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GOVERNMENT OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

STATE OF ERITREA
MINISTRY OF LAND, WATER AND ENVIRONMENT

STUDY
ON
GROUNDWATER DEVELOPMENT AND WATER SUPPLY
FOR
SEVEN TOWNS IN SOUTHERN REGION
OF
ERITREA

OPERATION AND MAINTENANCE MANUAL FOR WATER SUPPLY FACILITY

JANUARY 1999

SANYU CONSULTANTS INC.

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List of Reports

This volume is part of the following reports:

Executive Summary

Debarwa	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Mendefera	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Adiquala	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Dekemhare	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Segeneiti	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Adi Keyih	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings
Senafe	Volume I	Main Report
	Volume II	Appendix
	Volume III	Drawings

Operation and Maintenance Manual for Water Supply Facility

Hygiene Education Manual

Training Manual for Staff of WSA

CONTENTS

Appendix

Abbreviations & Glossary

WSA : Water Supply and Sanitation Authority

WSAO : Water Supply and Sanitation Authority Office

pH : Potential hydrogen

NH_4 : Ammonium Salt

Cl : Chloride

Fe : Iron

Mn : Manganese

F : Fluoride

NO_3 : Nitrate Nitrogen

1 INTRODUCTION

The objective of water supply is to provide the public with a stable supply of safe water, which meets the water demand. Operation and maintenance (hereinafter referred to as "O&M") of waterworks plays an important role in realizing this objective. O&M works are divided into the following;

- inspection, operation, maintenance and repair,
- water volume control,
- water quality control and
- measures to accidents.

This O&M manual aims at preventing the facilities from damage and accidents, so as to operate the water supply facilities effectively and enable uninterrupted water supply and Sanitation Authority. It is prepared exclusively for the staff in charge of O&M stations at the Water Supply Service Office (hereinafter referred to as "WSAO") in the municipality office and the regional offices. Consideration on the present status of O&M in the seven towns is taken into this manual. However, it seems to be difficult to implement some parts of this manual at present, and therefore stepwise implementation of O&M in this manual is recommended. As this manual is stated standard facilities, it shall be modified according to the manufacturer's instructions and operation manual of the actual facilities.

With regard to the intake facilities, the groundwater is the main water source in the seven towns. This manual therefore covers the superintendence of groundwater pumping facilities.

2 WATER QUALITY CONTROL

2.1 General

In order to supply safe and stable water to the water users through pipes, the water shall be disinfected or its quality shall be well controlled by the responsible agency in the municipality or in the region. The quality of water to be supplied shall be within the acceptable limits as specified in the WHO Guidelines or the water quality standards formulated by the responsible agency.

2.2 Water Quality Analysis

Water quality analysis is divided into three types by its conducting frequency; daily, monthly and yearly analyses. Water quality analysis shall be carried out on the following by responsible staff in the WSAO, regional office in main city such as Mendefera, Dekemhare and Adi Keyih or other relevant organizations such as health centers, hospitals, etc. These data shall be kept for more than 5 years.

- water quality analysis of raw water,
- water quality analysis of tap water at the end user to check residual chlorine.

2.2.1 Daily Analysis

Following items shall be analyzed daily, and water for analysis shall be sampled at the end of distribution network.

- Odor
- Color
- Taste
- Turbidity
- pH
- Residual Chlorine

2.2.2 Monthly Analysis

Following items shall be analyzed monthly and water for analysis shall be sampled at the end of distribution network.

- Odor
- Color
- Taste
- Turbidity
- pH
- Residual Chlorine

- Temperature
- Conductivity
- Total Dissolved Solids
- Total Hardness
- Organic Substance
- Total Alkalinity
- NH_4
- p
- Cl
- F
- Mn
- F
- NO_3
- Coliforms
- Total Colonies

2.2.3 Yearly Analysis

Tap water sampled at the end of distribution network and raw water shall be analyzed yearly. The items for the analysis shall be same as those for the monthly analysis items.

2.2.4 Countermeasures

In the event that water quality analysis shows unsatisfactory results, appropriate measures shall be taken immediately. In case that water quality is found harmful, water supply shall be suspended. Simultaneously, it is desirable to identify the cause/s in cooperation with the health centers, clinics and hospitals.

2.3 Water Quality Control of Raw Water

2.3.1 Inspection of Water Source

Water source shall be properly fenced to prevent entry of animals, and there shall be no space for dumping or disposal of garbage and waste around the water source. If a mechanical operator is stationed at the water source, the operator shall pay attention to such matters and inform the WSAO when he has any doubts about the quality or environmental conditions in and around the water source.

2.3.2 Measures to Abnormal Water Quality

In order to take immediate action if any abnormal situations in the quality of raw water are found, the superintendent shall, in advance, know the necessary measures to be taken and shall prepared a schematic

flow of actions to the emergency case. The schematic flow chart shall be prepared by taking into account of the status of the WSAO.

