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SAFETY AND SECURITY OF DRINKING WATER SUPPLY SYSTEMS - APPROACHES AND INSTRUMENTS FOR IMPLEMENTATION

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IN LOVING MEMORY OF MY DEAR MOTHER JOSEPHINE

PREFACE

This master's thesis was carried out in the Department for Water Atmosphere and Environment, Institute of Sanitary Engineering and Water Pollution Control in the University of Natural Resources and Applied Life Sciences (BOKU) Vienna Austria: In collaboration with the Faculty of Agrobiology Food and Natural Resources, Department of Microbiology, Nutrition and Dietetics of the Czech University of Life Sciences, (CULS) Prague Czech Republic.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The safety and security of drinking water supply systems has gained a lot of attention in recent years with a lot of concern over the potential possibilities of intentional or accidental contamination with biological, chemical, radiological contaminants or toxins on the drinking water supply networks that would result in devastating public health and other socio-economic impacts. The water supply systems infrastructures are being assessed globally to determine their vulnerabilities to intentional or accidental contaminations events.

This thesis stresses the need for new approaches and instruments to be implemented in the drinking as well as the whole water supply systems. The main threats facing the water supply sector are biological, chemical, cyber, physical and radiological threats. The physical threats have more likelihood to occur in the form of stealing, vandalizing or destruction of the water supply systems assets with bombs/explosives or fire. The biological threats (bacteria, viruses, protozoa) which contaminate drinking water, causing illness and/or death are of the most concern to public health. The general acceptable safety standards in regular water supply systems on a global perspective within the framework of the World Health Organization, the European Union and the United States of America was explored and briefly discussed.

The proposed approaches and instruments to be implemented to successfully influence daily routine in drinking water supply systems are the water safety plans, online contaminant monitoring system and early warning systems. Some commercially available instruments that can monitor biological, chemical and radiological contaminants have been described and listed. Impressions from the monitoring stations of first Vienna water spring mains located at Kaiserbrunn in Lower Austria was briefly described and illustrated with pictures.

Finally, water supply professionals have to understand their own individual systems, in order to successfully use available instruments to effectively counter contamination events. They also need to set up baseline water quality parameters upon which surrogate parameters are based, because these available instruments require knowledge of the baseline water quality conditions to be applied appropriately. With appropriate, case specific baseline water quality and surrogate parameters, the instruments only need to identify significant variation in the baseline conditions to provide an alarm condition.

KEYWORDS

Biochemical warfare, early warning systems, online water monitoring instruments, public health concern, water safety, water safety plans, water supply security, water supply systems, water terrorism, water quality measurement.

1. INTRODUCTION

Access to safe drinking-water is a major concern throughout the world. It is also an important health and development issue at a national, regional and local level. Safe drinking-water is essential to health, a basic human right and a component of effective policy for the protection of public health. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards while improved access to safe drinking-water can result in tangible improvements to public health (WHO, 2006).

Drinking water that is safe for human consumption must be free from microorganisms capable of causing disease. It must not contain minerals and organic substances at concentrations that could produce adverse effects. Drinking water should be aesthetically acceptable, meaning it should be free from apparent turbidity, color and odor and from any objectionable taste (HDR Engineering, 2001).

There are various ways in which contaminants may enter the drinking water supply system - some accidental such as runoff or leaching of contaminant from lands near the source waters, effluent discharge upstream and breaks in pipes or leaks in tanks that are either underground or above ground and - some others purposeful like those dumped into finished water storage tanks, injected into pipes under pressure through a bleeder valve, forced upstream under pressure from any tap or fire hydrant.

The consequent problems caused by contamination in water supply systems include; public health problems that may lead to illness and death of the consuming population, economic problems arising from the use of contaminated water, lack of potable water and the loss of public confidence in the drinking water supply utility. (ASCE et al, 2004).

Supplying drinking water to the household tap is a complex and demanding process (Spellman and Drinan, 2000). The water supply system utilities play the major role of making the accessibility of safe drinking water across the developed world as well as parts of the developing world possible. They also bear the sole responsibility to achieve the provision of safe drinking-water quality as far as practicable. To meet up with this enormous challenge, water supply professionals have to continuously update and upgrade their systems, hence, the need for new approaches and instruments to be implemented in the water supply systems.

2. PROBLEM STATEMENT

The goal of the drinking water industry has always been to provide safe and aesthetically pleasing water to its customers even though most water-supply systems differ in their operational requirements and practices (ASCE et al, 2004). Drinking water or potable water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking, washing and other household applications (Spellman and Drinan, 2000).

Therefore, safe water is one that is suitable for consumption, cooking, washing, showering and other domestic uses (Hecq et al, 2004) as well as water that is safe for a lifetime of consumption that does not represent any significant risk to health over a lifetime of consumption, taking account of different sensitivities that occur between life stages (WHO, 2006).

The tragic events of September 11, 2001 have heightened concerns that drinking water supply systems, particularly distribution systems are potential targets for saboteurs. With the distribution system covering a large geographic area, and being readily accessible, it is very important that contamination in the distribution system be detected in a timely manner to ensure adequate time to respond and protect public health (Highsmith et al, 2004).

Contamination of water supply systems has been a problem for as long as such systems have existed. Intentional contamination of wells and other water supplies was also an accepted tactic in warfare. Intentional contamination can occur at a wide range of locations and virtually any part of the system to which an attacker gains access is a potential insertion site, though some sites are more vulnerable than others.

The most easily accessible sites in most water supply systems include the source waters, finished water storage facilities, many portions of the distribution system such as pipes, valves and pumps, fire hydrants, backflow check valves and customer taps. While treatment plants are generally more difficult for an outside attacker to penetrate, a compromised insider could relatively easily attack there. (ASCE et al, 2004).

Potential threats to water supplies can arise from a variety of sources. For example, severe pollution by industrial and municipal chemical and sewage wastes; industrial accidents resulting in chemical spills into surface and sub-surface water sources; deliberate chemical or biological attack on water sources, processing, storage, and distribution infrastructure.

These threats can exhibit a wide range of chemical, physical, radiological, toxicological, and biological properties. This enormous range of properties presents the analytical chemist and microbiologist with a substantial scientific challenge in terms of problem definition, choice of techniques for agent identification, and methodologies (Highsmith et al, 2004).

The main characteristics for a contamination scenario are: The particular contaminant species, the amount of contaminant inserted, the location of the insertion, the rate at which or method by which it is inserted and the properties of the water system (ASCE et al, 2004).

It is important that the water supply infrastructures are protected, in order to secure the continuous supply of safe drinking water. Achieving this depends on the ability every water supply utility to identify and evaluate threats. This will depend on several things including day-to-day surveillance and response to an actual event. Therefore, the protection of water infrastructure requires preparedness on multiple levels, given present and recent global conditions.

In light of the foregoing, there is an urgent need to determine the best approaches and instruments that can be implemented and successfully used to prevent contamination events in the water supply systems. Irrespective of the size, location and economic capacity of the water supply system, the perceived approaches and instruments should also be able to detect water contaminants, raise the necessary alarm and thereby give room for response.

3. OBJECTIVES

The objectives of this thesis will be to:

1. Discuss the general acceptable safety standards in regular water supply systems on a global perspective within the framework of the world health organization, the European Union and the United States of America.

2. Find what toxins, biological, chemical and radiological threat agents are of the most concern to public health with reference to:

a) Concerns regarding regular and ordinary water supply operations.
b) Concerns regarding specific operational conditions in situation of security needs

3. Find out the approaches and instruments that can be implemented to successfully influence the everyday operational routine in drinking water supply systems and therefore, promote the provision of safe water and enable effective response to emergency situations in an intentional or accidental water contamination event.

These objectives will be achieved through desk research of available materials on the state of the art approach in matters relating to security and safety of drinking water and will be aimed at an elaboration of the threat to drinking water supply and the presumptive approaches and instruments that can be implemented to mitigate these threats.

Security in the sense of this work means securing the water supply infrastructures from every act of malevolence aimed at disrupting the water supply services, triggering fear on the population for political gains and ultimately to cause harm or death in a magnitude of significance. The materials will be based on available resources on this issue in the form of books, journals, research reports, scientific workshop presentations and the internet.

4. RESULT OF LITERATURE REVIEW ON THREATS

4.1 THE THREATS TO THE WATER SUPPLY SECTOR

A threat is an indication that a harmful incident, such as contamination of the drinking water supply, may have occurred. The threat may be direct, such as a verbal or written threat, or circumstantial, such as a security breach or unusual water quality. A water contamination threat occurs when the introduction of a contaminant into the water system is threatened, claimed, or suggested by evidence while a water contamination incident occurs when a contaminant is successfully introduced into the water supply.

Both water contamination threats and water contamination incidents could be designed to disrupt system operations and interrupt the delivery of safe water to a population, cause physical damage to the system's infrastructures, interrupt fire protection services, create public panic, reduce public confidence in the water supply services, result in economic loss through the cost of remediation and replacement and cause disease or death in a population (USEPA, 2003). The main threats to the drinking water supply as currently known are: -

(1) Biological Threats,

(2) Chemical Threats,

(3) Cyber Threats,

(4) Physical Threats and

(5) Radiological Threats.

4.2 BIOLOGICAL THREATS

There are two types of biological threats namely: "Pathogens" and "Toxins".

4.2.1 PATHOGENS

These are living organisms, such as bacteria, viruses or protozoa, which infect and cause illness and/or death. They require a host population and certain environmental conditions (temperature, humidity/water, and protection from sunlight) for survival. Upon infection, the pathogen must "grow" in the host. The latency period requires time, depending on the organism, from hours to weeks.

Furthermore, water-related microbial pathogens of public health significance could be categorized into two broad groups namely: "Water-based pathogens" and "Waterborne pathogens". Water based pathogens are those that spend part of their life cycle in water and need a vector to reach and infect their host while the water borne pathogens are those transmitted through ingestion of contaminated water and are generally orally transmitted through fecal microorganisms.(Hickman, 1999; Mays, 2004). Table 1 show the threat potential of Pathogens.

TABLE 1: Threat Potential of Pathogens (adapted from Hickman, 1999)

AGENT	TYPE	WEAPONIZED	WATER THREAT	STABLE IN WATER	INFECTIOUS DOSE	CHLORINE TOLERANCE
Anthrax	B	Yes	yes	2 yrs spare	6,000	Spores resistant
Brucellosis	B	Yes	Probable	20-72 days	10,000	Unknown
Clostridium Perfringens	B	Probable	Probable	Common in sewage	~500,000	Resistant
Tularemia	B	Yes	Yes	<90 days	25	Inactivated, 1ppm, 5 min
Shigellosis	B	Unknown	Yes	2-3 days	10,000	Inactivated, 0.05 ppm, 10 min
Cholera	B	Unknown	Yes	“Survives well”	1,000	“Easily killed”
Salmonella	B	Unknown	Yes	8 days, fresh water	10,000	Inactivated
Plague	B	Probable	Yes	16 days	500	Unknown
Q fever	R	Yes	Possible	Unknown	25	Unknown
Varuika	V	Possible	Possible	Unknown	10	Unknown
Hepatitis A	V	Unknown	Yes	Unknown	30	Inactivated, 0,4ppm, 30 min
cryptosporidiosis	P	unknown	Yes	Stable days or more	130	Oocysts resistant

4.2.2 BIOLOGICAL TOXINS

Biological Toxins are chemicals derived from the natural metabolic processes of animals, plants, or micro organisms; primarily bacteria and fungi, which cause chemical toxicity resulting in illness and/or death. From a practical perspective, toxins more closely resemble chemical threats than biological pathogens and have been claimed to be chemicals because they cannot replicate or be replicated in a human system.

Some toxins may be synthesized in a laboratory and many others are environmentally stable and water soluble. Large scale fermentation of the parent organism and toxin recovery are also possible, particularly for bacteria derived toxins. Extremely small doses are very effective in causing havoc, thereby facilitating its use for sabotage (Hickman, 1999). A fundamental premise of toxicology is that virtually any chemical is toxic to humans if the dose is high enough (ASCE et al, 2004).Table 2 shows the threat potential of biological toxins

TABLE 2: Threat Potential of Biological Toxins (Hickman, 1999)

AGENT	WEAPONIZED	WATER THREAT	STABLE IN WATER	ESTIMATED EFFECTIVE DOSE	CHLORINE TOLERANCE
Botulinum toxin	Yes	Yes	Stable	0.07mg	Inactivated, 6ppm, 20 minutes
T-2 mycotoxin	Probable	Yes	Stable	None give	Resistant
Aflatoxin	Yes	Yes	Probably stable	2mg	Probably tolerant
Ricin	Yes	Yes	Unknown	None given	Resistant at 10ppm
Staph Enterotoxins	Probable	Yes	Probably stable	4µg	Unkwon
Microcystins	Possible	Yes	Probably stable	1mg	Resistant at 100ppm
Anatoxin A	Unknown	Probable	Inactivated in days	None given	Unknown
Tetrodotoxin	Possible	Yes	Unknown	1mg	Inactivated, 50ppm
saxitoxin	Possible	Yes	stable	0.3mg	Resistant at 10ppm

4.3. CHEMICAL THREATS

Chemical threats can be categorized into two categories namely: “Chemical weapons” and “Industrial chemical poisons”.

4.3.1 CHEMICAL WEAPONS

Chemical weapons also called “Chemical Warfare Agents” are of various types namely: “Nerve agents”, “Blister agents”, “Choking agents”, “Blood agents”, and “Hallucinogens”.

