following to match variable renewables, and tight quality control because the downstream electrolyser typically requires ASTM Type II ($\leq 1$ µS/cm) permeate.

Plus, mini desalination(rural) units typically run at 25–35 bar, draw brackish water that can swing from 3 g $l^{-1}$ TDS to >10 g $l^{-1}$ after rain, and rely on cartridge filters, solar pumps and GSM alarms.

Core competence blocks, therefore, include:

**Table 1: Green Hydrogen Desalination/Plant Operations Competency Family (proposed)**

| Competence family | Typical elements | Why it matters – Mini desalination (rural 25–35 bar) | Why it matters – Green $H_2$ (industrial 80 bar) |
|---|---|---|---|
| **Membrane and Pressure Vessel Ops** | RO/UF element loading, SDI strip tests, pressure decay & vacuum checks, CIP recipes | Skids foul quickly on iron rich boreholes; on site artisan must diagnose and clean without vendor | $\geq 1$ µS $cm^{-1}$ permeate trips electrolyser; integrity tests feed warranty KPIs |
| **Pre treatment and Adaptive Dosing** | Cartridge/media filter change out, antiscalant, chlorine/bisulphite, manual jar tests | Cartridge blindness is #1 call out; correct dosing extends filter life when logistics are slow | Dynamic dosing must follow rapid turndown; chemistry shift prevents shock fouling |
| **High Pressure Hydraulics and Energy Recovery** | 25–35 bar multistage pumps, simple ERDs or none; seal change out, pressure gauge calibration | Wrong start/stop cracks casings; pump failure cuts village supply for weeks | 80–85 bar plunger pumps + isobaric ERDs dictate energy cost and uptime |
| **Brine / Reject Management** | Safe reject disposal, evaporation trenches, livestock exclusion, fluoride/boron awareness | Poor reject handling contaminates nearby wells and grazing lands | ZLD loops or marine diffusers must meet lender ESG covenants and modelled dilution |
| **Corrosion / Scaling Control** | PVC/HDPE joints, FRP housings, basic hardness & iron tests | Prevents premature cartridge and housing failure in high $Cl^-$, high iron water | Duplex SS, FRP, CP systems protect high value assets from pitting at 80 bar |
| **Instrumentation and Remote Monitoring** | GSM SMS alarms, basic conductivity & pressure transmitters, manual log sheets | Single artisan must react to SMS fault codes; no SCADA room on site | Full SCADA/historian, vibration & $\Delta P$ trending enables semi autonomous operation |
| **Energy and Process Integration** | PV pump curves, battery SOC, simple VFD start/stop logic | Matching skid duty to solar window avoids battery abuse and dry run | Demand side response aligns RO duty with RE intermittency to protect LCOH |
| **Water and $H_2$ site Safety (HSE)** | Lock out/tag out, chemical handling, confined space in pump house | Prevents chlorine burns and electrical accidents when contractor support is remote | ATEX zoning, fire and gas, $O_2$ management protect personnel and adjacent $H_2$ blocks |
| **Quality Assurance and Data Analytics** | Paper log sheet, weekly handheld TDS & flow tally | Enables district officer to spot fouling trends and schedule filter orders | ISO 17025 sampling, digital twin analytics underpin performance guarantees |

We have examined the following qualifications:

**Table 2: Overview of examined qualifications**

| Qualification No. | Trade name (NTA) | Level | Relevant content |
|---|---|---|---|
| **Q1045** | National Vocational Certificate in Water Supply & Sanitation | 2 | Foundations in lab tests, basic mechanical/electrical skills, safety and sampling – no membrane or HP equipment coverage |
| **Q1046** | National Vocational Certificate in Water Supply | 3 | Adds advanced chemistry, control room ops and instrumentation (Unit 2147, 10 credits) – still municipal in focus |
| **Q1047** | National Vocational Certificate in Sanitation | 3 | Strength in sludge handling and ICA equipment (Unit 2147), plus lab skills; little relevance to seawater systems |
| **Q1048** | National Vocational Certificate in Water Supply | 4 | Introduces "Demonstrate an understanding of desalination water treatment processes" (Unit 1836, 15 credits) – the only direct desalination content |

After examining each qualification, we have concluded the following:

