SPECIFICATION OF SUPPLY AND INSTALLATION OF UV DISINFECTION SYSTEM

TABLE OF CONTENTS

DESCRIPTION **PAGE NO**

1. Introduction 2
1.1 Purpose 2
1.2 background 2
1.3 Abbreviations 2
2. UV Disinfection Overview 2
2.1 Disinfection by UV light 2
2.1.1 UV Light 2
2.2 Disinfection Mechanisms 3
2.3 UV Dose 4
3. Definitions 4
4. System Components 6
4.1 UV Lamps 6
4.2 Lamp Sleeves 7
4.3 Ballasts 7
4.4 Cleaning Systems 7
4.5 Sensors 8
4.5.1. UV Intensity Sensors 8
4.5.2. Temperature Sensors 8
4.5.3. UV Transmittance sensors 8
4.6 UV Reactors 8
4.6.1 Materials 8
4.6.2. Appurtenances 9
4.6.3 Redundancy 9
4.6.4 Inlet pipework 9
4.6.5 Flow Distribution and Control 9
4.6.6. Flow Measurement 9
4.6.7 Air Release Valves 9
4.6.8 Isolation Valves 9
4.9 Safety Signage 9
4.10 Spare Parts 9
4.11 Training 10
4.12 Instrumentation and control 10
4.12.1 PLC and SCADA 10
4.12.2 Operator Interface Panels 10
4.12.3 Dose Monitoring 10
4.12.4 System Automation 10
4.13 Electrical 10
4.13.1 Standards 10
4.13.2. Power Requirement 10
4.13.3 Harmonic Distortion 10
4.13.4 Back-up Power 11
4.13.5 Grounding and insulation 11
5. PARTICULAR SPECIFICATIONS 12
5.1 Design Water Quality Parameters 12
5.2 UV equipment 13

1. Introduction

1.1 Purpose

This specification specify the minimum requirements for UV disinfection systems for disinfection of drinking water and treated wastewater. Design water quality parameters are given in the particular specification.

1.2 background

Ultraviolet radiation in the range of 200 – 300 nm wavelength is an effective germicide. Therefore UV light shall be used to disinfect drinking water and treated wastewater (effluent). UV disinfection systems including UV reactors and ancillary equipment shall be provided for this purpose in water and wastewater treatment plants. UV reactors shall be either fully enclosed as a pressured pipeline component or constructed in an open channel arrangement.

1.3 Abbreviations

LED	Light Emitting Diode
LP	Low Pressure
LPHO	Low Pressure High Output
MP	Medium Pressure
NWSDB	National Water Supply and Drainage Board
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
TCP/IP	Transmission Control Protocol/Internet Protocol
TDS	Total Dissolved Solids
UPS	Uninterruptible Power Supply
US EPA	United States Environmental Protection Agency
UV	Ultraviolet
UVT	UV transmittance

2. UV Disinfection Overview

2.1 Disinfection by UV light

In UV disinfection, the water to be disinfected shall exposed to short wave length UV light. This UV-radiation is a quick and effective germicide. Being a physical process UV disinfection shall not add any chemicals to the water and shall not leave any residual.

2.1.1 UV Light

In the electromagnetic spectrum, the region between visible light and X-rays are classified as Ultraviolet (UV). The UV spectrum is further divided into four regions.

Vacuum UV (100 to 200 nanometers (nm)
UV-C (200 to 280 nm)
UV-B (280 to 315 nm)
UV-A (315 to 380)