The superintendent in the WSAO shall identify whether the abnormal condition of the raw water quality would affect the public health or not, by checking the following;

- whether the significant difference in color or turbidity is identified by some unknown reasons,
- whether any significant difference is identified in odor or taste.

If there is an obvious danger to the public health, following measures shall firstly be taken.

- Pumping of groundwater and water supply shall be suspended immediately.
- WSAO or the municipality office shall inform the necessary matters to the water users, relevant personnel of health centers, clinics and hospitals. It is preferable to conduct water quality analysis by the health centers, clinics or hospitals. The necessary actions shall then be taken based on the results of analysis.
- The WSAO or the municipality office, through public relations, shall inform the water users about suspension of water supply and tentative measures being taken for alternative water supply such as by water bowsers.

3 SANITARY CONTROL OF THE FACILITIES

3.1 General

In order to supply safe water steadily to the people in meeting the water demand, water supply facilities shall be free from any contamination. Sanitary control of water supply facilities is therefore extremely important. Personnel engaged in water supply shall pay utmost attention to the sanitary condition of themselves and the facilities.

3.2 Prevention of Contamination

Water supply facilities such as intake facilities, pumping facilities, transmission pipelines, reservoirs and distribution pipelines shall be kept clean at all times, because there is a possibility of contamination from outside. It is preferable to take following measures to prevent contamination.

- Water supply facilities shall be fenced to prevent access of outsiders.
- Signboards or notices shall be displayed for attention of the people.
- Drainage facilities in the water supply facilities shall be kept in good condition.
- In the event of suspension of water supply for maintenance works or rehabilitation, the pressure within transmission, distribution and service pipes will be decreased, and there is a possibility to alow drain water/contaminated groundwater entering into the pipes. Therefore, after such works, attention must be paid not only to suck this water out, but also to disinfect the water before supply.

3.3 Suspension of Water Supply during Emergencies

In order to maintain safe water supply, superintendent in the WSAO shall suspend water supply when abnormal condition in water quality is identified. Water supply shall be suspended in the following cases

- When pumped up or transmitted water is found contaminated with a harmful substance or pathogens.
- When a significant difference is identified in color or turbidity by unknown reasons.
- When a significant difference is identified in odor or taste.
- In addition, the water supply should be suspended, if necessary, when it is difficult to implement disinfection due to facilities being out of order or due to shortage of chemicals.

3.4 Disinfection

3.4.1 Disinfection of the Water

Water shall be disinfected in order to keep the supplied water safe and to prevent accidents from contaminated pipeline. Therefore, disinfection system shall be well maintained at all times and preferably a standby system must be installed. Dosing ratio shall be decided so as to keep residual

chlorine below 1 ppm at the end of distribution pipelines.

3.4.2 Disinfection of the Facilities

When water supply facilities are newly constructed or drastically rehabilitated, water supply shall be commenced only after the facilities are disinfected with water containing ample chlorine.

Reservoirs and pump pits for booster pump shall be filled with disinfected water which has a residual chlorine content of about 10 ppm and is allowed to stay for five to six days before commencement of operation. In case of cleaning, disinfection shall be done with water which has a residual chlorine content of about 2 ppm.

Transmission and distribution pipelines shall be disinfected by the following procedure:

- wash inside of newly installed pipes with water,
- inject water which has a residual chlorine content of about 10 ppm into the pipe letting the inside water to be drained off,
- ensure that drained water changes into clean water and that residual chlorine content does not decrease drastically,
- inject piped water and commence operation when drained water completely replaced by the piped water.

4 SUPERINTENDENCE OF THE FACILITIES

Intake facilities consist of deep well or shallow well, submersible pump, control panel and so on.

4.1 Intake Facilities

4.1.1 Operation of Deep Well

Operation of intake facilities aim at prevention of over-pumping and ensuring that groundwater is pumped up stably at the safe pumping rate specified by pumping analysis. Drawdown will increase by over-pumping, and besides, the followings are mostly caused by over-pumping.

- high velocity at screen,
- appearance of a spiral voltex at screen,
- clogging at screen by sand,
- adherence of scale and slime on screen,
- compression of aquifer.

4.1.2 Inspection and Observation Works

(1) Intake Facilities

In order to keep intake facilities in good condition, staff stationed at the WSAO shall inspect status of the water source facilities once a day. The staff in the WSAO shall take suitable action, if necessary.

In case pump pit is installed beside the borehole, the staff shall observe turbidity, color, inflow of sand and water level.

(2) Observation of Groundwater

a) Static water level

In order to know changes of groundwater table, observation of static water level shall be made by the staff of technical section in the WSAO or the regional office at least twice a year.

Observation of the static water level shall be carried out when hourly water consumption is lowest. The time for observation shall be decided in accordance with the water consumption pattern of the town.