4.3.2 INDUSTRIAL CHEMICAL POISONS

Industrial chemical poisons, represents the several dangerous industrial chemicals, hazardous materials, pesticides, fungicides and their likes that could be used as drinking water poisons. Both chemical weapons and industrial chemical poisons are acutely toxic to humans in doses that are readily obtainable and usually handy. They can be successfully used for deliberate drinking water contamination. These chemicals are primarily designed to be more effected through inhalation and by dermal exposure, however a few of them are lethal or incapacitating when placed in drinking water and ingested (Hickman, 1999; Mays, 2004). Table 3 gives summary of chemicals effective in drinking Water

TABLE 3: Summary of Chemicals Effective in Drinking Water (adapted from Mays, 2004).

CHEMICAL AGENTS (milligrams per liter (mg/l) unless otherwise noted)	**ACUTE CONCENTRATION**	**RECOMMENDED GUIDELINES**	
	0.5 L	**5 L/Day**	**15 L/day**
Chemical Warfare Agents			
Hydrogen cyanide	25	6.0	2.0
Tabun (GA, microgram/liter (/l))	50	70.0	22.5
Sarin (GB , /l)	50	13.8	4.6
Soman (GD, /l)	50	6.0	2.0
VX (/l)	50	7.5	2.5
Lewisite (Arsenic fraction)	100-130	80.0	27.0
Sulfur Mustard (/l)	-	140.0	47.0
3-quinuclidinyl benzilate (BZ, /l)	-	7.0	2.3
lysergic acid diethylamide (LSD)	0.050	-	-
Industrial Chemical Poisons			
Cyanides	25	6.0	2.0
Arsenic	100-130	80.0	27.0
Fluoride	3000	-	-
Cadmium	15	-	-
Mercury	75-300	-	-
Dieldrin	5000	-	-
Sodium fluoroacetatec	-	None provided	-
Parathion	-	None provided	-

4.4 CYBER THREATS

Cyber threats on the drinking water supply system arises when outsiders, unauthorized persons or users gain access to important data components of the system which can either be stolen, diverted or wrongfully modified and invalidated in a way that the system fails or becomes less or non responsive to the original purpose. According to Mays, 2004; cyber threats of the water supply sector could be in the following forms:-

- Physical disruption of a Supervisory Control and Data Acquisitions (SCADA) network
- Attacks on central control system to create simultaneous failures
- Electronic attacks using worms/viruses
- Network flooding
- Disguise data to neutralize chlorine or add no disinfectant thereby allowing addition of microbes.

4.5 PHYSICAL THREATS

Physical threats encompass a wide range of internal and external destruction of the physical structural components of the drinking water supply system. Examples include destruction of dams, pumping stations and distribution lines, attacks on the groundwater aquifers or treatment facilities etc. These physical threats can be carried out by a broad category of personalities namely:

- **VANDALS** – Those who are intent on defacing, damaging, or destroying property.
- **CRIMINALS** – Those whose primary motivation is the desire to obtain equipment, tools, or components that have inherent value and can be sold.
- **SABOTEURS** – Those typically motivated by political, doctrinal or religious causes, as well as revenge.
- **INSIDERS** – Persons with access to the water supply facilities or portions of the system as part of their daily work with the objective of compromising the effectiveness of the system by stealing valuable items, cross contamination or injuring other employees. (ASCE and AWWA, 2006).

According to Larry Mays, 2004; physical threats of water systems also includes:-

- Water hammer effect which results in simultaneous main break effects, which is caused by the opening and closing of major control valves and the turning of pumps on and off too quickly, and
- The loss of water pressure that eventually compromises firefighting capabilities and possibly leads to bacterial buildup in the system.

Generally, in order to successfully affect operations by physical attack on the water system, the enemy would have to dissect the water distribution system to target components vulnerable to attack and by destroying the right equipments, a single terrorist or a small group of terrorists could easily cripple an entire city (Hickman, 1999).

Physical disruption may result in significant economic cost, inconvenience, and loss of confidence by customers, but has a limited direct threat to human health. Exceptions to this generalization include destruction of a dam that causes loss of life and property in the accompanying flood wave and an explosive release of chlorine gas at a treatment plant.

Table 4 shows recent physical forms of terrorist attacks against American targets using car bomb technologies.

TABLE 4: Recent Terrorist Attacks against American Targets (sited in Mays 2004)

Date	Target/location	Delivery /material	TNT equivalent (lb)	Reference
Apr.1983	US embassy Beirut Lebanon	Van	2,000	www.beirut-memorial.org
Oct. 1983	US marine barracks Beirut Lebanon	Truck, TNT with gas enhancement	12,000	www.usmc.mil
Feb, 1993	World trade center new York USA	Van, urea nitrate and hydrogen gas	2,000	www.interpol.int
April 1995	Murrah Federal Bidg Oklahoma City USA	Truck ammonium nitrate fuel oil	5,000	senate documents
June 1996	Hobar Towers Dhahran, Saudi Arabia.	Tanka truck, plastic exposive	20,000	www.fbi.gov
Aug. 1998	US embassy Nairobi, Kenya	Truck, Tnt, possibly Semtex	1,000	News reports, Us senate documents
Aug. 1998	US embassy Dar es Salaam, Tanzania	Truck	1,000	Us Senate Documents
Oct. 2000	Destroyer USS Cole Aden Harbor, Yemen	Small watercraft possibly C-4	440	www.al-bab.com

4.6 RADIOLOGICAL THREATS

Radioactive materials are usually found in the natural environment, in extremely low concentration. They are also found in wastes from nuclear power plants, nuclear research organizations, and medical facilities. The radiation emanating from the radioactive decay may be a combination of electrons (beta particles), protons, helium nuclei (alpha particles), neutrons, nuclear fragments, and photons (x-rays and/or gamma rays) all at particular energies, depending upon the nuclide and its decay scheme. Because exposure to radioactive doses is generally very small, the main concern has been over long term exposure and its implications for health problems such as cancer. Therefore, a purposeful insertion of radioactive material into water systems would most likely lead to higher exposure over a relatively short time (ASCE et al, 2004).

Table 5 gives a brief summary of the threats to water supply safety and security.

TABLE 5: Summary of Threats to Water Supply Safety and Security (Rosen et al, 2007.)

(http://www.techneau.org/fileadmin/files/Publications/Publications/Deliverables/D1.1.9.pdf)

Hazard	Hazardous event	Type of hazard	Potential consequences
Sabotage and terrorist attacks	Physical damage (e.g. bombing attack)	Physical	Water shortage and technical damage
	Intentional chemical contamination	Chemical	Health effects, water shortage and remediation of supply system
	Intentional microbial contamination	Microbial	Health effects, water shortage and remediation of supply system
	Cyber attack (e.g. manipulation of operational steps)	Cyber attack	Health effects and water shortage
	Non accessible information. To prevent sabotage and terrorist attacks information regarding source water, treatment and distribution are classified. Due to this all necessary information might not be available to the personal and people in general.	Non accessible information	If the personal operating the system does not have all necessary information actions might be taken that introduce new risks to the system. Also people in general might, because of lack of information, act in a way that pose new risks to the system. Water shortage and health effects are possible.
	Changed human behaviour after terrorist attacks leading to avoidance of tap water	Anxiety, human behaviour	Indirect damage. Because of lack of trust in tap water people use water from other sources and if this water is of poor quality it might cause negative health effects.
Conflicts	Military conflicts	Military	Technical damage, water shortage and health effects
	Political conflicts	Political	Political actions leading to water Conflicts shortage
	Competing land use	Competing interests	Water shortage, contaminated source water and health effects
New chemicals and changed chemicals	Discharge of new chemicals to source waters due to e.g. accidents or continuous leakage	Chemical	Health effects, water shortage and remediation of supply system
	Discharge of chemicals due to new applications	Chemical	Because known chemicals are put into new pathways they may cause poor water quality leading to water shortage, negative health effect and remediation of supply systems.
Emerging pathogens	Discharge to source waters	Microbial	Health effects, water shortage and remediation of supply system
	Changed infection patterns (increased susceptibility to infections among the population)	Microbial	Health effects and water shortage
Public concern	Reports on detection of chemicals or pathogens of very low tolerability	Anxiety (microbial and/or chemical)	Anxiety and decreased trust in water supply
Climate change	New precipitation and evaporation patterns	Water availability	Water shortage
	The climate changes' effects on water quality (changed surface runoff and material transport effecting water quality)	Chemical and/or microbial	Water shortage and possible health effects due to poor water quality
Aging distribution and technical damage systems	Damaged distribution system and possible intrusion of contaminants	Physical, chemical and microbial	Water shortage, health effects . Aging distribution and technical damage
	Increased retention times due to oversized systems	Microbial	Health effects

4.7 WHICH ONE OF THESE THREATS WILL MORE LIKELY HAPPEN?

The physical destruction of a water distribution systems assets or the disruption of water supply by stealing/vandalizing could be more likely than contamination with biological, chemical, radiological or toxicological contaminants. This can be achieved with the use of explosives which are readily available and can be obtained or developed.

Explosives pose a reduced risk to the assailant when compared to biological or chemical agents and require a lower level of education to use than contaminants such as biological or chemical agents. It will be very easy to use a bomb carried by a car or truck to carry out an act of terrorism because truck or car bombs require less preparation, skill or manpower (Hickman, 1999; Mays, 2004; Arendt, 2003).

Fire is another physical and easy method of destruction. It could effectively damage computer control systems, pumps, motors, and other physical structures. More so, once a water supply system is reduced, the ability to fight fires is compromised and other critical infrastructure elements become threatened (Arendt, 2003).

Contamination by chemical or biological agent is generally viewed as the most serious potential terrorist threat to water systems. Chemical or biological agents could spread throughout a distribution system and result in sickness or death among the consumers. For some agents, the presence of the contaminant might not be known until emergency rooms reported an increase in patients with a particular set of symptoms (Clark et al, 1995 sited in Mays, 2004)

According to Bernard and de Burbure in management of intentional and accidental water pollution 2005, to achieve a chemical sabotage by classical inorganic poisons (arsenic, xyanide, ricin,) that can lead to fatalities, very large amounts can be difficult to obtain or to handle. However, a range of extremely toxic chemicals such as those used in chemical warfare do exist, but most of them are rather very difficult to obtain as they cannot be purchased and their production requires a high level of scientific and technological expertise.

A more readily available source of poisonous substances is represented by the dual use chemicals which are produced in large volumes for peaceful purposes (pesticides, precursors or intermediates in the chemical or pharmaceutical industry) but might be deviated from their habitual use. These chemicals are cheap and can therefore be bought in large quantities, or simply stolen from remote or insufficiently protected industrial sites.

The terrorists may decide to use doses that are too affectingly low to cause casualties but sufficient to create a large scale panic and a disruption of water supply affecting a given civilian population or infrastructures. Good candidates for such a scenario could be for example radioactive chemicals, long lived radioisotopes in particular, some water soluble potent carcinogenic or neurotoxic agents.

Generally, the effects of deliberate contamination of water-supply systems are usually limited by dilution, disinfection, and filtration, nonspecific inactivation (hydrolysis, sunlight, and microbial degradation/predation), and the relatively small amount of water to which individuals are usually exposed compared with the total supply. However, with determination and the necessary resources, any part of the system can be penetrated (WHO Guidance, 2004)

4.8 CONTAMINATION AGENTS OF THE MOST CONCERN TO PUBLIC HEALTH

Finding out what agents (biological, chemical and radiological) can be successfully used in terrorist attacks to contaminate drinking water is an extremely important issue that needs to be given immediate attention. Because, it is important that contamination in the drinking water distribution system be detected in a timely manner to ensure adequate time to respond and protect public health. The main goal would be to detect as many contaminants as possible at a concentration that will allow response before consumers become ill, paying particular attention to ensure that all contaminant classes (chemical, biological, toxin, and radiological) are covered (ASCE et al, 2004).

Table 6 lists the main biological pathogens of public health concern as given in Mays, 2004.

TABLE 6: Pathogens of Public Health Concern (adapted from Mays, 2004).

PATHOGEN	DISEASE	INCUBAITON PERIOD	IMMUNIZATION
Salmonella enteritidis	Salmonellosis	8-10h up to 48h	none
Sabmonella enteritidis var. paratyphi A	Paratyphoid fever	1-10 days	Heat killed vaccine
Sabmonella typhi	Typhoid fever	1-2 weeks some times 3 weeks	Heat killed vaccine
Salmonella choleraesuis	Salmonella septicemia	1-2 weeks some times 3 weeks	Heat killed vaccine
Shigella dysenteriae, s.flexneri, s. boydii, S. sonnei	Shigellosis Bacillary dysentery	1-4 days Not more than 7 days	None
Vibrio cholerae	cholera	Few hours	Killed vaccine
Vibrio parahaemolyticus	gastroenteritis	8-48 h	-
Yesinia enterocolitica	gastroenteritis	8-48 h	-
Clostridium perfringens	gastroenteritis	8-48 h	-
Bacillus cereus	gastroenteritis	8-48 h	-
Escherichia coli, enteropathogenic	Endemic diarrhea	2-4 days Max. 3 week	Heat killed vaccie
adenovirus	gastroenteritis	1-3 days	-
Coxsackei virus	Gastroenteritis	3-5 days	None

PATHOGEN	DISEASE	INCUBAITON PERIOD	IMMUNIZATION
Hepatitis A virus	hepatitis	15-50 days	Passive
Norovirus	gastroenteritis	48-72 hours	Passive
Polio virus	poliomyelitis	Usually 1-2 weeks range 3 days to 4-5 weeks	Salk vaccine (Killed): sabin vaccine (lives)
Cryptosporidium	cryptosporidiosis	7-days	-
Entamoeba histolytica	amoebiasis	3-4 weeks	-
Naegleria fowleri	Primary amebic meningoencephalities	3-14 days	-

Finally, the determination of the chemicals that can be effectively added to water supply, either accidentally or by a purposeful attacker, and thereby cause illness, death, or economic loss, centers on several key parameters:

- Toxicity by all routes of exposure
- Solubility/miscibility in water—that is how well it is borne by water?
- Volatility—that is, does it stay in the water?
- Survivability—(for example, half life) in water.
- Warning signs that should alert the public—(such as taste, smell, or color)
- The production of toxic by-products through reactions in water or wastewater (ASCE et al, 2004).