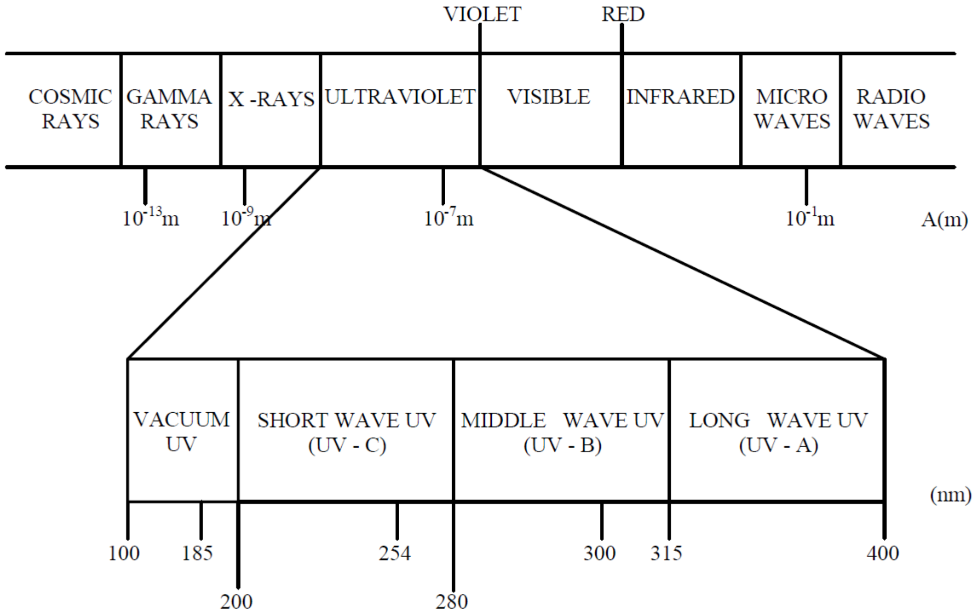

Figure 1 *Ultraviolet Spectrum*

Radiation in UV-B and UV-C ranges are the most effective for germicidal action. The effect of UV-A light is minimal in comparison to UV-B and UV-C light.

Although light in the vacuum UV range is able to provide germicidal action, its use is impractical because of the rapid dissipation in water over very short distances.

Germicidal action reaches a maximum at or near 260 nm for most microorganisms, before dropping to zero near 300 nm. A local minimum shall occur around 230 nm. Low Pressure Pump (LP) and Low Pressure High Output (LPHO) lamps shall produce UV light at 254 nm.

2.2 Disinfection Mechanisms

UV light damages the nucleic acids in microorganisms thereby leaving them unable to perform vital cell functions. The effectiveness of germicidal action is influenced by the UV frequency, intensity of radiation, water quality and the radioresistance of the microorganisms.
Viruses have no repair mechanism to reverse the UV damage. However, bacteria and other microbes are capable repairing DNA damaged by UV radiation, through phenomena known as light repair (photoreactivation) and dark repair (base excision repair).
Disinfection by UV shall require direct line-of-sight between the UV source and microorganisms. Suspended particles in water, fouling and films on the UV bulb reduce the radiation energy available for disinfection.

2.3 UV Dose

The degree of inactivation by UV radiation is directly related to the UV dose applied to the water. *US EPA Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule, 2006* specify specific UV doses required for various levels of log inactivation as given in Table 1.

Table 1 *UV doses for target pathogens (mJ/cm2)*

	UV dose in mW·s/cm2							
Log Inactivation	0.5	1	1.5	2	2.5	3	3.5	4
Target pathogens								
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

The UV dose requirements in Table 1 do not account for uncertainties like hydraulic effects of the UV installation, the UV reactor equipment and sensors. Due to this, UV systems shall undergo validation testing to determine a Validated Dose, which is the UV dose delivered by the reactor. Validated Dose shall be greater than or equal to the required dose. Fouling and aging also affect the UV dose delivery. The UV dose from clean lamps multiplied by the fouling and aging factors shall be greater or equal to the design UV dose.
A minimum reduction equivalent dose of 40 ml/cm^2 shall be considered and the design dose shall be estimated considering the validation, fouling and aging factors.

3. Definitions

Absorbance
A measure of the amount of UV light that is absorbed by a substance at a specific wavelength.

Absorbance at 254 nm (A254)
A measure of the amount of UV light that is absorbed by a substance at 254 nm.

Ballast
An electrical device that provides the proper voltage and current required to initiate and maintain the operation of a UV lamp.

Combined aging/fouling factor
Product of the lamp aging factor and the fouling factor.

Design UVT
The UVT that shall be used to size a UV facility. The design UVT and design flow are typically used by the UV manufacturer to determine the appropriate UV equipment for a target pathogen inactivation. The design UVT may not necessarily be the minimum operating UVT.