Based on the results of the observations, groundwater balance and the borehole characteristics shall be analyzed. Decline of water table in the borehole is usually caused by over-pumping or clogged filter. In case of over-pumping, the optimum pumping rate shall be checked or the pumping rate shall be modified. In case of clogged screen, well development measures such as swabbing and over-pumping, shall be carried out.

b) Dynamic water level

In order to ensure proper operation of submersible pumps and control of pumping rate, regular observations of dynamic water level shall be carried out monthly by the staff stationed at the WSAO. Such observations shall be carried out, as much as possible, by the staff of the technical section in the WSAO or the regional office.

Necessary action shall be taken when a significant change is notice from the observation of dynamic water level. Change of dynamic water level is usually attributed to the borehole and/or the pumping facilities. In case the problem is with the borehole itself, measures to be taken are as same as those stated in 1) Static Water Level. In case the problem is with the pumping facilities, their rehabilitation or replacement is necessary.

Groundwater shall be pumped below the pumping rate decided by pumping tests conducted in the construction stage. Therefore, it is necessary to know the relationship between pumping rate and dynamic water level from the past records. The optimum pumping rate shall be modified when there is a large difference.

(3) Pumping Facilities

In order to prevent breakdowns and accidents, the staff in charge of mechanical facilities shall know mechanical structures, capability and maintenance methods, operation status of submersible motor pump. The facilities to be inspected are the submersible motor pump and electrical system. The following items shall be visually inspected.

a) Submersible motor pump

Inspection procedures by visual observation are as follows;

- Before commencement, stop valve shall be fully closed to prevent suction of sand. The stop valve shall be opened gradually confirming the pressure gauge indication.
- Check whether suction of sand occurs or not.
- Check whether abnormal vibrations and noise are identified. This inspection shall be once a week and the results shall be recorded.
- Check whether leakage occurs at the pressure gauge.
- Check whether big water hammer occurs or not when switching off the pump.
- Occasionally, total head shall be checked by keeping the stop valve fully closed. The total head shall be obtained by adding pressure ratio to head difference between pressure gauge and static water level.
- Check whether electric current ratio is below the specified ratio. This inspection shall be once a week and the results shall be recorded.
- Check whether pumping rate is almost same as the optimum-pumping rate specified by the staff of the technical section in the WSAO or the regional office. This inspection shall be once a week and the results shall be recorded.

- In case there is a standby borehole, it shall be operated once a month.

b) Electrical systems

The following item shall be visually inspected.

- Insulation resistance shall be measured once every six months.

The protection instruments shall be inspected and adjusted.

(4) Water Quality

Water quality analysis shall be carried out for the raw water as stated in the section 2.2. Concerning the items of water quality to be identified by visual observation, the effect and the measures to be taken are as mentioned below.

a) Turbidity

Change in turbidity is usually caused by inflow of sand. In case inflow of sand is observed temporarily at commencement of operation, submersible motor pump shall be operated at a lower rate, position of the pump shall be changed or pumped water shall be drained off until water becomes clean.

b) Color

Groundwater usually changes its color by presence of Mn and Fe. When Mn or Fe are identified from water quality analysis, purification facilities will be needed for their removal.

(5) Measurement Instruments

In order to ensure proper maintenance of borehole, pumping facilities shall be equipped with measurement instruments such as pressure gauges and flow meters. These instruments shall be inspected daily by the operator stationed at the water source, by visual observation, to confirm whether these are operational or not.

In addition to the above, when the submersible motor pump is newly installed or replaced, it is recommended to install a guide pipe, along with the riser pipe, for measuring the groundwater level.

4.1.3 Maintenance of the Facilities

(1) Submersible Motor Pump

Submersible motor pump can be operated at least for 5 years. However, life span of the pump depends on of operation and maintenance conditions. Therefore it is necessary to survey and know the status of operation. Consumable items such as mechanical seal, oil seal, o-ring, cable packing, etc., shall be replaced periodically. In addition, they should be inspected and replaced whenever found necessary.

(2) Control Panel

Various kinds of switches and measurement instruments shall be gathered into a control panel. It is

preferable to replace the spare parts at intervals of about ten years.

4.2 Transmission and Distribution Facilities

Transmission facilities convey water from intake facilities to reservoir and are composed of boosting pump facilities and transmission pipelines. Distribution facilities store the transmitted water in the reservoir and distribute it to the service area by gravity. The distribution facilities are composed of reservoir, elevated tank and distribution network.

These transmission and distribution facilities occupy a large percentage of the construction cost.

4.2.1 Objectives of the Facilities and Fundamentals of Superintendence

Transmission and distribution facilities require meticulous superintendence for controlling water pressure, water quality and consumption rate.

In addition, as pipelines are usually laid underground along the roads, it is required to maintain close contact with the officials in charge of roads.

Fundamentals for superintendence of the transmission and distribution facilities are as follows:

- to prevent piped water from contamination and to keep the piped water being safe,
- to supply necessary volume of water under proper pressure by adjusting pumps and stop valves,
- to prevent leakage,
- to take measures for replacements and against corrosion,
- to exchange views with the officials in charge of roads regarding laying of pipelines,
- to sort out and keep the as-built drawings of pipeline routes, structural drawings and plans,
- to measure and record the distribution rate, pressure rate, water quality data and valve operation, and
- to reinforce the organization of the WSAO to meet emergency situations.