5. GENERAL STANDARDS IN REGULAR DRINKING WATER SUPPLY

There have already been extensive work and standardized regulations regarding quality of drinking water and therefore its safety in relation to laboratory analysis protocols and specific parameters in respect of contaminants (biological, chemical, toxins, radiological), hence, repeating them will result in redundancy.

Generally drinking water supply systems consist of the following components:

- A Water Source - such as a lake, reservoir, river intake, spring catchment tank, or groundwater borehole;
- A Raw Water Main - which connects the drinking-water source via a pipeline or aqueduct to a water-treatment plant;
- A Treatment Plant - in which processes such as coagulation, sedimentation, filtration - active carbon treatment, ozonization, and chlorination are carried out;
- A Piped Distribution System - in which drinking-water is transported to end-users or, more commonly, to water tanks or water towers elevated above the end-users;
- Water Tanks and Towers - which can provide a steady supply of drinking-water at a more constant pressure; and
- A Local Piped Distribution System - in which pumped or gravity-fed water under pressure is provided to residential water tanks and taps or other end-users (WHO Guidance, 2004).

The Water supply systems can be considered as a number of steps aimed at assuring the safety of drinking-water, including:

- Preventing pollution of source waters;
- Selective water harvesting;
- Controlled storage;
- Treatment prior to distribution;
- Protection during distribution; and
- Safe storage within the home and, in some circumstances, treatment at the point of use (Mays, 2002).

5.1 THE EUROPEAN UNION (EU) DRINKING WATER LEGISLATION

Drinking water directive (DWD) of the EU basically states that the supply of water is a service of general interest and that water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such. Hence, the (DWD 98/83/EC) of the EU aims to protect human health from adverse effects of contamination in water intended for human consumption; as well as water used in the production and marketing of food; with the exception of natural mineral waters, medicinal waters, and water used in the food industry. Not affecting the final product by ensuring that drinking water through its legislations is wholesome and clean (Council Directive, 98/83/EC).

According to European Communities Drinking Water, No. 2 Regulations 2007: A wholesome and clean water is one that is free from any micro-organisms and parasites and from any substances which in numbers or concentrations, constitute a potential danger to human health and one that meets the standard quality parameter and parametric values for microbiological, chemical, radioactivity and indicator parameters. The Regulations prescribe quality standards to be applied and related supervision and enforcement procedures in relation to supplies of drinking water, including requirements as to sampling frequency, methods of analysis, the provision of information to consumers and related matters.

The EU commission requires its member states to monitor the quality of drinking water and to take measures to ensure that it complies with the minimum quality standards stipulated in its regulations. It also lays down a number of requirements for reporting to the commission, and for making information available to the public regarding the quality of drinking water. The main principles are that the quality of the water should be such that consumers can drink and use water for domestic purposes for a lifetime without the risk of adverse health effects. Also special attention is paid to the protection of vulnerable groups such as children and pregnant women (EU Directive, 2000).

An effective control of drinking water quality is based on data obtained from samples analyzed in laboratories and the DWD specifies that the analytical methods used for drinking water should ensure that the results obtained are reliable and comparable within the member states. A regular check of the water quality is defined for some key parameters in so-called "check monitoring", and a more comprehensive check of the water quality including all other parameters is carried out with a much lower frequency in so-called "audit monitoring". On the whole the EU regulation on drinking water has contributed significantly to the supply of safe and wholesome drinking water to European citizens (Hecq et al, 2004).

5.2 STANDARD REGULATIONS IN THE UNITED STATES

The Safe Drinking Water Act (SDWA) of the United States of America compelled its Environmental Protection Agency (USEPA) to establish a national health based standards aimed at reducing public exposure to microbiological, chemical and radiological contaminants of concern through its "Total Coliform Rule", "Surface Water Treatment Rule", "Ground Water Rule", "Lead and Copper Rule" and regulations for large number of chemicals of public health concern.

The SDWA contain specific criteria and procedures, including requirements for water monitoring, analysis and quality control, to ensure that the drinking water system is in compliance. The SDWA also places strong emphasis on protecting source waters, improving the regulatory processes and conducting research on contaminants of concern. Provisions are also made to address the special needs of small water systems, and include requirements for making water quality information available to consumers, conducting "Health Risk Reduction Benefit Analysis", and helping individual states meet water system infrastructure needs.

The USEPA requires all public water systems using surface water to disinfect and provide specific levels of treatment for microbial pathogens; most systems were required to filter their water. The USEPA also established treatment techniques for a wide range of microorganisms, disinfectants, disinfection byproducts, inorganic and organic chemicals, and radionuclides (EPA, 2004a sited in Hecq, et al, 2004). as well as setting up the National Secondary Drinking Water Regulations for contaminants that affect the aesthetic (taste, color or odor), cosmetic (skin or tooth discoloration) or technical (corrosives or scaling) qualities of drinking water.

The Federal, State and local governments is also required to provide baseline information to community water systems required to conduct vulnerability assessments regarding which kinds of terrorist attacks or other intentional acts are the probable threats to substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water or otherwise present significant public health concerns (Bioterrorism Preparedness and Response act, 2002).

5.3 GUIDELINES OF THE WORLD HEALTH ORGANISATION (WHO)

Worldwide, the principal starting points for the setting of water quality standards are the World Health Organization (WHO) water safety framework within which the Guidelines for Drinking Water Quality (GDWQ) provide a range of advice on the microbial, chemical, radiological and acceptability aspects of drinking water with the primary aim of protecting public health (WHO, 2004).

The Guidelines for Drinking Water Quality (GDWQ) provide an assessment of the health risk presented by microorganisms, chemicals and radionuclides present in drinking-water. The recommended values in the guidelines for individual constituents of water are not mandatory limits – rather they are intended to be used in the development of risk management strategies, including national or regional standards developed in the context of local or national environmental, social, economic and cultural conditions (Highsmith et al, 2004).

WHO adopted the hazard analysis and critical control point (HACCP) based approach for water supply in its water “Water Safety Plans”. The HACCP is a preventive risk management system that has been used in the food manufacturing industry. Its principles are based on developing an understanding of the system, prioritizing risks and ensuring that appropriate control measures are in place to reduce risks to an acceptable level. These principles have been refined and tailored to the context of drinking-water following the application of HACCP in drinking water supply utilities. The experience of the application of HACCP by water utilities led to the development of the water safety plan approach.

The Water Safety Plan is an improved risk management tool designed to ensure the delivery of safe drinking water. It identifies the hazards that the water supply systems are exposed to and the level of risk associated with each water supply utility and goes on to elaborate on how each hazard will be controlled, how the means of control will be monitored, how the operator can tell if control has been lost, what actions are required to restore control and how the effectiveness of the whole system can be verified (Godfrey and Howard, 2004).

Figure 1 below is the framework for drinking water safety as presented in the world health organization (WHO) water safety plan manual, 2006.

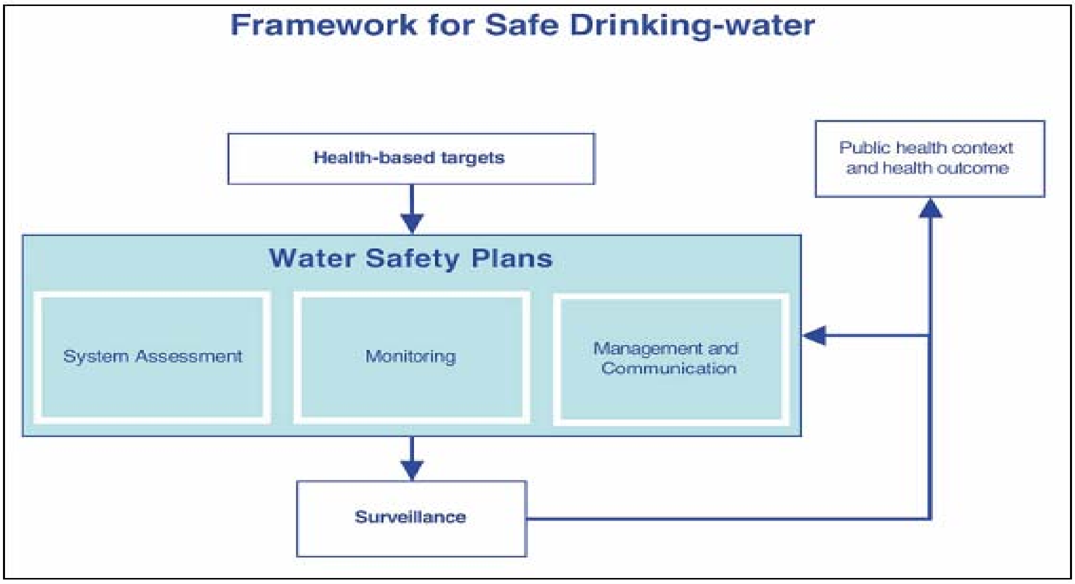


FIGURE 1: Framework for Drinking Water Safety (Source: Water safety plan Manual; WHO 2006)

In summary, it is not in the best interest of the public to promote the adoption of an international standard for drinking water quality, as much as it is would be expected. This is because, the nature and form of drinking-water standards vary among countries and regions and there is no single approach that is universally applicable. More so, approaches that may work in one country or region will not necessarily transfer to other countries or regions. However, it is considered to be of a better advantage to rather introduce a qualitative or quantitative risk benefit approach in the establishment of national standards and regulations (WHO Guidance, 2004).

6. APPROACHES AND INSTRUMENTS TO BE IMPLEMENTED

The approaches and instruments that can be implemented to successfully influence the everyday operational routine in drinking water supply systems and therefore, promote the provision of safe water and enable effective response to emergency situations in an intentional or accidental contamination event include the following.

6.1 PHYSICAL PROTECTION SYSTEM

A physical protection system consists of physical and electronic security measures used for the physical protection of systems against identified adversaries, referred to as the design basis threats (DBTs), such as vandals, criminals, saboteurs and insiders, with specified motivation, tools, equipment, and weapons. According to ASCE and AWWA, 2006; the main elements of a Physical Protection System include:

6.1.1 DETERRENCE

Security measures such as lighting, the presence of closed circuit television (CCTV), a clearly visible facility with no visual obstructions, locking systems like mechanical or electrical keypads, card reader systems or people in the area may deter an adversary from attacking a facility. Deterrence is not generally considered a part of a physical protection system with a predictable level of effectiveness; However, it can reduce the occurrence of crime or low level vandal attacks.

6.1.2 DETECTION

Security measures such as sensors are intended to detect the presence of an intruder. An effective detection system should include electronic features such as sensors as well as cameras or visual observation for assessment of alarm validity. Depending on the types of sensors, a detection system may include lighting systems, motion detectors, monitoring cameras, access control equipment, or other devices.

6.1.3 DELAY

Delay features consist primarily of physical hardening devices often employed in multiple layers to provide protection in depth. Security features such as physical barriers like fence and intrusion detection systems are designed to delay an adversary until a response force can interrupt the adversary’s actions. Delay features are only effective when placed within a layer of detection.

6.1.4 RESPONSE

Actions taken to interrupt and counter the task of the adversary: the water utility’s security response force or law enforcement may carry out the response with the appropriate responder, depending on the threat and policy of the utility. Normally, the capabilities of the responders to a security event, including number, authority, and weaponry, should be greater than the capabilities of the perceived threat to the facility.

6.2 WATER SAFETY PLANS

Water Safety Plans (WSP) is a central component of the 3rd edition of the WHO Guidelines for Drinking-water Quality. Water Safety Plans (WSP) is an approach to drinking-water safety management that has its roots in the multiple barrier principle of water treatment, and the Hazard Assessment of Critical Control Points (HACCP) used for the safety of foods. The application of this approach is aimed at ensuring good drinking water supply practices through; the prevention of source waters contamination, the reduction or removal of contamination through treatment processes to meet health-based targets, and the prevention of contamination during storage, distribution and handling.

The basis for the implementation of the water safety plans (WSP) is to ensure the most effective means of maintaining consistency in the safety of the supplied water. This is achieved through the water safety plans' comprehensive risk assessment and risk management approach, which is based on sound science; and supported by appropriate monitoring that encompasses all steps in water supply, from catchment to consumer. This approach to water quality management presents challenges for process monitoring and puts new demands on analysis.