Dose
The UV energy per unit area, reported in units of mJ/cm^2 or J/m^2.

Dose-response
The level of inactivation of a microorganism as a function of dose.

Duty UV intensity sensor
The duty (online) UV sensor installed in the UV reactor that monitors UV intensity during UV equipment operations.

Emission spectrum
The relative power emitted by a lamp at different wavelengths.

Fouling factor
The transmittance of a fouled lamp sleeve and sensors well relative to that of a new sleeve and sensor well.

Germicidal range
The range of UV wavelengths responsible for microbial inactivation in water (200 to 300 nm).

Inactivation
A process by which a microorganism is rendered unable to reproduce, thereby rendering it unable to infect a host.

Intensity
The power passing through a unit area perpendicular to the direction of propagation.

Lamp aging factor
The output of a lamp relative to that of a new lamp.

Lamp sleeve
The quartz tube that surrounds and protects the UV lamp. The exterior is in direct contact with the water being treated.

Minimum operating UVT
The lowest UVT expected to occur during the lifetime of the UV facility. The UV reactor shall be designed and validated for the range of UVT and flow-rate combinations expected at the water treatment plant.

Reactor validation
Full-scale testing by an independent third party to determine the operating conditions under which a reactor can deliver a specific dose.

Reduction Equivalent Dose (RED)
Dose derived by using the log inactivation measured during full-scale reactor testing in the dose-response curve that was derived through collimated beam testing. Reduction equivalent dose values are specific to the challenge microorganism used during experimental testing and the validation test conditions for full-scale reactor testing.

Required dose
The dose in units of mJ/cm^2 needed to achieve the target log inactivation for the target pathogen.

Target pathogen
The microorganism for which a public water system wants to obtain inactivation credit using UV disinfection.

Target log inactivation
For the target pathogen, the specific log inactivation the public water system wants to achieve using UV disinfection.

UV intensity sensor
A photosensitive detector used to measure the intensity at a point within the reactor.

UV transmittance
A measure of the fraction of incident light transmitted through a material.

Validation
The testing of a reactor to determine its performance under all operating conditions, including flow, UV transmittance, and lamp power.

Validated dose
The dose in units of mJ/cm^2 delivered by the reactor as determined through validation testing. The validated dose is compared with the required dose to determine log inactivation credit.

Validation factor
An uncertainty term that accounts for the bias and uncertainty associated with validation testing.

4. System Components

Following are the main components of a UV disinfection system.

4.1 UV Lamps

There are several types of UV lamps available.

- **Low Pressure Lamps (LP)**
  This is a type of gas discharge lamp with mercury vapor pressure about 0.1-10 Pa. They emit UV in narrow bands of wavelengths with a majority of emissions in 254 nm.
- **Low Pressure High Output Lamps (LPHO)**
  These lamps operate at a higher temperature than LP lamps and have a higher Q output power per unit length.
- **Medium Pressure Lamps (MP)**
  Operating at about 100 kPa, these lamps a produce a much higher intensity of UV radiation. Emission spectrum is broader than in LP lamps.

- **Light Emitting Diodes (LED)**

Recent developments in Solid-state semiconductors have lead to the development of LEDs that emit UV-C which are now available as germicidal lamps. Available systems are generally suited for domestic and low-flow applications only. Adequate manufacturer recommendations and documentation shall be provided to ensure the suitability to the application.

4.2 Lamp Sleeves

UV lamps shall be placed in a sleeve to maintain an optimal operating temperature and protect the lamp from physical damage. The sleeves shall be made of quartz. Sleeves shall absorb some UV radiation and may affect the UV dose delivered to water. Lamp sleeves shall undergo fouling which will reduce UV transmittance. The sleeve diameter shall typically be 25 – 50 mm for LP and 35 – 100 mm for LPHO and MP lamps. The annular space between the outside of the lamp and the inside of the sleeve shall be approximately 10 mm. Manufacturer's documentation shall be produced.