4.2.2 Reservoir

(1) General

Reservoir will not only cope with the peak demand, but also store water when required for emergencies such as fire, electric suspension and contamination of raw water. Therefore, in case available storage capacity is inadequate, it is required to construct an extra reservoirs.

(2) Measurement and Adjustment of Water Volume

Generally, consumption rate is low soon after completion of the system expansion and the water will be stored for a longer period than before. Therefore, it is necessary to keep water level low so that the residual chlorine content will not fall below the specified ratio.

Distribution rate shall be adjusted by taking into consideration of the residual chlorine at the end of distribution network. In adjusting the distribution rate, attention shall be paid on the following:

- not to allow water level lower than the design low water level,
- not to allow water level rise above the design high water level by excess water storage from midnight till early morning, and
- to record daily distribution rate and hourly peak demand for distribution adjustments and future expansion plans.

(3) Inspection and Cleaning

In case of reservoirs of reinforced concrete made, concrete will be corroded by chlorine. Therefore, the reservoir shall be emptied once a year and the leakages shall be inspected. Inlet pipe, outlet pipe, drain pipe etc., shall be inspected as well. Sediments, sand and fur shall be taken out. After cleaning the reservoir, inside of the reservoir shall be disinfected.

In the case of reservoirs made of metal or FRP, inside of the reservoir shall be repainted at an interval of five years. The paint shall be harmless and safe from viewpoints of water quality.

Water level indicator shall be maintained once a month and repaired, if necessary.

In order to avoid contamination from external elements and animals, reservoir shall be fenced and kept locked. Overflow pipe and vent shall be inspected to ensure that they do not give access to small animals and insects. The valve boxes shall be kept covered and locked.

4.2.3 Pumping Station

(1) Objective and Fundamentals

Pumping station is generally composed of pumps, generator, control panel, measurement instruments and pump pit. Inspection of pumping facilities shall be carried out regularly for preventive maintenance.

(2) Operation and Inspection

Pump will be operated in meeting the water level in the pump pit. Therefore a method to confirm the water level shall be formulated.

It is necessary to pay attention to inlet water level, inlet pressure and outlet pressure. Flow control shall be carried out by pumps. Moreover, the standby pump, if available, shall be operated alternately.

(3) Inspection and Maintenance

Pump pit shall be emptied and cleaned once a year. Inside of the pit, water level indicator and inlet pipe shall be inspected and cleaned up.

Ventilation and rainwater drainage shall be given with due considerations in design of pumping room.

(4) Prevention of Contamination

Pumping room shall be fenced to prevent entry of animals, and the drainage facilities shall be constructed in such a way to avoid contamination.

(5) On-site Power Generators

In towns where water supply facilities are operated by hydroelectricity, it is recommended to install on-site generators to meet emergencies by power interruption. For such case, the on-site generator shall be inspected and maintained regularly.

4.2.4 Transmission and Distribution Networks

Transmission and distribution pipelines are usually laid underground in a long distance. Their inspection by visual observation and maintenance are difficult.

In order to check leakage from pipelines, it is recommended to confirm, using an electric conductivity meter, whether water in puddles is rain water or piped water. The conductivity of rain water is lower than that of piped water.

For proper maintenance of pipelines, the date of laying, replacement and removal of pipes shall be recorded together with diameters and lengths of the pipe.

4.2.5 Valves

(1) Stop Valve

Stop valves are used for changing the distribution zone and controlling the pressure and volume. In order to maintain its proper operation, the stop valves including the wash out valves shall be operated and inspected.

In order to avoid contamination, the valve boxes shall be kept covered.

(2) Air Valve

Air valves are installed to release the air from the pipe or to prevent damage by negative pressure. The air valves shall be inspected occasionally.

(3) Pressure Reducing Valve

When distribution network is expanded, it is necessary to install pressure reducing valves at where large head emerges. Secondary pressure shall be observed, inspected and maintained.

4.2.6 Distribution Control

The aim of distribution control is to supply water to the whole service area with sufficient pressure.

Control of the pressure shall be done by the valve operation. Opening ratio of valves shall be decided from the pressure at key points.

4.2.7 Measures Against Accidents

In case distribution rate is lower than water demand due to deficiency at a water source such as drying up of wells, some measures shall be taken tentatively to restrict water supply and to control stored water in the reservoir. Appropriate measures such as construction of new boreholes shall be taken based on the results of the survey.

4.2.8 Replacement of Pipes

Replacement of pipes shall be carried out along with the future plans. Drawings of the pipeline shall be revised and sorted out in accordance with the replacement program.

4.2.9 Restoration Works

(1) Water Suspension Works

Valve operation shall be done carefully and water shall be drained off after completion of valve operation works.