**Table 3: Alignment of TVET Pathways with Desalination Needs**

| Pathway | Key desal relevant content now in place | Fit for MINI desalination (rural 25–35 bar) | Fit for GREEN $H_2$ SWRO (80 bar) | Principal gaps / unit standard evidence |
|---|---|---|---|---|
| **Water Supply track (Q1045 L2, Q1046 L3, Q1048 L4)** | Chemistry, control room culture, instrumentation (Unit 2147 10 credits), basic pumps & package plant operation (Unit 1809 8 credits) plus theory on desalination (Unit 1836 15 credits) | GOOD foundation. Covers sampling, filter hygiene, cartridge change out and borehole pump basics needed by mini skid caretakers. | Partial match. Lacks HP pumps, ERDs, membrane autopsy, ATEX & brine diffuser design. | No RO membrane integrity, scaling indices, HP hydraulics or ATEX |
| **Sanitation / Waste water track (Q1047 L3)** | Strong lab & process control depth, ICA hardware (Unit 2147 10 credits) | MODERATE value – good for cartridge cleaning, jar testing & water safety education around reject streams. | LOW value – little seawater, HP or corrosion coverage. | No membrane, seawater chemistry, corrosion or brine disposal<br><br>Focus on sludge not saline concentrate |
| **Environmental / Water Care elements (Unit 1814 in L2)** | Broad awareness of water environment & EIA duties | Adds community brine safety & hygiene narrative for rural schemes. | Supplementary only – useful for ESG reporting but not plant ops. | No plant level technical depth |
| **Plumbing and Pipe Fitting CBET L4 (Windhoek VTC – in pipeline)** | PVC/HDPE jointing, booster pumps, solar thermal rigs (to be accredited 2026) | HIGH relevance for leak repairs, cartridge housing swaps, solar pump loops on mini skids. | Ancillary – useful for utilities piping inside SWRO pretreatment block. | Needs desal specific solvent weld & FRP familiarity; no duplex SS |
| **Electrical / Instrumentation and Control trades (NIMT / NamWater HRDC)** | Basic PLCs, calibration, SCADA installation (part of Unit 2147) | Medium – supports GSM/SMS alarm panels and VFD pump control on skids. | Essential backbone – but curriculum must add historian set up, ΔP / vibration trending, digital twin analytics. | Present focus is hardware install; little on analytics & predictive CBM |

**Key take-away:** The existing Water-Supply pathway (Q1045 → Q1046 → Q1048) already provides the best "backbone" for a desalination-for-$H_2$ technician – through embedding chemistry, control-room culture, and an introductory desalination unit.