4.3 Ballasts

Ballasts shall be provided to regulate the incoming power supply to the level needed to energize and operate the UV lamps. Electronic ballast type shall be provided unless otherwise specified in the specific specifications. (Site conditions such as the distance between the lamp and ballast may oppose using Electronic ballast over magnetic ballast.)
The ballasts shall be provided with a sufficient cooling system and the manufacturers' literature shall be provided to ensure that provided cooling mechanism is adequate to maintain the recommended environment for ballast.
A ballast cooling system shall be required to maintain the ballast temperature below the maximum specified limit. The supplier shalll have to mention it during reactor selection.

4.4 Cleaning Systems

Online cleaning shall be incorporated unless project requirements specifies otherwise. It should be recognized that reactors fitted with a mechanical cleaning system may still require manual cleaning.
On-line cleaning methods shall consist of mechanical wipers that are moved along the sleeves by means of electric motor or pneumatic piston drives. The wipers shall be stainless steel brush collars or Teflon rings.
In case of cleaning systems utilize a moving collar that is filled with cleaning solution to dissolve the material fouling the sleeves, the cost of cleaning agent, availability at local market, frequency of refilling of cleaning agent shall be clearly specified with the offer.

4.5 Sensors

4.5.1. UV Intensity Sensors

UV intensity shall be monitored inside the reactor by using a UV sensor. Sensors shall be placed in the reactor or mounted on the outside of the reactor along with a monitoring window. Sensors shall also foul over time and require cleaning.
The sensor output shall be 4-20mA / 0-20V signal as specified by the site conditions where PLCs are incorporated or give specific alarms (buzzer/ indicator) at preset levels.

4.5.2. Temperature Sensors

Waste energy in a UV reactor shall be converted to heat and absorbed by the water. Continuous flow of water therefore prevents the reactor from overheating. However, at lower flow rates or water levels, there is a risk of reactor overheating. It is important, therefore, that the reactor shall be fitted with a temperature sensor to monitor the reactor water temperature. As per the site conditions, the PLC shall be programmed to shut the system down when the temperature rise above the preset values of operating range. For places where SCADA/PLC is not incorporated, appropriate measures shall be taken to turn off the lamps when temperature rises above the preset value. The maximum allowed temperature shall be capable of adjusting within the limits of manufacturer's recommendations.

4.5.3. UV Transmittance sensors

A UVT (Ultra Violet Transmittance) sensor shall be provided for dose monitoring unless otherwise specified in the specific specifications.

4.6 UV Reactors

UV Reactor shall be non-contact or contact type. In both types reactor design shall be on the cross-flow configuration, in which the direction of flow is perpendicular to the placement of the lamps or on the parallel configuration, in which the direction of the flow is parallel to the lamps.
In contact type reactors, series of mercury lamps shall be enclosed in quartz sleeves to minimize the cooling effects of wastewater.
In noncontact reactors, UV lamps shall be suspended outside a transparent conduit, which carries the water/ treated wastewater to be disinfected.
Appropriate type of the reactor shall be selected to site conditions and the water/treated wastewater parameters.
The flow to the reactor shall be controlled to be constant using flap gates or weirs.
Working pressure of the reactor shall be specified by the manufacturer.

4.6.1 Materials

The UV reactor shall be fabricated from materials that do not corrode, do not transmit UV light, and do not impart taste, odour, colour, or toxic materials to the water.

Module : Aluminium, SUS316
Protection tube : Quartz glass
Switch board : SUS304

4.6.2. Appurtenances

Strainers shall be fitted on both the inlet and outlet of the reactor. A reactor drain-down tapping shall be provided to enable the water to be drained from the reactor when it is taken out of service. Tapping points and valves upstream and downstream of the reactor shall be considered to enable flushing, venting and sampling.

4.6.3 Redundancy

Standby reactors shall be provided in parallel in all installations. They shall automatically take-over if a duty reactor fails. Isolation valves provided at appropriate locations shall enable isolation of reactors.

4.6.4 Inlet pipework

A minimum of five pipe diameters of straight pipe shall be provided upstream of UV reactor. Isolation valves shall not be placed within this segment.