(2) Filling of Water

When filling the pipeline with water, high pressure will sometimes develop due to the residual air which may damage the pipes or disconnect the joints. Therefore, it is preferable to fill the pipes with water from lower side of the pipe. If filling is done from higher side of the pipe, it shall be done gradually with small amounts of water.

(3) Cleaning and Disinfection

Cleaning of pipes shall be done by draining the entrapped water through drain pipe and communal water points. It is preferable to maintain the flow velocity below 1.0 m/sec.

4.2.10 Prevention of Water Leakage

(1) Water Leakage

Water leakages from pipeline will cause low pressure at taps and concaves of road profiles, and contamination of water due entry of polluted water during suspension of water supply or at times of low pressure.

Physical losses vary from about 20% to 40%. In the seven towns, physical losses are mainly due to water leakage, and any counter measures have not been taken yet.

As a measure of preventive maintenance, the following actions are recommended;

- ground observation work, such as concaves of road profiles,
- measurement by flow meter

(2) Ground Observation Work

Ground observations work shall be carried out by the staff in the WSAO based on information from the

public and from their own regular inspections. Regular inspection of pipelines shall be conducted once in every six months.

When a puddle is found during regular inspection, electric conductivity of water shall be measured. In case the measured value is less than 100 μs/cm, it could be rain water.

(3) Measurement by Flow Meter

In case a movable flow meter is available in the regional office or any other organizations related to waterworks, it is recommended to measure the leakage using the flow meter.

The zone to be measured shall be isolated from others by closing stop valves, and the volume of water flowing into the zone shall be measured by the meter.

(4) Preventive Measures for Leakage

In order to prevent water leakage, it is preferable to take measures such as replacement of aged pipes, prevention of corrosion, utilization of flexible joints, etc.

In case of high pressure, water leakage could be avoided to some extent by adjustment of pressure by operating stop valves.

Water leakage occurs also from service pipes. Therefore material of service pipes shall also be be inspected. Use of short service pipes is preferable.

4.3 Service Facilities

4.3.1 Fundamentals of Service Facilities

Service facilities consist of house connections, yard connections and communal water points. Water users are responsible for inspection of service facilities. WSAO shall inform the water users regarding the following and request cooperation in their responsibilities;

- necessity of the service facilities and the responsibilities of the water users,
- informing the WSAO on occurrence of leakage, if identified,
- illegal connections, and
- abuse of the facilities.

4.3.2 Maintenance of Service Facilities

(1) Improvement of Facilities

In meeting the increase of water consumption improved living standards, improvement of facilities will also be carried out by the WSAO from a preventive view point.

(2) Water Leakage

Water users are responsible for maintenance of the service facilities. However, it is necessary that the

service facilities are repaired by the WSAO.

When a water user moves from one place to another, it is preferable to disconnect the service facilities.

(3) Illegal Connections and Abuse of Facilities

Service pipes or distribution pipe shall not be connected to any service pipe from another water source.

The service pipes shall not be connected to the transmission pipelines.

(4) Water Meter

In order to ensure correct measurements, water meters shall be selected by WSAO or the municipality office.

In order to read water meter easily, the WSAO shall instruct or recommend the water users where the water meter should be installed.

Any disorders shall be identified by the meter reader of the WSAO at the time of meter reading.

When replacing a water meter, attention shall be paid to the following points;

- to avoid any shocks to the meter,
- to set the meter counter board in horizontal position,
- to install the meter only after closing the stop valve and draining off the water,
- to confirm the inflow direction, and
- to fill the water gradually to take the air out, and to check if there is any leakage.

(5) Taps

Taps shall also be inspected by the meter reader of the WSAO at the opportunity of meter reading.

4.4 Mechanical and Electrical Facilities

4.4.1 Fundamentals for Maintenance of Mechanical and Electrical Facilities

Mechanical and electrical facilities are key parts of water supply facilities, and therefore maintenance of these facilities is extremely important. The superintendence of these facilities is divided into the followings;

- operation woks such as observation, operation and maintaining records, and
- preventive works such as inspection and repair.

Operation works shall be carried out by the WSAO and, for the moment, the preventive works shall be carried out by the O&M Section of the municipality office.

Such preventive works shall preferably be carried out by the WSAO, after the mechanician and

electrician are employed and station in the WSAO.

In addition to the above, on-site generator for emergencies such as suspension of electricity, and standby booster pump shall be inspected regularly.

4.4.2 Maintenance of Pumping Facilities

Various kinds of pumps are utilized in water supply facilities. In order to ensure continuous and smooth operation of pumps, proper inspection and maintenance are essential. It is necessary to keep the pumping facilities in good condition at all time through careful O&M.

Pumping facilities shall be inspected daily by the operator, or the staff of the WSAO, on any abnormal sounds and, oil or water leakage. Results of the inspection including operation conditions of the pumps shall be recorded and compiled.