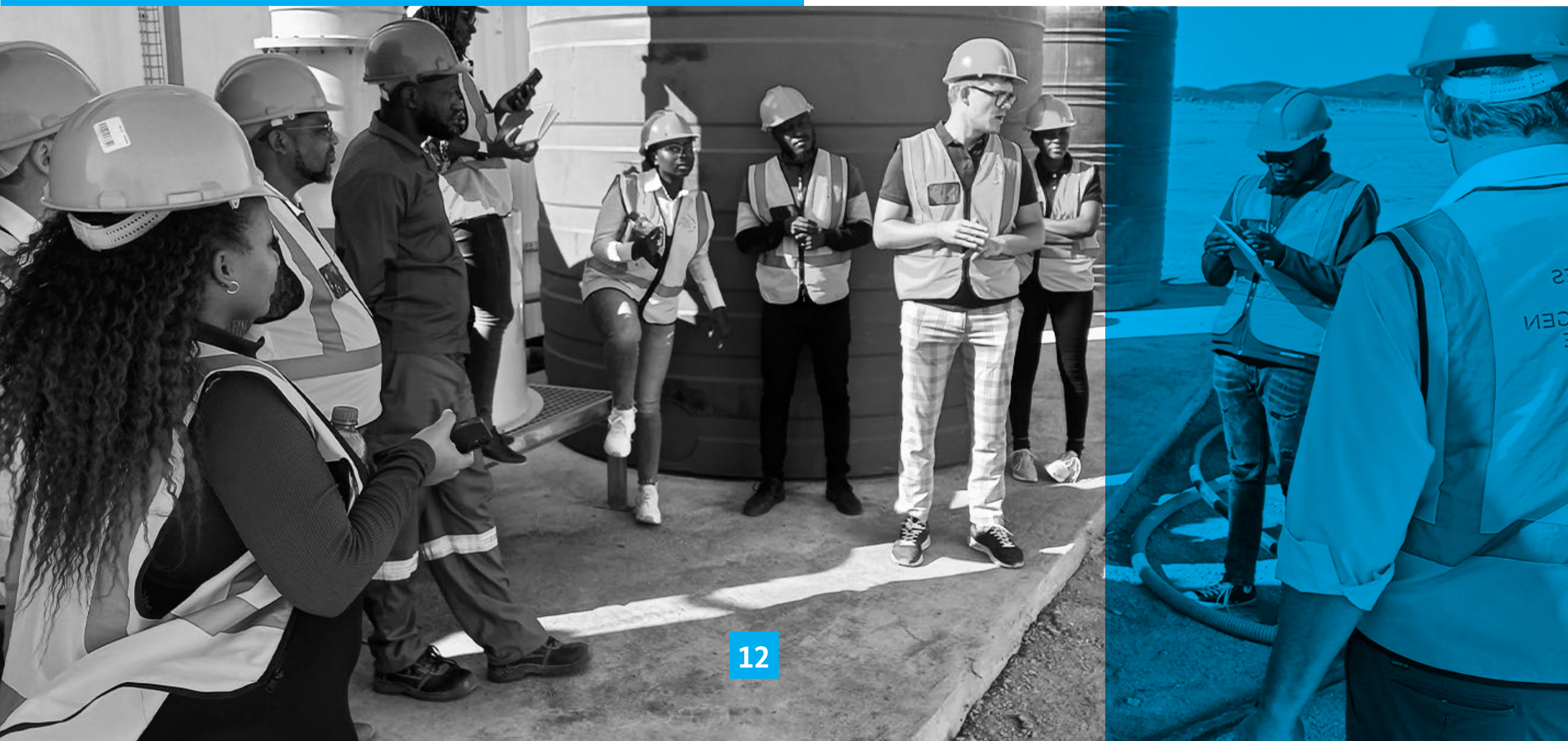
However, it is limited to "understanding"; while failing to incorporate hands-on competence with high-pressure RO trains, energy-recovery equipment, or hydrogen-site safety.

Sanitation and broader environmental programmes remain valuable for auxiliary systems – polishing of domestic water, grey-water reuse, and compliance monitoring – but will not meet the operational or safety-critical demands of a $GH_2$ desalination block.

**Recommendation:** develop an up-skilling module or hybrid qualification that stacks onto the Level-4 Water-Supply certificate, covering:

- RO-specific hydraulics and energy recovery
- Brine management and marine outfall hydraulics
- Materials and corrosion in high-salinity, high-pressure contexts
- SCADA-based predictive maintenance and digital-twin analytics
- Hydrogen-plant HSE and cross-process integration

This targeted add-on would leverage existing TVET infrastructure while meeting the competency envelope required by investors and EPC consortia in the emerging $GH_2$ sector.



# 2

# RECOMMENDATIONS FOR NECESSARY TRAINING MEASURES FOR DESALINATION/WATER OPERATIONS

To be able to recommend training measures when it comes to desalination meaningfully, the following should be considered:

- **Groundwater quality drivers –** Coastal and southern Karas/ Erongo boreholes often exceed 25 g TDS $l^{-1}$; northern Oshikoto/ Kunene/Kavango wells are typically brackish (3–10 g $l^{-1}$) with high hardness, iron and fluoride. Inter-annual variability is large, so O&M staff must diagnose changing feedwater and adapt pre-treatment

- **Field evidence –** MAWFLR runs ≈ 12 mini-RO units (borehole-skids). Handover training was “one day”; contractors returned to pull fouled cartridges because local artisans “don’t know what high pressure means”.

Therefore, two parallel but articulated skill ladders are necessary: Mini-desalination upskilling (5-day bursts) that can travel to rural VTCs and Industrial-scale modules that bolt onto the Water-Supply Level-4 spine (Q1048).

Based on our analysis, the prioritised list of training measures and rationale are as follows.