The objectives of water safety plans are applicable to large piped drinking-water supplies, small community supplies and household systems and are achieved through:

- Development of an understanding of the specific system and its capability to supply water that meets health-based targets
- Identification of potential sources of contamination and how they can be controlled;
- Validation of control measures employed to control hazards
- Implementation of a system for monitoring the control measures within the water system
- Timely corrective actions to ensure that safe water is consistently supplied and
- Undertaking verification of drinking-water quality to ensure that the WSP is being implemented correctly and is achieving the performance required to meet relevant national, regional and local water quality standards or objectives (WHO, 2005).

A Water Safety Plan comprises, as a minimum, three essential actions that are the responsibility of the drinking-water supplier in order to ensure that drinking-water is safe. These are:

I. **A system assessment:** To determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets health-based targets. This also includes the assessment of design criteria of new systems;

II. **Effective operational monitoring:** Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance is rapidly detected in a timely manner; and

III. **Management:** Plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes (WHO, 2004).

In the guidelines for drinking water quality, World Health Organisation identified five key components that are required to deliver safe drinking water which are also embedded in the water safety plans, they include:

1. The establishment of health-based targets for microbial and chemical quality of water,
2. A system assessment to determine whether the water supply chain from catchment to consumer can deliver safe drinking water at the point of consumption,
3. Monitoring of identified control measures within the water supply chain that provide assurance of safety,
4. Management plans documenting the system assessment and monitoring and which describe the actions to be taken during normal operation and incident conditions to secure water safety,
5. Independent public health surveillance of water safety. (WHO, 2004). These key components are represented diagrammatically in the Table 7.

TABLE 7: Key Components in the Water Safety Plans (Source: WHO 2006)

Component		Requirements
1: Setting Health-based Targets	➲	Targets are based on an evaluation of health concerns and need to be set at a tolerable level for the community (e.g. are risk-based and can be coordinated with national guidelines, standards or WHO guidelines).
2: System Assessment	➲	An assessment is conducted to characterise the water supply system, assess risks and to determine whether the drinking-water supply (from source through treatment to the point of consumption) as a whole can deliver water that meets the health-based targets).
3: Operational Monitoring	➲	Monitoring of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety. Monitoring at multiple points within the system, rather than relying on end-product monitoring, provides the supplier with assurance that unsafe product does not end up with the consumer.
4: Management Plans	➲	Management plans are set up and encompass: ▪ Documentation of the system assessment ▪ Monitoring plans including normal and incident operations, upgrades, improvements and communication
5: Surveillance	➲	A system of independent surveillance verifies that the above components are operating properly and effectively.

6.2.1 STEPS IN THE DEVELOPMENT OF A WATER SAFETY

The steps involved in the development and implementation of the water safety plans is simplified in the flow chart illustrated in Figure 2.

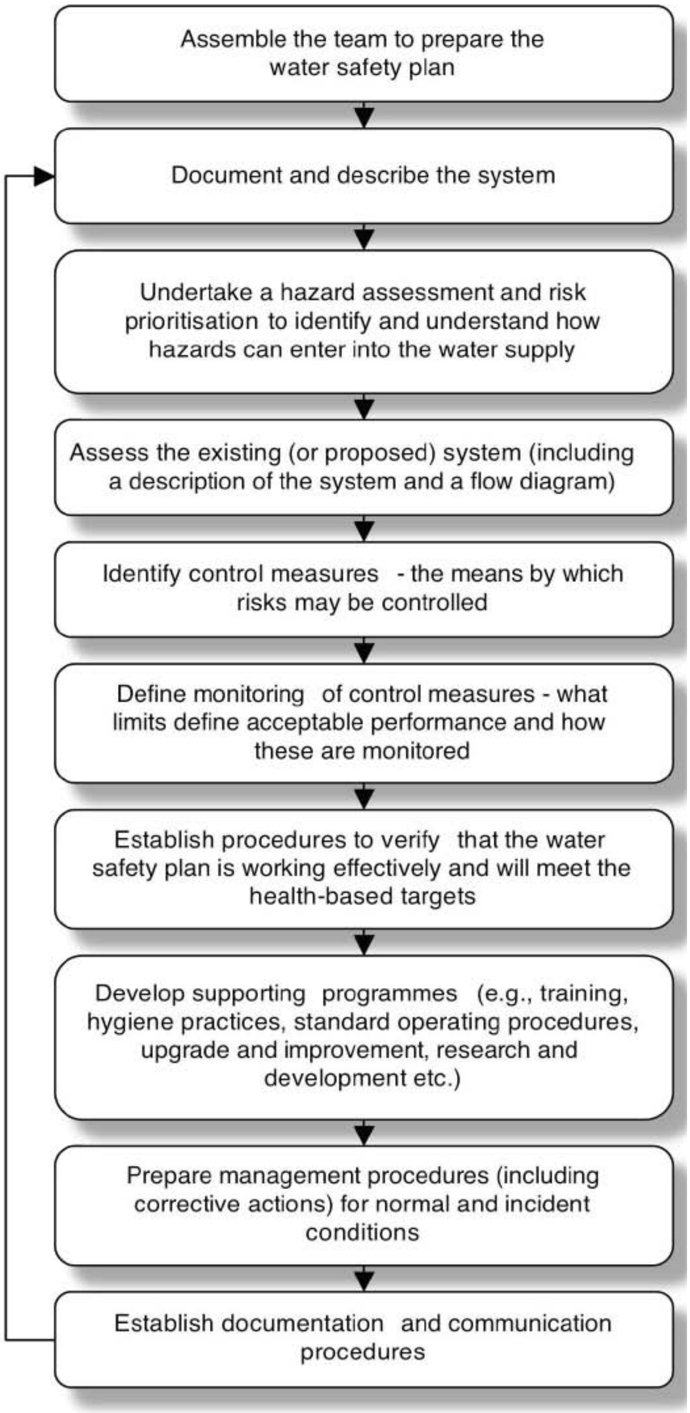


FIGURE 2: Overview of the key steps in developing a Water Safety Plan (Water Safety Plan WHO, 2006)

The water safety plans need to be supported by accurate and reliable information obtained by industrial bodies, from scientific and technical literature and from expert judgment, in order for it to be relied upon for controlling the hazards and hazardous events for which it was set in place.

6.3 ONLINE CONTAMINANT MONITORING SYSTEM

An online contaminant monitoring system can help detect contaminants in the water. It can also manage the complex risks that are related to contamination, and therefore, mount to an appropriate response that would protect the public health; depending on the specific risk reduction needs in various water supply utilities.

The Online Contaminant Monitoring System is used to:

- Detect and characterize all “important” contamination events; distinguish from benign excursions from nominal operating values.
- Where possible, identify contaminant(s) or class (es) of contaminant.
- Where possible, estimate contaminant concentration.
- Determine location, extent, and flow of contaminant through the system.
- Acquire sample for laboratory study when threshold is reached.
- Provide alarm or alert information to decision makers in sufficient time and detail to:
    - Eliminate all false negatives
    - Minimize false positives
    - Implement appropriate responses
    - Improve normal operations
- Develop good baseline data showing ways in which operations can be improved through deployment of an Online Contaminants Monitoring System.
- Supplement existing surveillance system in meeting regulatory requirements.

The design of an online contaminant monitoring system (OCMS) is complex. It is done in a rigorous analytical mode, considering all details, all interactions /interdependencies and established engineering principles. However, because, not all the requisite scientific knowledge is available, the guidance needed for the design and implementation of an online contaminant monitoring system (OCMS) is in the form of “Best Practice Standards” (based on the availability of knowledge acquired through experience and/or research).

6.4 EARLY WARNING SYSTEM

An early warning system is a suite of instruments and monitors that provides early warning in the instance of a contamination event. Its primary goal is to detect as many contaminants as possible, at a concentration that will permit an effective local response. This will in turn, reduce or entirely avoid the adverse impacts that may result from such an event. While particularly ensuring that, all contaminant classes (chemical, microbiological, toxin, and radiological) are covered. As well as, reliably identifying low probability/high-impact contamination events in a distribution system’s finished water, or in source water (ASCE et al, 2004; Hasan et al, 2004).

The design of an Early Warning System involves fully charactering the system to be monitored. Such as, the distribution infrastructure with respect to access points, flow and demand patterns, and pressure zones as well as identifying and characterizing the system vulnerabilities. Unfortunately, a continuous monitoring "silver bullet" does not exist. It will likely take a suite of instruments and monitors to provide early warning in the instance of a contamination event.

Summarizing, the desired properties of a water supply early warning system include:

- Ability to detect as many contaminants as possible per contaminant class (Chemical, Microbiological, Toxin, Radiological)
- Capability to detect these contaminants below health threat levels (e.g. LD_{50})
- Minimal false positives and negatives
- Ability to produce quantifiable and reproducible results
- Compatibility with infrastructure that is in place (e.g. SCADA, sanitary, power)
- Availability of remote monitoring
- Ability to withstand all seasons/climates/conditions
- Alarm triggered auto-sampling for further analysis and evidence

Before a decision is made about which instrument to implement, in order to achieve an online contaminant monitoring system or an early warning system; a baseline for water quality conditions based on water quality sampling for each water utility has to be defined so as to determine what pollutants are specifically of concern to each water supply utility.

Detection methods include the use of:

- Water quality surrogates such as pH, temperature, conductivity, flow/pressure, turbidity, residual chlorine, total organic carbon etc,
- Technologies for detection of specific contaminant,
- Toximeters used to quickly determine whether water is potentially toxic; with the use of bacteria (*Vibrio fisheri*) or enzymes (luciferase), small crustaceans (*Daphnia magna*) or specific chemicals, to indicate toxic contaminants, through a change in the color or intensity of light produced by a decrease in the dissolved oxygen uptake rate, in the presence of the contaminants.
- Turbidity meters that measure the average amount of light scattered over a defined angular range, for sample clarity.
- Spectrometry-UV (UV-Vis spectrometers) also used for effective detection and identification of contaminants
- Luminometers used as luminescent toxicity screening instruments that uses freeze-dried reagent or naturally luminescent organism *(Vibrio Fisheri* like), which produces *luciferase* as part of their metabolic pathway, to determine the inhibitory effect of water soluble samples (suspended solids)
- Fluorometery used to detect microbiological contamination in water (source waters) for chlorophyll-a and algal biomass, and
- Biomonitors – use of living organisms in toximeters, flouromtery and luminometers

7. TOOLS USED FOR SAFETY AND SECURITY IN WATER SUPPLY

There are many well tested and understood instruments that measure a wide variety of water properties with good reliability and accuracy. These instruments will be among the group of devices to be implemented in a contemporary online contaminants monitoring system and early warning system. Some examples of the real time monitoring tools and other state of the art instruments currently in use throughout the water supply system include:

7.1: SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEMS (SCADA)

Supervisory Control and Data Acquisition Systems (SCADA), shown in Figure 3, is a system that collects data from various sensors at a factory, plant or in other remote locations, and then sends this data to a central computer, which then manages and controls the data. SCADA primarily functions in the acquisition, communication, presentation and control of data. It is broadly used in a wide range of industrial processes, such as in: Water and Waste Water Management Systems, Electric Power and Distribution Systems, Traffic Signals, Mass Transit Systems, Environmental Control Systems and Manufacturing Systems, to provide monitoring and control of remote equipment and facilities.

7.1.1 APPLICATION OF SCADA IN THE WATER SUPPLY SECTOR

The water supply sector applies SCADA in water filtration plants, water distribution systems and pump stations for report generation in the management of remote and unattended operations, alarm and events management through process monitoring and control in the collection, storage, retrieval and archive of data.

A SCADA system includes the remote Terminal Units (RTUs), Remote Process Unit (RPUs), Programmable Logic Controllers (PLCs) and Human Machine Interface (HMI) which is a user interface. From a central reading location a SCADA system can track a number of remote sites equipped with Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs).

The RTUs via different sensors can obtain real-time measurements of an array of conditions and a wider variety of parameters, including temperature, pressure, current, voltage flow, and tank levels. The data acquired is then sent back via the communication link. Some of the larger systems can monitor 10-20,000 remote sites, with each site handling as many as 2000 input/output (I/O) points. These units in turn report back to the Central Processing Unit (CPU) that carries out the control functions and needed analysis. The HMI of a SCADA system is where data is processed and presented to be viewed and monitored by a human operator. This interface usually includes controls where the individual can interface with the SCADA system.