Some pumping facilities are provided with standby pumps so that immediate action could be taken in the event of breakdowns. Such standby pumps shall be operated regularly and alternately. In order to ensure stable supply of water, other components of the pumping facilities shall also be inspected and maintained regularly.

In case of breakdowns of pumps including standby pump, the WSAO shall request the water users to conserve water. In order to minimize the damage by the accidents, it is necessary to maintain the reservoir full of water.

In addition to the above, it is necessary to construct proper drainage facilities in and around the compound of the pumping facilities to prevent the facilities from being submerged.

4.5 Disinfection System

4.5.1 Disinfection Methods and Chemicals

Water supplied to the water users shall be safe and free from contamination. Therefore, a disinfection system shall be installed in the water supply facilities, and water shall be disinfected using this system without any interruption.

At the seven towns, disinfection is now implemented only occasionally, and any facilities for chemical injection have not been provided yet. Considering the present availability of the WSA staff in charge of handling chemicals, recommended disinfection facilities shall be provided when suitable staffs are assigned to these facilities.

As disinfection chemicals, there are liquid chlorine, hypochlorite and bleaching powder. Considering its availability, hypochlorite is employed here as the disinfection chemical. Hypochlorite is an unstable substance even at the normal temperature. Therefore, it is necessary to take precautions against chlorine efficiency decrease and to know changes in the concentration.

Hypochlorite is a highly alkaline chemical, and therefore, anti-corrosive materials shall be adopted for the storage tanks and pipes. In case of handling this chemical such as receiving, delivering and inspection,

it is necessary to pay attention not to have direct contact with the skin. Further, this chemical shall not be mixed with acidic solutions such as aluminum sulfate.

A standby disinfection system shall also be installed in order to ensure immediate action during accidents. Additional parts such as injection facilities shall also be secured.

In addition to the above, the disinfection facilities shall be installed and maintained in the control room. The location of the disinfection facilities shall be decided considering the accessibility to the facilities.

4.5.2 Storage Facilities

(1) Inspection Items and Methods

Storage tank shall be fixed onto the floor, and it is necessary to pay attention to its safety.

Before and after receiving the chemical, the following items shall be inspected.

- status of level indicator before receiving,
- whether electricity is supplied or not before receiving,
- whether the ratio indicated is within the specified ratio before receiving,
- to operate in accordance with the specified procedures and adjust the manual valve gradually after receiving,
- to observe liquid level in the tank at every time of receiving,
- to check any leakages from the valve and pipe of ammonia solution.

(2) Building and Storage Tank

Storage tank and the exterior of the building for the tank shall be inspected once a day.

The storage tank shall be inspected once a day for any leakage of hypochlorite.

Consumption rate of hypochlorite shall be estimated from the difference of levels on a particular day and two days before. Leakage shall be checked based on the consumed volume as well.

(3) Corrosion and Cracking of Storage Tank

Inside and bottom of the tank shall be inspected every six months for corrosion and cracks, when liquid level is low.

If there are any troubles, the standby system shall be operated, and the system shall be inspected and repaired. Corrosion of metal-made components such as ladder, manhole covers etc. shall be inspected.

(4) Liquid Level Indicator

Difference between the actual liquid level and the level indicated should be calibrated once a year.

(5) Strainer

Strainer shall be inspected once a year and any scale formed shall be removed. After cleaning, the spare parts shall be replaced.

(6) Storage Tank

Storage tank shall be inspected and necessary repairs shall be done. Replacement of the tank shall be considered from the status of necessity.

(7) Others

Volume of chemical required for more than ten-days consumption shall be secured.

4.5.3 Injection Facilities

Inspection items and methods are as followings.

(1) Injection Pump

Connections between injection pump and pipes shall be inspected once a day for any leakage of hypochlorite. The protection facilities, such as small embankment provided against hypochlorite leakage, shall also be inspected.

In case of abnormal sound or vibration generating from the injection pump during its operation, flow of the pump shall be inspected.

Temperature of pump during operation shall be inspected and compared with that of normal operation.

(2) Injector

In case scale adheres around the injection outlet, injection rate becomes unstable, and there is a tendency to increase the opening ratio of the valve. The parts shall be replaced when necessary.

(3) Valves and Pipes

As well as the pump and injector, valves and pipes shall be inspected in the dry season and replaced when necessary.

4.5.4 Facilities for Formation of Hypochlorite

(1) Method of Formation

Hypochlorite is formed by the following reactions:

- electorolysis of salty water in the tank, and
- forming chlorine gas and NaCl.

There are two methods for mixing; non ion exchange method and ion exchange method. It is possible to obtain the required volume of hypochlorite by these methods. The method shall be employed in meeting

with the availability, skill and experience etc., of the WSA staff in charge of chemical handling.

(2) Maintenance of Facilities

The following points shall be considered in the maintenance of the facilities, in case of non ion exchange method.