**Table 4: Alignment of TVET Pathways with Desalination Needs**

| Rank (all) | Short course / skill gap | Why every operator in Namibia needs it | Indicative hours* |
|---|---|---|---|
| C 1 | Fundamentals of RO pressure and safety (lock out, burst disc, pressure decay test) | One day contractor induction is not enough; pressure mis handling is the root cause of most skid failures | 12h |
| C 2 | Cartridge / bag filter change out and pre treatment troubleshooting | High iron/floc loads in northern boreholes blind filters weekly; skills lacking in both TVET and field manuals | 8h |
| C 3 | Feed water diagnostics for variable salinity (TDS strip, iron, fluoride quick kits; scaling index calc) | Groundwater quality shifts seasonally; rapid field tests avoid unnecessary CIPs or membrane swaps | 12h |

Additionally, the following upskilling tracks are to be considered. The table below reflects the needs of rural water supply.

**Table 5: Mini Desalination (Rural) Upskilling Track**

| Mini Rank | Short course / skill gap | Vocational level rationale (rural artisans, L2–L3) | Hours |
|---|---|---|---|
| M 1 | Skid mounted RO start up / shut down and drought idle mode | Most units sit idle >3 months; wrong shut down causes bio film & scale | 16h |
| M 2 | Chemical dosing with household scale pumps (antiscalant, chlorine, bisulphite) | Contractors leave drums but artisans mis dose or run dry; no related unit standard at L2 | 10h |
| M 3 | Low pressure plumbing repairs (PVC/HDPE solvent and electro fusion) | Leaks and vacuum breaks cited as frequent call outs; aligns with planned CBET Plumbing L4 | 14h |
| M 4 | Solar powered borehole pump and RO skid integration | Many mini plants tied to off grid PV; rural techs need basic MPPT, battery care | 18h |
| M 5 | Basic SCADA / SMS alarm acknowledgement | New EIF funded skids include GSM text alarms; artisans ignore them | 6h |

| Mini Rank | Short course / skill gap | Vocational level rationale (rural artisans, L2–L3) | Hours |
|---|---|---|---|
| M 6 | Spare parts logistics & inventory (filters, seals, membranes) | Lead time ex South Africa 4–6 weeks, so buffer stock maths is critical | 6h |
| M 7 | Community water safety and reticulation hygiene | Fluoride rich reject often dumped in school yards; risk awareness module | 8h |

The table below reflects the needs of desalination operations for $GH_2$ industry.al Green $H_2$ Desalination Track

**Table 6: H2 Desalination upskilling track for medium-term implementation**

| $H_2$ Rank | Short course / skill gap | Vocational level rationale (technicians, L3–L4) | Hours |
|---|---|---|---|
| H 1 | High pressure pumps and isobaric ERDs (strip down, seal fit, vibration trending) | Not covered in any unit standard; downtime & energy cost driver | 35 h |
| H 2 | Membrane integrity, autopsy and CIP optimisation | Electrolyser feed spec $\leq 1\ \mu S\ cm^{-1}$; requires diagnostic depth absent from current quals | 30 h |
| H 3 | Brine disposal design and ZLD / marine diffuser hydraulics | ESG permitting for Hyphen & SS1 plants depends on compliant brine plans | 25 h |
| H 4 | Corrosion and materials (duplex SS, FRP, cathodic) | High salinity + 80 bar; premature failure is major CAPEX risk | 20 h |
| H 5 | SCADA, historians and digital twins | Unit 2147 only teaches installation; operators must configure alarms & CBM | 30 h |
| H 6 | Hydrogen site HSE and ATEX for water staff | No overlap between water TVET and explosive atmosphere codes | 16 h |
| H 7 | Variable renewable load following and energy optimisation | Desalination duty must track PV/wind to protect LCOH | 16 h |
| H 8 | Advanced dosing and bio fouling under intermittency | Municipal chemistry modules ignore stop start regimes | 20 h |
| H 9 | Performance guarantee analytics and financier reporting | Required by offtake contracts; builds on H 5 | 24 h |

*Hours ≈ contact time; Mini track assumes 100 % practical; $H_2$ track assumes 60 % labs/rigs

- The first training budget for rural Namibia should be directed to basic RO safety, filter handling and region-specific feed water diagnostics: all deliverable in a single 5-day caravan.
- For the hydrogen mega projects, the Water Supply L4 certificate is a useful springboard, but it must be topped up with high-pressure, energy integration, and ATEX content to create a full-scope desalination technician capable of meeting electrolyser specs.