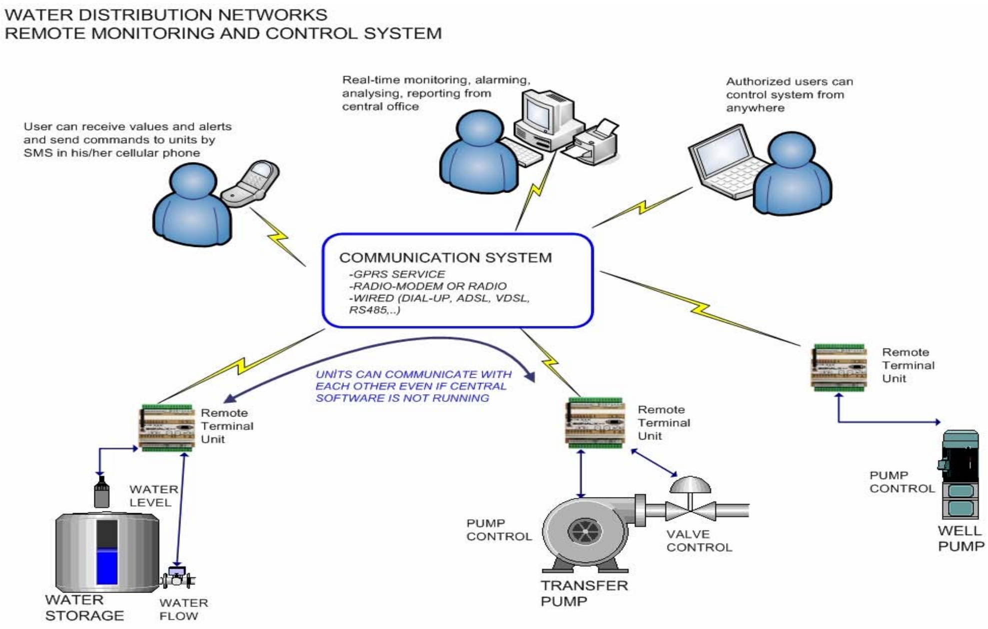


FIGURE 3: Water supply and distribution SCADA:
(www.elkontek.com/eng/schema_water_scada_eng.jpg; Visited 8.07. 2008)

7.2 TOXPROTECT 64 (TOXIMETER)

DESCRIPTION: The *Tox*Protect (Figure 4) is an automated monitoring system to protect drinking water supplies from accidental or malicious contamination due to harmful substances. It is an instrument used in the online monitoring of drinking water to detect toxic substances present in the water. It uses a number of fish swimming in the continuously sampled water and detects anomalies in their swimming behavior due to toxicity stress.

The ***Tox*Protect** monitors the swimming activity of up to 20 fish by measuring the frequency of interruption of an array of light barriers. The result is given in interrupts per minute per fish. In the event of the values falling below a given threshold for a certain period of time, the alarm verification process is activated. Immobile fish at the bottom and in the upper region of the aquarium are also registered. The fish species used can be selected by the user, with recommendations given in the specifications; however all fish must be active and 4-6cm in length.

Due to naturally occurring random variations in fish behavior, each alarm criterion is met from time to time by accident. In order to prevent false alarms, a verification system is required. This is achieved by increasing the illumination inside the aquarium during the verification period. Normally, this leads to a dramatic increase in fish activity. Under toxic conditions, however, this may be different. Hence by monitoring the “increase” in activity during modified illumination, it is possible to accept or reject the initial alarm.

As a result, the ToxProtect instrument detects contamination, regardless of what it might be, in real time, and sets off an alarm if there are signs of abnormal behaviour, which starts at hundreds of times lower than lethal concentrations. It also identifies events due to terrorist activity, or accidental toxicity, as a result of chemical spillage or runoff. It is also a low cost solution to online contaminant monitoring. It is equally applicable to dam monitoring, waterway analysis and assessment, general environmental monitoring, intake assessment and chemical analysis.

FEATURES:

- **Sensitive to a wide range of toxins**: detection of toxins using fish is a well-established method, with sensitivity data for nearly every combination of fish and toxin readily available.
- **Closely comparable to humans**: test organisms must react to substances harmful to humans; the use of fish gives the closest practical comparison available in the expected scenario.
- **Reliable**: false alarms MUST be reduced to an absolute minimum in order to increase user confidence and avoid unnecessary expense; for this, the ToxProtect uses an integrated alarm verification system.
- **Easy to operate at affordable costs**: for a high level of security, it may be necessary to employ multiple monitoring locations; the ToxProtect is a low-price, low-maintenance device which lends itself to multiple site applications within a water company or agency.

PARAMETERS OBSERVED/ SAMPLED: The **ToxProtect** is equipped with internal sensors to monitor and report on instrument malfunction in: Inadequate sample flow, Drain blockage, Temperature loss, Accidental/unauthorized exposure of test chamber to ambient light, High chlorine concentration.

FIGURE 4: Toxprotect 64 Water Monitoring System: (www.bbe-moeldaenke.de/; Visited 24.06. 2008)

7.3 The Microtox Model 500 Analyzer

DESCRIPTION: The Microtox Model 500 Analyzer (Figure 5) is a laboratory-based, temperature-controlled, self-calibrating photometer that measures light production from a luminescent bacteria and easily interfaces with a PC – using MicrotoxOmni™ Software – to efficiently collect, analyze, and store test data. The microtox toxicity testing technology is a biosensor-based measurement system for toxicity and provides an effective way to monitor for either accidental or deliberate contamination of water supplies.

Microtox text systems are based upon the use of luminescent bacteria known as *vibrio fischeri* which produce light as a byproduct of normal metabolism. Any inhibition of normal metabolism such as that caused by toxicity; results in a decreased rate of luminescence. The higher the toxicity level the greater the inhibition of light production. The microtox test system quickly reveals any changes in the level of toxicity of drinking water. This provide for an effective means of water supply surveillance when supplies are monitored regularly at strategic points. They are uniquely suited for drinking water surveillance because they provide rapid screening and confirmation results, which are cost-effective and easy to perform.

A typical application by many drinking water treatment systems involves texting the water at the sources, at the treatment plant and at strategic points along the distribution system. The sampling and analysis usually occurs from once to multiple times per shift and samples are collected at numerous points such as the intake from the water source (reservoir, river, etc), various points throughout the treatment process, before and after chlorination, and at key points in the distribution piping.

FEATURES:

- Rapid Results - Acute Toxicity results in less than 15 minutes!
- Testing is completed at your site – no outside lab needed
- Requires a small sample volume.
- Proven technology - successfully used throughout the world

PARAMETERS OBSERVED/ SAMPLED: Table 8 shows a Partial list of toxic compounds detected by microtox systems.

TABLE 8: Partial List of Toxic Compounds Detected by MicroTox
http://www.sdimicrotox.com/pdf/Microtox-for-drinking-water.pdf

Arsenic	Sodium cyanide	Mercury	Selenium
Potassium cyanide	PR-Toxin	Chromium	Copper
Aflatoxin	Rubertoxin	Ochratoxin	Chloroform
Ammonia	Benzoyl cyanide	Sodium lauryl sulfate	Lindane
Ddt	Formaldehyde	Cresol	Malathion
Carbaryl	Trinitrotoluene (TNT)	Flouroacetate	Parathion
4-phenyl Toluene	Pentachlorophenol	Carbofuran	patulin
Paraquat	Cyclohexamide	Diazinon	Cadmium

FIGURE 5: The Microtox Model 500 Analyzer: (http://www.sdimicrotox.com/pdf/Microtox-for-drinking-water.pdf; visited 24.06. 2008)

7.4 THE DELTATOX ANALYZER

DESCRIPTION: the Deltatox analyzer (Figure 6) is a simple and portable test system for acute toxicity that uses the same specialized strain of luminescent bacteria as the microtox to provide a direct measurement of the toxicity of a sample and simultaneously detect thousands of potential contaminants. It is ideal for screening for chemical contamination. It is portable and is easily used at remote locations, such as reservoirs, storage tanks, or at locations throughout the water supply distribution system. Test results are available within minutes and data can be stored by the unit for later downloading and analysis.

FEATURES:

- Results available in minutes
- Broad range of toxins detected - >2,000 compounds
- Microbial detection level in drinking water – 100 cfu/mL
- Excellent correlation with HPC methods
- Inexpensive
- Portable

FIGURE 6: The Deltatox Analyzer: (www.sdix.com; visited 24.06. 2008)

7.5 BBE ALGAE TOXIMETER

DESCRIPTION: The bbe Algae Toximeter (Figure 7) is used to continuously analyses water for the presence of toxic substances. Standardized algae are added to the water sample and the instrument detects the photosynthetic activity of the chlorophyll. If the algae are damaged, for example by herbicides, a reduction in algae activity and indirectly in oxygen production is caused and an alarm is activated after a pre-defined threshold has been exceeded.

It also serves as a measuring instrument for the precise determination of algae concentration in the water. It Works with a double test loop; short measuring intervals, and a PC for online data analysis, which permits a high temporal resolution of the water to be monitored. The instrument has an automatic cleaning device and a low level of maintenance.

FIGURE 7: bbe Algae Toximeter: (http://www.bbe-moldaenke.de/; visited 24.06. 2008)

7.6 BBE DAPHNIA TOXIMETER

DESCRIPTION: The bbe Daphnia Toximeter (Figure 8) observes daphnids - water fleas, under the influence of constantly running sample water. Based on the Extended Dynamic Daphnia Test, bbe developed a new sensitive method to detect hazardous compounds in water from rivers (source-water protection), plants, distribution systems and production drains to preserve human health and to monitor water.

Application: Sample water (0.5 - 2 l/h) continuously runs through the measuring chamber containing the Daphnia. The live images obtained using a CCD-camera are evaluated online with an integrated PC to analyse changes in the behaviour of the Daphnia. If this change is statistically significant, an alarm is triggered. The method of image analysis enables a series of measurement methods and plausability tests to assess the Daphnia behaviour using different criteria [(*speed measurements*-average speed, speed distribution)(*Behaviour observation* - swimming height, fractional dimension:measurements for turns and circling movements, curviness) (*growth observation* - determination of daphnia size)].

FIGURE 8: bbe Daphnia Toximeter: (http://www.bbe-moldaenke.de/202.html. (Visited 24.06. 2008)

7.7 COLIFAST AT-LINE MONITOR (CALM)

DESCRIPTION: The Colifast At-Line Microbial monitor (CALM) (Figure 9), is an automated early warning system for rapid and systematic quality monitoring. The CALM provides water quality data for thermo-tolerant *coliforms/E.coli* and total coliforms. This early warning system offers rapid results for earlier hazard assessment as part of an integrated emergency response program, or for routine microbial monitoring.

The CALM creates value through earlier results for faster operational decisions. Whether evaluating source water quality in supply networks or monitoring waters for environmental management, this system provides results earlier to enhance performance; reduce response times and improve services. It is applied in source water/raw water quality, environmental/recreational water, industrial process water, effluents, water plant quality control operations, distribution of finished water

FEATURES:

- Rapid results. Results obtained within 2-12 hours.
- Automated analyses = easy-to-use.
- Early Warning and Quantitation. Depending on level of bacteria in the water there are two main methods to use: I) Rate of MU-production as an indicator of fecal contamination II) MPN (most probable number) for coliform/microbial growth.
- Remote Warning System for earlier operational decision.
- User defined alarm level: The user can set an alarm level according to the limit for taking action.
- More frequent sampling and better safety: Automatic sampling allows more frequent analyses without increasing labor. More frequent analysis ensures a better control with the water, and safety for the public.

- Time saving = cost saving: Rapid results for rapid decisions reduce release time of product.

PARAMETERS OBSERVED/ SAMPLED: Provides water quality data for thermotolerant coliforms/E.coli and total coliforms.

FIGURE 9: The Colifast At-line Monitor (CALM): (http://www.colifast.no; visited 25.06. 2008)

7.8: COLIFAST ANALYZER

DESCRIPTION: The Colifast Analyser (Figure 10) is a semi-automated early warning system for rapid and systematic water quality monitoring. It tests for thermo-tolerant coliforms */E.coli,* total coliforms, total viable organisms and *Psudomonas Aeruginosa* are available. Applications for water monitoring are in: source water quality, surface and groundwater, non-disinfected waters, marine and recreational waters

FEATURES:

- Rapid results, e.g., Coliform results are obtained within 2-12 hours (18-24 h for traditional methods).
- Automated analysis – easy-to-use: After addition of the test sample to the Colifast medium and registration, only hit “Start and the Colfast Analyser performs the analysis automatically.
- Remote warning system: The Colifast Analyser´s remote warning system gives automatic and early warning of positive sample status allowing earlier operational decisions by e-mail.
- More frequent sub-sampling = faster results: Automatic sub-sampling allows more frequent analyses without increasing labour. Faster results ensure better control of water and safety for the public.
- Time saving = cost saving: Rapid results for rapid decisions reduce release time of product.
- Multiple samples loading for all day testing: Multiple sample batches can be loaded and tested simultaneously throughout a work-shift according to the day’s testing requirements.

- Customized test runs for specific testing regimes: Test run parameters can be customized for specific testing matrices/requirements. Test confidence levels can be adjusted for earlier reporting of positive results, according to experience with local water sources and test regimes.

PARAMETERS OBSERVED/ SAMPLED: Tests for thermo-tolerant coliforms /*E.coli,* total coliforms, total viable organisms and *P. aeruginosa*, are available.

FIGURE 10: The colifast Analyzer; (http://www.colifast.no; visited 25.06. 2008)

7.9: SIX-CENSE^{TM}

DESCRIPTION: The Six-CENSE™ (Figure 11) is a 6-in-1 multiparameter in-line sensor that can measure Chlorine (free chlorine), Monochloramine, or Dissolved Oxygen, pH, Conductivity, Oxidation-Reduction Potential, and Temperature. This electrochemical technology sits on a robust ceramic chip.

Six-CENSE™ is the only multi-parameter sensor designed for direct insertion into pressurized water mains from 2 inches to 72 inches in diameter. This capability makes the Six- CENSE™ ideally suited to fulfill the requirements of water utilities to monitor the water quality throughout their distribution systems. The unit is easy to install, simple to calibrate, and is designed for durability and minimum operator maintenance. The Six-CENSE™ technology and uses thin and thick film plating/printing techniques to produce a sensing array on a single ceramic chip.