- There is a possibility of scale formation during electrolysis. The volume of scale depends on the quality of raw salt used. The cost of raw salt, difficulties in handling, cost of scale removal etc. shall be considered comprehensively.
- In case the solvent water has high hardness, it will cause formation of scale. Water with low hardness shall be used as a solvent, or softening facilities shall be provided.
- Electrodes shall be cleaned at intervals of about thousand (1000) hours. The scale shall be dissolved and removed, and the electrodes shall be well rinsed. The waste fluid after cleaning shall be drained off after neutralizing with caustic soda.
- The electrodes shall be replaced when necessary
- The facilities shall be operated so as that the effective chlorine concentration is kept at around 0.8%.

4.5.5 Dosing Ratio

Dosing ratio shall be decided in such a way to keep the residual chlorine at one (1) ppm at the end of distribution pipeline. In deciding the dosing ratio, the chlorine consumption, not only by water to be mixed but also by the equipment in contact with, shall be taken into consideration.

The dosing ratio for hypochlorite is obtained by the following formula.

$$V=Q \times R \times (100/c) \times (l/d) \times 10^{-3}$$

Where,

V: Injection volume (liter/hour)

Q: Volume of water to be disinfected (m^3/hour)

R: Dosing ratio (ppm)

C: Effective chlorine density (%)

d: Specific gravity at c %.

Appendix 1. Inspection Items for Protection Relay of Pumping Facilities

	Equipment	Inspection Items	Interval	Measures
Routine Inspection	Protection Relay	- Changes on the exterior	Weekly	Cleaning
		- Abnormal sound	Weekly	Adjustment
		- Abnormal vibration	Weekly	Adjustment
Regular Inspection	Protection Relay	- Loosened bolts	Yearly	Tightening
		- Operation of manual recovery equipment	Yearly	Adjustment
		- Dust inside	Yearly	Cleaning
		- Control coil deformed or faded	Yearly	Repair or replacement
		- Damage on connections	Yearly	Polishing or replacement
		- Gear mesh		Adjustment
		- Resistance of insulation		Measurement

Appendix 2. Inspection Items for Electromagnetic Switch of Control Panel

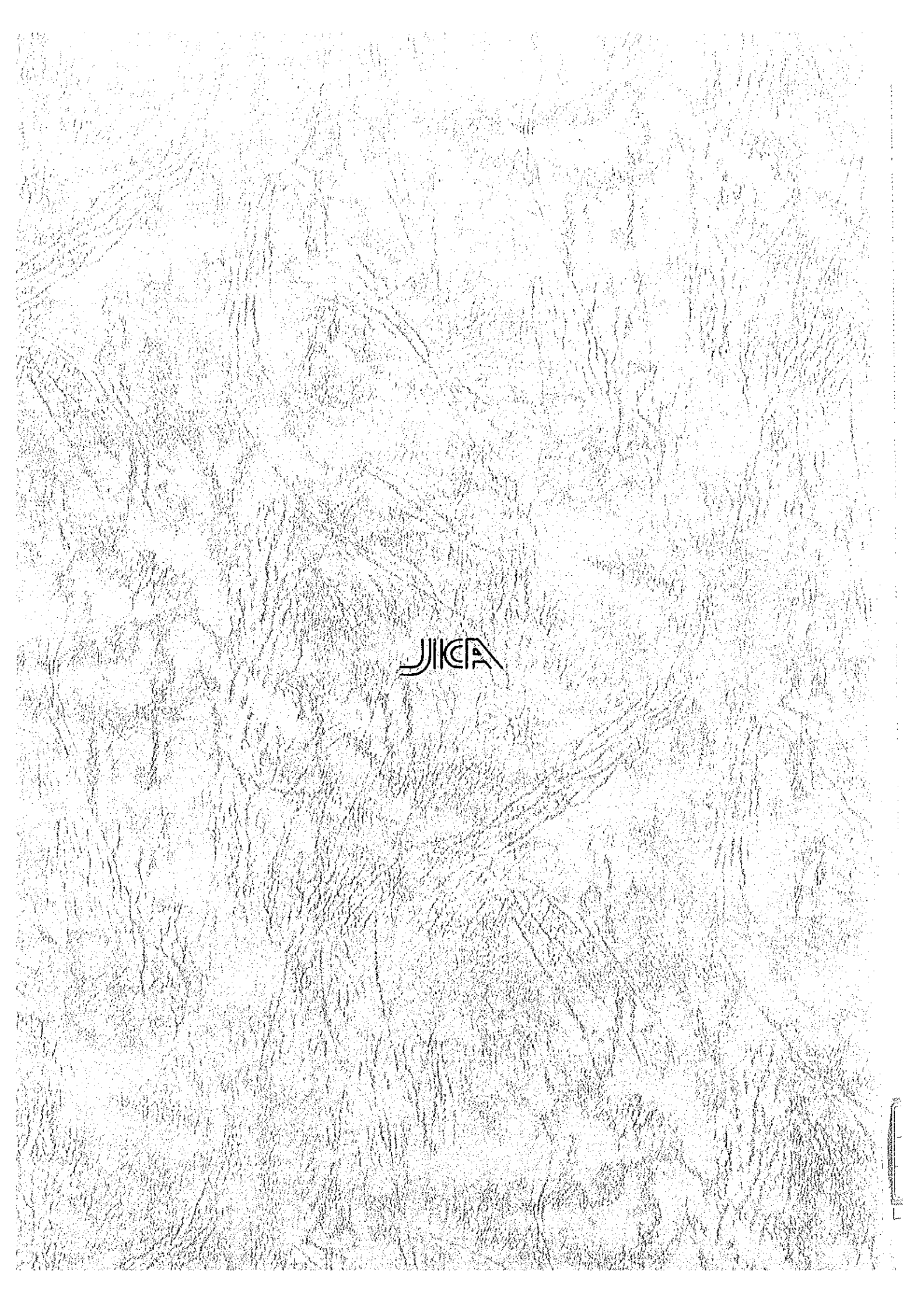
	Equipment	Inspection Items	Interval	Measures
General Inspection	Exterior	- Abnormal sound in electro-magnetic parts	Weekly	Adjustment
		- Abnormal smell due to overheating	Weekly	Adjustment
		- Dirt due to water, oil, dust etc.	Weekly	Cleaning
		- Cracks and insulation	Weekly	Adjustment
Regular Inspection	Exterior	- Loosened bolts	Yearly	Tightening
		- Rust or corrosion in the metal parts	Yearly	Repair or replacement
	Main connection	- Damage at the connection	Yearly	Polishing or replacement
	Operation equipment	- Switch function	Yearly	Adjustment
	Coil part	- Fading due to overheating	Yearly	Repair
	Electromagnetic part	- Frictional wear and damage at the connection face		Repair or replacement