These two ladders share a common core (C 1 – C 3), allowing MAWFLR and donor-funded VTCs to build modular, stackable credentials while keeping rural water security and future-facing $GH_2$ competitiveness on the same national skill map.

## 2.2 Short Course 1: Fundamentals of Reverse Osmosis Pressure and Safety (Priority 1)

**Table 7: Fundamentals of RO pressure and safety course outline**

| Element | Details |
|---|---|
| **Course overview and key competencies** | A hands on, plant rig–based module that teaches operators to<br>• Carry out safe lock out/tag out (LOTO) on RO skids and high pressure (HP) pumps.<br>• Inspect and replace burst discs / pressure relief valves; verify correct rating vs pump curve.<br>• Perform and interpret pressure decay and vacuum hold integrity tests.<br>• Diagnose cavitation, seal wear and over pressure excursions from gauge/historian data.<br>• Set and acknowledge GSM/SCADA high pressure alarms (mini skid and industrial variants).<br>• Completion standard: trainee can start up, shut down and put an RO train into safe idle without supervision. |
| **Recommended providers / venues** | Primary TVET hosts<br>• Keetmanshoop VTC – houses planned HP rigs for $GH_2$ Centre of Excellence.<br>• NamWater HRDC (Okahandja) – existing RO pilot plant; trainers familiar with Q1046/Q1048 content.<br>Industry/OEM partners<br>• Pump and ERD OEMs (e.g., Sulzer SSA, Energy Recovery Inc.) for train the trainer kits.<br>• Hyphen / SS1 project EPCs to lend 80 bar demo skid during off line months. |
| **Duration and delivery model** | • Mini desalination cohort – 16 contact hours (2 days) delivered via mobile training caravan; 60 % practical on a 25–35 bar trailer skid.<br>• $GH_2$ cohort – 35 contact hours (5 days) at Keetmans pilot hall; 70 % practical on an 80 bar rig. Blended classroom (pump curves, failure case studies) + “break and fix” drills on live equipment. |
| **Target group and entry requirements** | • Existing rural artisans or water caretakers with Water Supply L2 or equivalent experience; OR<br>• Shift technicians / apprentices enrolled in Water Supply L3–L4 (Q1046/Q1048).<br>• Prerequisites: basic OHS, ability to read pressure and flow units, numeracy for simple calculations. |
| **Capacity building and partnerships** | • Embed as credit bearing short course under NQA, stackable toward Water Supply L3 elective list.<br>• Adopt train the trainer cascade: OEM specialists certify 12 TVET instructors who then deliver nationwide.<br>• Use shared equipment pool (Sweagloc / EPC loan model) to avoid duplicate capex across VTCs.<br>• Sign MoUs with regional VTCs to schedule rural deliveries during school holidays, maximising plant access. |