FEATURES:

- Data available in 4-20 mA, Modbus, Ethernet and others.
- Single point calibration makes installation and set-up easy, with low maintenance.
- Direct and reagent-free measurement of Chlorine
- Capability for measuring Monochloramine for plants using chloramination.
- Membrane-Free measurement of Dissolved Oxygen
- Sensor chip field replaceable with typical six-month service life under normal potable water parameters.
- Units available in NEMA 4X/IP66 and IP68/submersible enclosures.
- Installs in 1.5" or 2" corporation stop.

PARAMETERS OBSERVED/ SAMPLED: chlorine (no reagents required), monochloramine or dissolved oxygen, pH, temperature, conductivity, ORP/REDOX.

Probe Head and Chip

Six-CENSE™ Insertion into Pipe

FIGURE 11: The Six-CENSE™ (http://www.dascore.com/sixcense.htm; visited 25.06. 2008)

7.10: WATER DISTRIBUTION MONITORING PANEL (WDMP) MODEL

DESCRIPTION: The Water Distribution Monitoring Panel (Figure 12) provides 24/7 surveillance of drinking water distribution systems. The WDMP is designed to monitor multiple indicator parameters that can signal changes in water quality profile. It Includes: Hach CL17 Chlorine Analyzer, Free or Total (to be specified when ordering), Hach 1720D Turbidimet. The Water Distribution Monitoring Panel (WDMP) panels are ideally located in plants, pump houses, system stations, and more vulnerable sites such as hospitals and schools.

FEATURES:

- The right tool to establish your distribution system's baseline
- Instruments you can count on, each ranked top in category
- A sole-source supplier with breadth of product and depth of service
- Flexible system can be enhanced with on-line TOC analyzer and autosampler
- A partner you can depend on

PARAMETERS OBSERVED/SAMPLED: chlorine, conductivity, pH, turbidity, pressure, temperature.

FIGURE 12: Water Distribution Monitoring Panel (WDMP) Model; (http://www.hach.com/; visited 25.06. 2008)

7.11 WATER DISTRIBUTION MONITORING (PipeSonde In-pipe Probe)

The Water Distribution Monitoring Panel (WDMP) PipeSondes (Figure 13) is another type of the above described and may be located to provide insight into the heart of the distribution system, such as major interconnections, trunk mains, air vaults, remote storage tanks and reservoirs, river intakes and other areas of concern. Both systems provide multiple-parameter measurement and continuous monitoring.

This supplemental/complementary monitoring strategy helps a system realize a comprehensive baseline, maximized continuous surveillance, and optimized real-time "fate and transport" profiling in the event of contamination. Utilizing both systems, operators have more information to identify the source and extent of contamination and to implement prompt and effective isolation.

FEATURES:

- Continuous monitoring of seven different water quality parameters - eliminates the manual sampling needed to establish an operating baseline, monitor for contamination, and comply with regulatory mandates under the Lead and Copper Rule, the Ground Water Rule, and Phase II D/DBP Rule

- Advanced yet established technology - familiar to operators and easy on cost of ownership.

- Sampling port for auto sampler, grab sampling and side stream analyzer - ideal for supplemental monitoring of key parameters such as TOC that are not suited for in-pipe measurement, or connecting to an auto sampler.

- Sensor housing, sensor guard, and adapter assembly constructed exclusively of 316-stainless steel (316-SS) - provides superior durability and corrosion resistance.

- 12 VDC power that can be provided by external battery, AC line converter, or solar panel - allows installation in a variety of conditions. (Includes plugin for AC.)

- Data communication to SCADA or other data management systems – real time surveillance, alarm, and response. (DB9 connector for RS232 or SDI

PARAMETERS OBSERVED/ SAMPLED: pH, ORP, conductivity, turbidity, dissolved oxygen, line pressure, temperature.

FIGURE 13: Water Distribution Monitoring PipeSonde In-pipe Probe: (http://www.hach.com/; visited 25.06. 2008)

7.12 MULTIPARAMETER WATER QUALITY MONITORING SONDES

DESCRIPTION: The multiparameter water quality monitoring sondes (Figure 14) is a tough and durable multiparameter water quality monitoring instrument.

FEATURES:

- Ammonium-- Disallows zero activity standard for $NH4^+$ and $NO3^-$. Corrects current setup values for $NH4^+$ and $NO3^-$.
- Ammonium -- Series 4a Sondes. Alters chloride and total ammonium computation formula.
- Chloride -- Series 4 Sondes. Adds language switches and changes "CL^-" to "Cl^-." Corrects default number of calibration points.
- Chloride -- Series 4a Sondes. Alters chloride and total ammonium computation formula.
- Conductivity -- Series 4 Sondes. Supports graphite conductivity sensor.
- Dissolved Oxygen -- Series 4 Sondes. To be used only with graphite
- Nitrate -- Series 4 Sondes. Disallows zero activity standard for $NH4^+$ and $NO3^-$. Corrects current setup values for $NH4^+$ and $NO3^-$.
- Nitrate -- Series 4a Sondes. Alters chloride and total ammonium computation formula.
- pH/Reference -- Series 4 Sondes. Disallows zero activity standard for $NH4^+$ and NO3-. Corrects current setup values for $NH4^+$ and $NO3^-$.
- pH/ORP/Reference -- Series 4 Sondes. Disallows zero activity standard for $NH4^+$ and $NO3^-$. Corrects current setup values for $NH4^+$ and $NO3^-$.
- Temperature -- Series 4 Sondes. Corrects TempC conversion to TempK (273=273.13).

- TDG -- Series 4 and 4a Sondes (mini TDG). Reports no setup for TDG:mV parameter.
- Turbidity (non-shuttered) -- Series 4 and 4a Sondes with non-Shuttered Turbidity. Note: Update Main MPL code to latest revision before loading driver.
- Chlorophyll -- Series 4 and 4a Sondes. Changes calibration acceptance window.
- Chlorophyll -- Resolution Driver. Increases SCUFA resolution to x.xx
- PAR -- Series 4 and 4a Sondes. Provides minor format changes.

PARAMETERS OBSERVED/ SAMPLED: ammonium, chloride, conductivity, dissolved oxygen, nitrate, pH/reference, pH/ORP/reference, temperature, TGD, turbidity, chlorophyll, PAR.

FIGURE 14: Multiparameter Water Quality Monitoring Sondes (http://www.hydrolab.com; visited 25.06. 2008)

7.13 THREAT DETECTION KIT™ (starter and maintenance kits)

DESCRIPTION: The Threat Detection Kit (Figure 15) not only can be used to assess water contamination after a security breach – but, also should be considered as a tool for daily monitoring – in effect an early warning system. If you are responsible for providing potable water to residents in your town or city or responsible for providing potable water to a food or beverage manufacturing facility, you should consider the use of the Threat Detection Kit at your water processing facility as a screening tool or early warning system.

The Threat Detection Kit is supplied in two forms: a Starter kit and a Maintenance kit. The kits contain the necessary supplies to conduct a month of testing (30 days) assuming 1 /test per day is performed. The Starter Kit is purchased once and contains supplies that are needed to get the test system and organism culture up and running in your facility.

The Maintenance Kit provides the expendable supplies needed to maintain your organism culture for 30 days and the necessary materials to perform an additional 30 tests.

FEATURES:

- Sensitivity – Detected most threat contaminants at 1/20 of the dose that would affect humans
- Simplicity – Scored with the unaided eye
- Quick – Provide results in 1 hour and 15 minutes
- Inexpensive – Less than 2 cents/person/month (including labor) for a town of 100,000
- Reliability – No complex machine required, inherently reliable
- Benefits – Safeguards the public against potential terrorist acts to our water supply.

PARAMETERS OBSERVED/ SAMPLED: The Threat Detection Kit not only can be used to assess water contamination after a security breach – but, also should be considered as at tool for daily monitoring – in effect an early warning system.

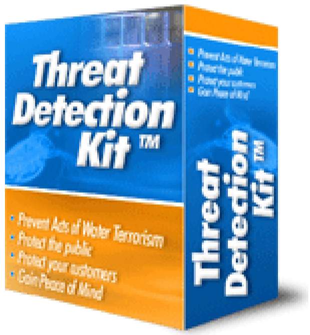


FIGURE 15: Threat Detection Kit™: (http://www.detect-water-terrorism.com/; visited 25.06. 2008)

7.14 PORTABLE CYANIDE ANALYZER (Figure 16)

FEATURES:

- Menu-driven display
- Over 50 pre-programmed tests with 10 user tests
- Automatic wavelength selection
- The SMART 2 Colorimeter is supplied with 4 sample tubes, AC adapter, and instruction manual including test procedures.

PARAMETERS OBSERVED/SAMPLED: Alkalinity UDV, Aluminum, Ammonia, Nitrogen-LR (Fresh Water), Ammonia, Nitrogen-LR (Salt Water), Ammonia Nitrogen, Boron, Bromine LR, Bromine UDV, Cadmium, Carbohydrazide, Chloride TesTab, Chlorine, Chlorine Free UDV, Chlorine Liquid DPD, Chlorine Total UDV, Chlorine Dioxide, Chromium, Hexavalent, Chromium TesTab, Chromium (Total, Hex & Trivalent), Cobalt, COD LR 0- 150 with Mercury, COD LR 0-150 without Mercury, COD SR 0-1500 with Mercury, COD SR 0-1500 without Mercury, COD HR 0-15,000 with Mercury, COD HR 0-15,000 without Mercury, Color, Copper BCA – LR, Copper Cuprizone, Copper DDC, Copper UDV, Cyanide, Cyanuric Acid, Cyanuric Acid UDV, DEHA, Dissolved Oxygen (DO), Erythorbic Acid, Fluoride, Hydrazine, Hydrogen Peroxide, Hydroquinone, Iodine, Iron, Iron UDV, Iron Phenanthroline, Lead, Manganese LR, Manganese HR, Mercury, Methylethylketoxime, Molybdenum HR, Nickel, Nitrate Nitrogen LR, Nitrate TesTab, Nitrite Nitrogen LR, Nitrite TesTab, Ozone LR, Ozone HR, pH CPR (Chlorphenol Red), pH PR (Phenol Red), pH TB (Thymol Blue), Phenol, Phosphate LR, Phosphate HR, Potassium, Silica LR, Silica HR, Sulfate HR, Sulfide LR, Surfactants, Tannin, Turbidity, Zinc LR

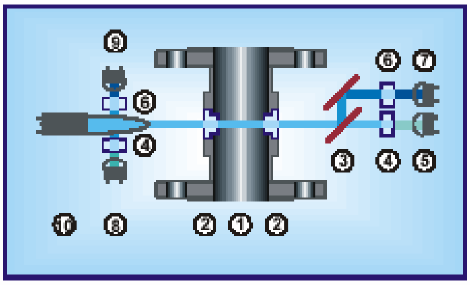
FIGURE 16: Portable Cyanide Analyzer: (http://www.lamotte.com/pages/wawa/smart2.html; Visited 25.06. 2008)

7.15 DUAL CHANNEL UV ABSORPTION SENSOR (Figure 17)

DESCRIPTION: Highly precise in-line UV Absorption sensors from Optek's measure UV-absorbing compounds, from high concentrations down to traces in the PPB range. This Optek's AF46 dual-channel / dual wavelength UV sensor features lamp intensity compensation for extreme stability and repeatability.

FEATURES:
• In-line, real time, dual UV wavelength photometric process analysis
• Compensates for background solids/species
• Dual reference detection circuits
• Modular and easy to install, set-up, and operate
• Extremely low maintenance, 2-4 year lamp life
• 24-hour technical support
• Superior product warranty
• NIST-traceable validation accessories for absolute measurement confidence
• Broad variety of line sizes, process connections and wetted materials
• Options for all Hazardous area classifications
• For CIP/SIP and Ultra-sanitary applications
• Sapphire Optics provide superior resilience to all abrasive and corrosive media

PARAMETERS OBSERVED/ SAMPLED: concentrations of acetone, aniline, enzene, halogens, HMF, hydrogen peroxide, ketones, trace mercury, nitric acid, ozone, phenols/phenates, sulfur dioxide, toluene, tracers, xylene



(1) Sensor Body (2) Sapphire Windows (3) Beam-Splitter (4) Ch.1 Filters (5) Ch.1 Measurement Detector (6) Ch.2 Filters (7) Ch.2 Measurement Detector (8) Ch.1 Reference Detector (9) Ch.2 Reference Detector (10) Low Pressure Mercury Light Source

FIGURE 17: Dual Channel UV Absorption Sensor: (http://www.optek.com/pdf/810-AF46-00-EN-A.pdf); Visited 25.06. 2008)

7.16 Dual Channel UV Absorption Sensor (Product No.: SSS-33-5FT)

DESCRIPTION: The Dual Channel UV Absorption Sensor (Figure 18) is a real-time radiation monitor in place to protect the water and the public. Model SSS-33-5FT solves the problem of drinking water sources vulnerability to accidental or knowing contamination by individuals, groups, industry, medical labs, terrorists and from naturally occurring radioactive materials (NORM)by continuously monitoring the water using both ion exchange resin beads and charcoal filter. The ion exchange resin collects and concentrates ions from dissolved metals; these are measured for activity by the 3" X 3" gamma spectrum detectors. The charcoal filter collects and concentrates any non-ionized stray chemical or particulate radioactives. The charcoal filter is monitored by the second scintillator

A final detector consists of crushed anthracene scintillation crystals through which the sample water flows. This detector measures alpha, beta and gamma from any non-ionized radioactive liquids. Measurements of radiation concentration and total discharge are logged 24hr/day 7day/week. This sensitive, fail-safe system utilizes flow-thru, anthracene crystals and gamma detectors which continuously measure and record, concentration in microCuries/ml (or other units) and total microCuries. It uses its own metering pump and controller to measure, record and alarm based on the precise number of microCuries per minute which you have set it for. It stops when daily, monthly or annual limit is approached. Applications are:

• Monitor drinking water against any & all Radioactive contaminants
• Monitor for leaks in Candu / heavy water reactors
• Monitor for contamination in ground or surface water
• Monitor liquid-waste-stream from laboratory or plant

FEATURES:

- real time, in-line, continuous
- true fail safe design
- no liquid scintillant
- easy calibration
- measures tritium to 100 picoCurie/ml
- plus 3'' X 3'' NaI, gamma spec channel

PARAMETERS OBSERVED/ SAMPLED: This detector measures alpha, beta, and gamma from any non-ionized radioactive liquids.