Appendix 3. Inspection Items for Submersible Motor Pump

	Equipment	Inspection Items	Interval	Measures
Daily Inspection	Pump	- Characteristics of pump: sound, vibration, temperature, rotation	Daily	Observation of changes in flow and pressure
	Measurement of current	- Regular sorting out of current measurement	Daily	Observation of changes in current and voltage
	Measurement of resistance of insulation	- Sorting out of current measurement	Daily	Checking of resistance of insulation
Regular Inspection	Casing	- Scratch, damage, corrosion of paint	5 years	Repair, repaint, removal of rust
	Impellor	- Frictional wear, deformation	5 years	Replacement if a big damage.
	Bush	- Damage and frictional wear	5 years	Replacement
	Liner ring	-do-	5 years	Replacement
	Strainer	- Corrosion, damage, clog	5 years	Replacement
	Cab tire cable	- Confirmation of measurement records of the resistance of insulation	5 years	Inspection or replacement
	Radial metal	- Damage and frictional wear	5 years	Replacement if a big damage
	Mechanical seal	- Damage and frictional wear	5 years	Replacement
	Oil seal	- Damage and deformation	5 years	Replacement
	O-ring	- Damage	5 years	Replacement
	Cable packing	- Damage	5 years	Replacement
	Liquid	- Turbidity and volume	5 years	Replacement

Appendix 4. Inspection Items for Disinfection Facilities

Equipment		Inspection		Maintenance	
		Interval	Items	Interval	Items
Storage Tank		Daily	- Damage, deformation, cracks and leakage on the exterior	Monthly	Cleaning of strainer
		Daily	- Operation status of liquid indicator	Yearly	Cleaning of the inside
		Monthly	- Rust and paint on the outside	5 to 7 years	Painting
		Yearly	- Exhaustion of connection packing	Yearly	Tightening of bolts
		Yearly	- Cracks, pinholes, paint and lining on the inside		
		Yearly	- Adjustment of liquid indicator		
		Monthly	- Checking of density measurement instrument		
Injection Facilities	Pump	Daily	- Leakage, abnormal noise, vibration, heat	3 months	Cleaning of check valve
		Daily	- Gas release	3 months	Adding of lubricating oil
		Monthly	- Fitting for fixing	5 months	Cleaning of rotor
		3 months	- Injection rate	Yearly	Disassembling of pump
		6 months	- Wear of brushes	Yearly	Tightening of bolts
	Flow Meter	Daily	- Operation status	Yearly	Cleaning of the inside
		Daily	- Rate indicated		
	Adjustment Valve	Daily	- Operation status	Yearly	Repair of Frictional wear
		Daily	- Leakage		
	Injector	Daily	- Solution volume	Monthly	Removal of scale
		Daily	- Suction pressure		
		Daily	- Leakage		
	Control Instrument	Daily	- Operation status		
		Daily	- Ratio indicated		
		Daily	- Leakage		
Valves and pipes		Daily	- Deformation of pipes	Monthly	Tightening of bolts
		Daily	- Leakage	Monthly	Cleaning of strainer
		Daily	- Operation status of valves	Yearly	Scale removal of pipes
		Daily	- wearing-out of packing	Yearly	Disassembling and cleaning of valve
				3 to 5 years	Painting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