## 2.2 Short Course 2: Cartridge and Bag Filter Replacement and Pretreatment Troubleshooting (Priority 2)

**Table 8: Cartridge and Bag Filter Replacement and Pretreatment Troubleshooting course outline**

| Element | Details |
|---|---|
| **Course overview and key competencies** | A rapid, hands-on module that equips trainees to:<br>• Select the correct micron rating and media type for high iron or high floc borehole water.<br>• Carry out safe, hygienic cartridge/bag change out (depressurise, drain, O ring inspection, torque spec).<br>• Diagnose premature blinding via ΔP trending and visual fouling assessment; relate symptoms to raw water quality.<br>• Adjust coagulant/antiscalant dose and back wash frequency to extend filter life.<br>• Implement an 8 step troubleshooting ladder (flow loss, colour break through, pressure surges, odour).<br>• Completing trainees can keep a skid running at target flow/TDS for ≥ 7 days without external intervention. |
| **Recommended providers / venues** | Mini desalination focus<br>• Regional VTCs in Oshikoto and Kunene, where iron rich boreholes are common + Namwater HRDC<br>• Industrial focus<br>• Keetmanshoop Centre of Excellence for integration with full pretreatment chain.<br>• OEM / industry partners<br>• Filter/water treatment suppliers (Pall, Pentair, Nafasi) to donate cut away housings and fouling “museum” samples. |
| **Duration and delivery model** | Standard module: 8 contact hours (1 full day) – 40 % classroom, 60 % practical.<br>• Morning – raw water diagnostics, dose calculation drill, ΔP log sheet exercise.<br>• Afternoon – live change out on a fouled 9 element cartridge skid, troubleshooting relay race.<br>Industrial elective add on: +4 h on multimedia filters, inline mixers & dose control loops. |
| **Target group and entry requirements** | • Village water caretakers, borehole-pump helpers, WATSAN artisans with at least Water Supply L2 or equivalent field experience.<br>• Shift technicians on Q1046/Q1048 track needing practical refresh.<br>• Prerequisite: completion of Short Course 1 (Pressure & Safety) or equivalent competency sign off. |
| **Capacity building and partnerships** | • Map the short course to Unit 1809 “Operate a small, specialised package plant” so graduates can RPL credit toward Water Supply L3.<br>• Finance first ten rural deliveries via MAWFLR’s Rural Water Supply budget.<br>• Implement a filter return scheme: used cartridges from field sites shipped to VTCs for inspection labs, supported by supplier CSR funds.<br>• Establish a regional trainer pool (8 instructors) certified jointly by Pall/Pentair and NamWater; rotate through northern and coastal VTCs each quarter. |

## 2.3 Short Course 3: Feed Water Diagnostics for Variable Salinity (Priority 3)

**Table 8: Cartridge and Bag Filter Replacement and Pretreatment Troubleshooting course outline**

| Element | Details |
|---|---|
| **Course overview and key competencies** | Trainees learn to:<br>• Collect representative raw water samples from boreholes or intake sumps.<br>• Use hand held EC/TDS meters and test strips to map salinity swings.<br>• Run field iron (phenanthroline) and fluoride (zirconium SPADNS) quick kits; interpret colour charts.<br>• Calculate Langelier Saturation Index (LSI) for brackish feeds and Stiff and Davis Stability Index for high TDS coastal wells.<br>• Translate indices into antiscalant dose tweaks, cartridge filter change frequencies and CIP triggers.<br>• Log data in a simple smartphone form; trend results to predict "fouling season".<br>Competency benchmark: operator produces a one page water quality profile and recommends a pre treatment adjustment plan. |
| **Recommended providers / venues** | Primary delivery sites<br>• NamWater HRDC laboratory (Okahandja) – existing glassware and colorimetry •<br>• Regional VTC mini labs in Oshikoto and Kunene, where iron rich, variable salinity boreholes are common.<br>• Keetmanshoop VTC for seawater/high TDS scenarios (tie in with Hyphen test wells).<br>Technical partners<br>• Hach / Palin test (quick kit suppliers) for starter packs & colour standards.<br>• University of Namibia Chemistry Dept. – guest lecturers on scaling thermodynamics. |
| **Duration and delivery model** | 12 contact hours (1 ½ days):<br>• Day 1 morning – sampling protocols and kit demonstration<br>• Day 1 afternoon – field excursion to borehole or intake; trainees run tests, log data.<br>• Day 2 morning – LSI/Stiff and Davis workshop (calculator templates); develop adjustment plan.<br>Optional industrial extension (+4 h) covers high precision titration and ion chromatography hand off for SWRO QA labs. |
| **Target group and entry requirements** | • Village water caretakers, WATSAN artisans, borehole supervisors.<br>• Water Supply L3 learners (Unit 1818 "specialist laboratory tests" creditable).<br>Prerequisites: numeracy to handle saturation index formula; completion of Short Course 1 or equivalent OHS sign off. |
| **Capacity building and partnerships** | • Align with existing Unit 1806/1807 (routine and intermediate lab tests) so graduates can claim RPL toward Water Supply L2–L3.<br>• Set up a shared data portal (Google Sheets + offline sync) where trainees upload TDS/iron/fluoride logs for national trend mapping.<br>• Memorandum of Cooperation between NamWater HRDC and UNAM Chemistry to co author the scaling index calculator (LibreOffice template).<br>• Train the trainer workshop: NamWater chemists certify VTC trainers; refresher every two years with new kit revisions. |

# 3

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