FIGURE 18: Dual Channel UV Absorption Sensor: (http://www.tech-associates.com/dept/sales/product-info/sss-33-5ft.txt; visited 25.06. 2008)

7.17 UV-VIS SPECTROMETER PROBES BY S::CAN LIQUID MONITORING NETWORKS: (VIENNA, AUSTRIA/ CINCINNATI, USA)

S::can is the leading supplier of UV-Vis spectrometer probes, other optical probes and accessories for the monitoring of waters and other kinds of liquids. S::can unique technology allows the measurement of numerous parameters in most diverse applications from drinking water, environmental monitoring, and waste waters up to industrial fluids. S::can experts will develop new parameters at the request of their customers if the parameters of interest are not available. Possible parameters are not restricted and include alarm parameters.

The s::can`s UV-Vs spectrometer probes are characterized by measuring various parameters for a multitude of predefined applications. They include: Spectro::lyser™ (many parameters in various applications) Carbo::lyser™ (organic carbon & turbidity/solids), Nitro::lyser™ (nitrate & turbidity/solids.), and multi::lyser™ (organic carbon & nitrate). The Spectro::lyser™ is described below.

7.17.1 THE UV/VIS SPECTROMETER™

DESCRIPTION: The s::can spectro::lyser™ (Figure 19) is an extremely sensitive submersible UV-Vis-Spectrometer with 100 mm optical pathlength. The instrument size is 500/44mm at 1,1kg. There are no moving parts - it is not even serviceable - and is built to run without ever leaving the water, at almost zero operating costs. The interface is digital (RS485/Modbus) and can be connected to any PC or SCADA system. The instrument is available with full stand-alone capability (integrated data logger and battery), or as a part of a network of autonomous solar-powered field stations, providing the telemetric control and data transfer from several field stations to a central data bank, accessible via any web browser. The patented 2-beam optical design ensures drift-free measurements over many months.

It works by blasting UV light from a high-energy long-life Xenon lamp (left) directly onto the liquid. The Zeiss 256 pixel diode array detector at the opposite side monitors the entire optical spectrum - from deep UV to the visible - and with the help of advanced chemometric algorithms running in the onboard minicomputer, the smallest amounts of various pollutants can be quantified, even in a complex matrix. Applications are for drinking water such as for water security stations, event detection, intake protection, distribution network monitoring and a source to tap monitoring networks.

FEATURES:

- Plug & Measure
- Long-Term-Stability
- Multi-Parametric
- Works-Calibrated
- Automatic cleaning device using compressed air
- In situ & on-line monitoring from drinking water to sewer systems
- Mounting devices for applications from aeration tank to environmental monitoring
- Robust terminals for data display, storage and transfer

SPECIFICATIONS

- TSS/FTU/TS + NO3N + COD/TOC + CODf/DOC
- UV-Vis fingerprints (200-750mm)
- RS485 Interface
- Power supply 12V/20W
- 2-Beam optical design (Auto compensation)
- Modbus protocol (38400 Baud Standard)

PARAMETERS OBSERVED:

Complete UV / VIS– Spectra, SAC, Nitrate and/or nitrite concentration, The load information expressed as DOC, TOC, COD and BOD, depending on the used algorithm, Turbidity, NH4, K+, free Chlorine, F-, TSS, Colour, pH, ORP, EC, Temperature, O2,O3, H_2S, AOC, Fingerprints, Contaminant Alarm, Plus any information you like at nearly any wavelength between 200.

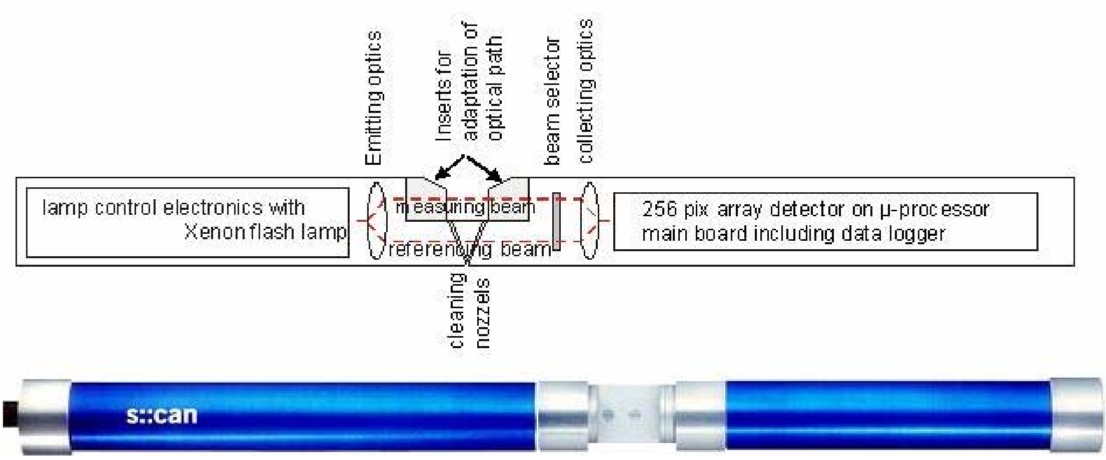


FIGURE 19: THE SPECTRO::LYSER™. SOURCE: http://www.s-can.at/index.php?id=58. (Sited 12.07.2008)

Figure 20 also illustrates how the SPECTRO::LYSER™ is interfaced with a SCADA system

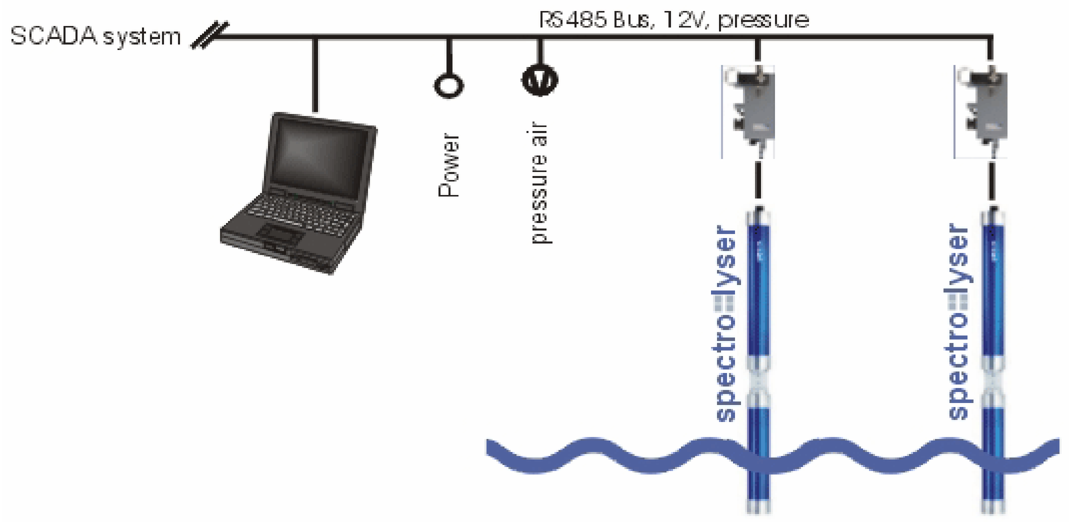


FIGURE 20: THE SPECTRO::LYSERTM INTERFACED WITH A SCADA SYSTEM

(http://www.s-can.at/index.php?id=31; sited 12.07.2008)

7.17.2 S::CAN WATER QUALITY MONITORING STATION

DESCRIPTION: The s::can "Water Quality Monitoring Station" (Figure 21) is a monitoring station for calculating integrated parameters. It is a modular combination of one s::can terminal, several s::can probes and flow-through-cells. It minimizes the complexity of water analysis to plug and measure. The main hardware and software are spectro::lyser: and ana::larm respectively Monitoring Built-in Sensors includes: spectro::lyser ammo::lyser, fluor::lyser oxi::lyser, free chlorine sensor and con::stat (further descriptions of these instruments are given at the website: http://www.s-can.at/fileadmin/scan/NEWS/MonitoringStation_20080227_Europe_low.pdf) sited on 12.07.2008. Applications: For drinking water, environmental water and waste water.

FEATURES:

- **integrated:** One terminal for all sensors and interfaces.
- **Most Comprehensive Contamination Warning System**
- **Reduces Complexity to an Absolute Minimum:** One software one user interface, one data format, one remote access tool for an unbelievable range of parameters.
- **Minimises the need for Local Infrastructure:** No need any more to build houses, chambers or containers. Just put your modules into a waterproof cabinet. Requires only 10% of the space of conventional analyser stations.
- **Plug & Measure:** Just connect the local water pipe, switch on the power, and start to measure.
- **Compact:** The most compact station for analytical parameters in the world.
- **Flexible:** Attach the modules on a flat wall, round the corner, put them in a cabinet or install them in a field enclosure.
- **Cost Efficient:** No reagents. No replacement parts except membranes of the ISEs. Manual or automatic cleaning. Minimum maintenance hours.
- **Minimal Maintenance:** The maintenance interval of a station is dependent on its weakest link.- though no weak link is allowed.. Remote maintenance reduces field visits to a minimum. 1 visit/month is sufficient for many applications.
- **Bypass Line:** Service any sensor without interrupting the flow.
- **Uniform Flow-Through Cells:** Allows simple and fast ordering, exchange and maintenance of sensors.

PARAMETERS OBSERVED: FTU/NTU, UV-254/SAC, Colour, TOC, DOC, NO_3, NO_2, NH_4, pH, K^+ ,OR, O_2, BTX, Conductivity, Temperature, Contaminant alarm, F^-, C_{l2}, and O_3

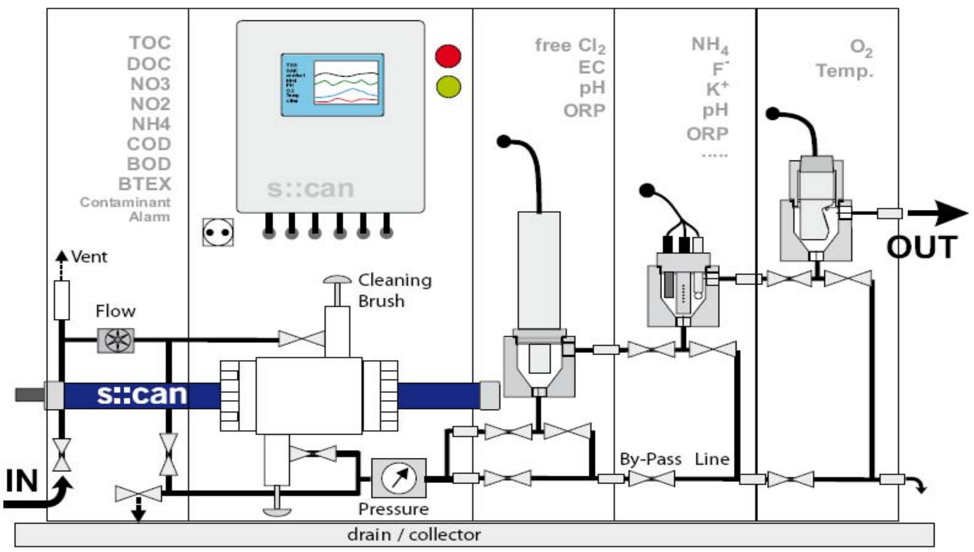


FIGURE 21: Diagram of the S::CAN WATER QUALITY MONITORING STATION: (http://www.s-can.at/fileadmin/scan/NEWS/MonitoringStation_20080227_Europe_low.pdf; visited 12.04.2008.

7.18: TURBIDIMETER MODEL 850

DESCRIPTION: The Model 850 (Figure 22) is an innovative turbidimeter which utilizes an insertion-type sensor. A submersible sensor is available for open channel applications. Since the sensor can be inserted in any size pipe, costly by-pass systems are not required. The design eliminates the effects of fluid color. In-situ measurements provide instantaneous accurate readings and a choice of isolated linear outputs is supplied as standard. A 4-position calibrated range dial allows for the selection of four NTU ranges.

The Model 850 Turbidimeter uses a pre-focused incandescent lamp to direct a beam of light through the process fluid. Particulate matter in the fluid scatters light in proportion to particulate concentration. The scattered light is detected by a silicon detector which generates a current signal proportional to the particulate concentration. The electronic signal converter amplifies and scales the current signal to provide a linear readout on a digital meter plus an isolated output signal.