4.6.5 Flow Distribution and Control

The pipework or channels in each UV train shall be sized and configured to provide an approximately equal head loss over the range of design flow rates. The power supplied to the UV reactor shall be controlled corresponding to the flow rate.

4.6.6. Flow Measurement

A dedicated flow meter shall be installed on each UV train to confirm that the reactor is operating within the design range.

4.6.7 Air Release Valves

UV reactors designed as pressure flow elements shall be kept free of air to prevent lamp overheating. A suitable air release valve shall be required to prevent air pockets and negative pressures developing.

4.6.8 Isolation Valves

For duty/standby configuration, each UV reactor shall be capable of being isolated and taken out of service. Isolating a UV reactor shall require valves upstream and downstream of the reactor. An actuated valve on the reactor inlet may be used as the isolation valve.

4.9 Safety Signage

Safety signage shall be provided in accordance with ISO 7010:2019.

4.10 Spare Parts

Required spare parts including lamp, sleeve, sensor, wiper, and ballast, shall be kept in storage at the site or a location specified by the NWSDB. The required spare parts shall be defined based on criticality due to duty/standby configuration, availability and design life. Following minimum requirements shall be provided.

Ultraviolet lamp	: 1 set
Automatic cleaning device	: 1 set
Ultraviolet ray strength sensor	: 1 set
Control panel including secondary wirings	: 1 set
Switch board	: 1 set

Itemized list of spares with prices shall be attached. Complete set of tools for maintenance & general repair shall be provided.

4.11 Training

Required training for the maintenance of UV disinfection system, removing and re-fixing of UV bulbs, wipers and other frequently changing parts shall be provided with clearly specified printed instructions.
All as built drawings for the unit and the control panel shall be supplied and verified.

4.12 Instrumentation and control

4.12.1 PLC and SCADA

The UV units shall be controlled by dedicated PLC equipped with TCP/IP communication module for integration with the plant control system. SCADA shall be provided for remote supervision and control, duty and standby communications. Alarms shall be immediately transferred via SCADA to the Operations Centre.

4.12.2 Operator Interface Panels

All key performance indication, instrumentation, controls and monitoring of the UV unit shall be communicated to an Operator Interface Panel. The Operator Interface Panel shall contain a data-logging system for historical data, alarming of key process variables and parameter set-points.

4.12.3 Dose Monitoring

Dose monitoring shall be required in order to confirm the UV dose delivery.

4.12.4 System Automation

Operation of the UV installation shall be fully automated. Automatic shutdown under critical alarm conditions shall be essential.

4.13 Electrical

4.13.1 Standards

All equipment and accessories supplied and installed shall comply with 17th Edition of IEE wiring regulation (BS 7671:2008).

4.13.2. Power Requirement

Power requirements for the various components may be different. The supply voltage and total load requirements shall be confirmed with the manufacturer.
All equipment supplied shall be operating 230/415V, 50 Hz. If the power requirement varies from specified, Contractor shall modify the local panel as per the requirement.

4.13.3 Harmonic Distortion

The varying nature of UV reactor loads can induce harmonic distortion which can affect/damage the electronic equipment. The Contractor shall measure the available harmonic distortion after completion of the installation of disinfection unit. Necessary equipment for the measurement shall be provided by the Contractor. Contractor shall ensure that the harmonic distortion at point of common coupling of the installation is not more than 10%. If the conditions are not satisfied, harmonic filters shall be installed on the power supply to control distortion.

4.13.4 Back-up Power

A continuous power supply is necessary for operation of the UV reactor. A back-up supply, such as an Uninterruptible Power Supply (UPS), shall be considered. A power generator of a suitable capacity also shall be provided to avoid water transfer without disinfection.

4.13.5 Grounding and insulation

UV systems shall be properly grounded to ensure the safety of personnel and equipment.

UV reactors shall be capable of being electrically isolated. The UV reactor shall be shut down before it can be opened for repairs or maintenance.

All exposed conductive, non-current carrying parts of the installation shall be connected to an electrically independent earth electrode which is to be taken from the common earth of the Electrical installation of the site.

All printed as built drawings printed and soft copies shall be submitted prior to handover.