FEATURES:

- Wide dynamic range
- In-line measurements assure maximum accuracy
- Hot-tap installation permits uninterrupted flow
- Linear isolated output
- Optional alarms, battery power
- Use in any size pipe
- High accuracy and reliability
- Insensitive to visible colors, flow, temperature & pressure
- 4-position range dial (0-2NTU, 0-20NTU, 0-200NTU, 0-2000NTU)

PARAMETERS OBSERVED: Turbidity

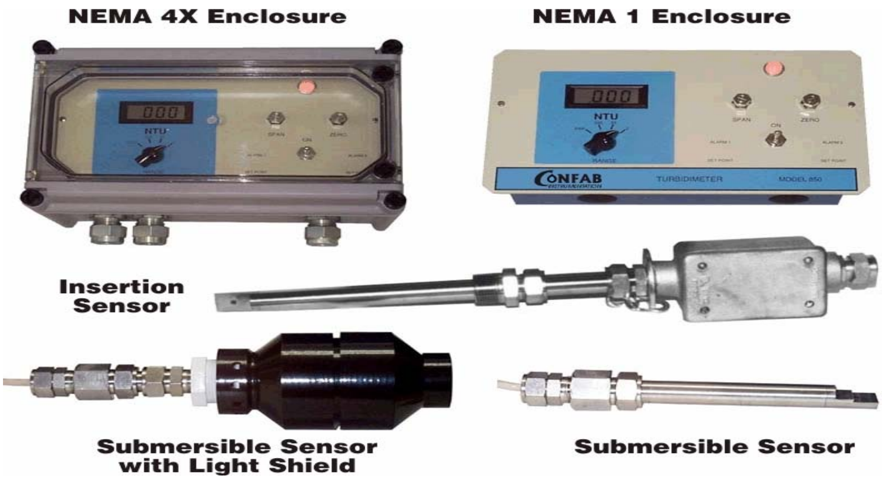


FIGURE 22: THE TURBIDIMETER MODEL 850, (http://www.confabinstrumentation.com/850/850info.htm; 13.07.2008).

All the above described instruments are compiled in the Table 9:

TABLE 9: List of Commercially Available Instruments(Partially Adapted from, ASCE et al, 2004)

Instrument	Product No/Model	Manufacturer/Source	Parameters observed/sampled
Colifast Analyser (CA)	Colifast Analyzer (CA)	Colifast http://www.colifast.no	Tests for thermotolerant coliforms/*E-coli* and total coliforms
Colifast At line Monitor	Colifast At-line Monitor (CALM)	Colifast http://www.colifast.no	Provides water quality data for thermotolernat coliforms/E-coli and total coliforms
Detection Kit	Threat Detection KitTM (starter and maintenance kits)	Kingwood Diagnostics, LLC http://www.detect-water-terrorism.com/	The Threat Detection Kit not only can be used to assess water contamination after a security breach – but, also should be considered as at tool for daily monitoring – in effect an early warning system
Drinking Water Rad-safety Monitor	SSS-33-5FT	Technical Associates http://www.tech-associates.com/dept/sales/product-info/sss-33-5ft.txt	This detector measures alpha, beta, and gamma from any non-ionized radioactive liquids.
Dual Channel UV Absorption Sensor	AF46	Optek http://www.optek.com/pdf/810-AF46-00-EN-A.pdf	concentrations of acetone, aniline, benzene, halogens, HMF, hydrogen peroxide, ketones, trace mercury, nitric acid, ozone, phenols/phenates, sulfur dioxide, toluene, tracers, xylene
Microtox®	Model 500 Microtox /AZF848503	Strategic Diagnostics Inc. /Azur environmental http://www.sdimicrotox.com/pdf/Microtox-for-drinking-water.pdf	Microtox Acute Toxicity, Microtox Chronic Toxicity, Mutatox, ATP
Multiparameter Water Quality Monitoring Sondes	Series 4 Multi-parameter Water Quality Monitoring Sondes	Hydrolab http://www.hydrolab.com	ammonium, chloride, conductivity, dissolved oxygen, nitrate, pH/reference, pH/ORP/reference, temperature, TGD, turbidity, chlorophyll, PAR
Portable Cyanide Analyzer	SMART 2 Colorimeter with the 3660-SC Reagent System	LaMotte Company http://www.lamotte.com/pages/wawa/smart2.html	Alkalinity UDV, Aluminum, Ammonia, Nitrogen-LR (Fresh Water), Ammonia, Nitrogen-LR (Salt Water), Ammonia Nitrogen, Boron, Bromine LR, Bromine UDV, Cadmium, Carbohydrazide, Chloride TesTab, Chlorine, Chlorine Free UDV, Chlorine Liquid DPD, Chlorine Total UDV, Chlorine Dioxide, Chromium, Hexavalent, Chromium TesTab, Chromium (Total, Hex & Trivalent), Cobalt, COD LR 0-150 with Mercury, COD LR 0-150 without Mercury, COD SR 0-1500 with Mercury, COD SR 0-1500 without Mercury, COD HR 0-15,000 with Mercury, COD HR 0-15,000 without Mercury, Color, Copper BCA – LR, Copper Cuprizone, Copper DDC, Copper UDV, Cyanide, Cyanuric Acid, Cyanuric Acid UDV, DEHA, Dissolved Oxygen (DO), Erythorbic Acid, Fluoride, Hydrazine, Hydrogen Peroxide, Hydroquinone, Iodine, Iron, Iron UDV, Iron Phenanthroline, Lead, Manganese LR, Manganese HR, Mercury, Methylethylketoxime, Molybdenum HR, Nickel, Nitrate Nitrogen LR, Nitrate TesTab, Nitrite Nitrogen LR, Nitrite TesTab, Ozone LR, Ozone HR, pH CPR (Chlorphenol Red), pH PR (Phenol Red), pH TB (Thymol Blue), Phenol, Phosphate LR, Phosphate HR, Potassium, Silica LR, Silica HR, Sulfate HR, Sulfide LR, Surfactants, Tannin, Turbidity, Zinc LR

Instrument	Product No/Model	Manufacturer/Source	Parameters observed/sampled
Six-CENSE	Six-CENSE ™	Dascore http://www.dascore.com/sixcense.htm	Chlorine (no reagents), monochloramine or dissolved oxygen, pH, temperature, conductivity, ORP/REDOX
The Algae Toximeter/ The Daphnia Toximeter		Bbe Moldaenke www.bbe-moldaenke.de	Toxicity indicators
The Deltatox Analyzer	AZF50A000/ Deltatox®	Strategic Diagnostics Inc., www.sdix.com,	partial list: phenol, lead, arsenic, mercury, sodium cyanide, selenium, potassium cyanide, chromium, PR-toxin, copper, aflatoxin, ochratoxin, rubratoxin, chloroform, ammonia, sodium lauryl sulfate, benzoyl cyanide, lindane, DDT, cresol, formaldehyde, malathion, carbaryl, flouroacetate, trinitrotoluene (TNT), parathion, 4-phehnyl toluene, carbofuran, pentachlorophenol, patulin, paraquat, diazinon, cyclohexamide, cadmium, quinine, dieldrin, microbiologicals
The UV/VIS spectrometer™	s::can spectro::lyser ™	s::can/ http://www.s-can.at/index.php?id=12	Complete UV / VIS– Spectra, SAC, Nitrate and/or nitrite, DOC, TOC, COD and BOD, Turbidity, NH4, K+, free Chlorine, F-, TSS, Colour, pH, ORP, EC, Temperature, O2,O3, H2S, AOC, Fingerprints, Contaminant Alarm, Plus any information you like at nearly any wavelength between 200.
Toxprotect 64		Technical and scientific equipment/bbe moldaenke www.techsci.com.au/www.bbe-moldaenke.de	The ToxProtect is equipped with internal sensors to monitor and report on instrument malfunction in: Inadequate sample flow, Drain blockage, Temperature loss, Accidental/unauthorised exposure of test chamber to ambient light, High chlorine concentration.
Turbidimeter	Turbidimeter Model 850	Confab Instrumentation http://www.confabinstrumentation.com/850/850info.htm	Turbidity
Water Distribution Monitoring Panel (WDMP)	5980000	Hach http://www.hach.com/	chlorine, conductivity, pH, turbidity, pressure, temperature
Water Quality Monitoring Station	The s::can Water Quality Monitoring Station	s::can http://www.s-can.us/index.php?id=58	FTU/NTU, UV-254/SAC, Colour, TOC, DOC, NO3, NO2, NH4, pH, K+ ,OR, O2, BTX, Conductivity, Temperature, Contaminant alarm, F-, Cl2, and O3
WDM PipeSonde In- Pipe Probe	PS4ABASE	Hach http://www.hach.com/	pH, ORP, conductivity, turbidity, dissolved oxygen, line pressure, temperature

8. DISCUSSION OF RESULTS

According to "World Health Organization" (WHO), 2006, a Water Safety Plan provides for an organized and structured system to minimize the chance of failure through oversight or lapse of management and for contingency plans to respond to system failures or unforeseen events. The water safety plans can be easily implemented in every water supply system across the globe irrespective of the cultural and infrastructural differences that exist in each water supply utility because its concepts are easily understood with no cultural obstacles. However, its development and implementation requires significant effort from every member of the water supply utility. There is also need for local experience such as site specific hazards and site specific documentation /procedures (Loret et al, 2008.)

With the help of the health based targets, targets are set to mark out milestones in the water safety plans so as to guide and chart progress towards a predetermined health and/or water quality goal, because health based targets are an integral part of health policy development. Tables 10 illustrate explicitly, the benefits of the health based targets.

TABLE 10: BENEFITS OF HEALTH-BASED TARGETS (Hasan et al, 2004)

Formulation	• Increases the transparency of health policy • Promotes consistency among national health programs • Provides insight into the health of the population • Reveals gaps in knowledge • Stimulates debate • Supports priority setting
Implementation	• Fosters accountability • Guides the rational allocation of resources • Improves commitment • Inspires and motivates collaborating agencies to take action
Evaluation	• Identifies data needs and discrepancies • Provides opportunity to take action to correct deficiencies / deviations • Supplies established milestones for incremental establishment

Health based targets also provide information against which to evaluate the adequacy of existing installations thereby, providing a benchmark for water suppliers. More so, different types of targets in different countries will be applicable for different purposes and care is taken in developing countries to develop targets that account for the exposures that contribute most to diseases. There are four principle types of health-based targets used as a basis for identifying safety requirements and this is shown in the Table 11.

TABLE 11: Health-Based Targets (WHO, 2005)

TYPE OF TARGET	NATURE OF TARGET	TYPICAL APPLICATIONS	ASSESSMENT
HEALTH OUTCOME Epidemiology based	Reduction in detected disease incidence or prevalence	Microbial or chemical hazards with high measurable disease burden largely water associated	Public health surveillance and analytical epidemiology
risk assessment based	Tolerable level of risk from contaminants in drinking-water, absolute or as a fraction of the total burden by all exposures	Microbial or chemical hazards in situations where disease burden is low and cannot be measured directly	Quantitative risk assessment
WATER QUALITY	Guideline value applied to water quality	Chemical constituents found in source waters	Periodic measurement of key chemical constituents to assess compliance with relevant guideline values.
	Guideline values applied in testing procedures for materials and chemicals	Chemical additives and by-products	Testing procedures applied to the materials and chemicals to assess their contribution to drinking-water exposure taking account of variations over time.
PERFORMANCE	Generic performance target for removal of group of microbes	Microbial contaminants	Compliance assessment through system assessment and operational monitoring
	Customised performance targets for removal of groups of microbes	Microbial contaminants	Individually assessment would then proceed as above reviewed by public health authority; would then proceed as above
	Guideline values applied to water quality	Threshold chemicals with effects on health which vary widelyb(e.g. nitrate and cyanobacteria)	Compliance assessment through system assessment and operational monitoring
Specified technology	National authorities specify specific processes to adequately Address constituents with health effects (e.g. generic /model water safety plans for an unprotected catchment)	Constituents with health effect in small municipalities and community supplies	Compliance assessment through system assessment and operational monitoring

Above all, it is important that health-based targets, defined by the relevant health authority, are realistic under local operating conditions and are set to protect and improve public health. Continuously monitoring water quality surrogate parameters in the distributions system is an effective approach for detecting chemical contamination events. This is because the chemicals will influence changes in water quality parameters (relatively to the concentration of the contaminant in the system), and induce a water quality instrument response. Some of the changes that may be caused by contaminants include:

- Changes in chemical makeup of the water through chemical reactions or changes in the amount of carbon or other elements.
- Changes in pH, oxidation-reduction potential and electrical properties through reaction of the contaminant with the water constituents or ionization of either the contaminant or water constituents.
- Changes in optical properties such as absorption, emission, or scattering of light at various wavelengths.
- Changes in biological makeup of the water.
- Changes in mechanical and acoustic properties of the water.

The surrogate parameter to be monitored will depend on the baseline parameter set by each water supply industry, depending on their specific concerns. Table 12 shows potential surrogates that might provide indications of the presence and concentration of contaminants.

TABLE 12: Potential Surrogate Parameters to Monitor in Detecting Contaminants (ASCE et al, 2004)

Chemical Surrogates	**Microbiological Surrogates**	**Toxin Surrogates**	**Radiological Surrogates**
pH	Toxicity indicators	Total Organic Carbon	Alpha
Turbidity	Turbidity	Biomonitors	Beta
Tortal organic carbon	Phosphate	Toxicity Indicators	Gamma
Chlorine residual	Toc		Toxicity indicators
Conductivity	Nitrate, nitrite		
Dissolved oxygen	Multi angle light scattering		
Nitrate, nitrite	Fluorometry		
Phosphate	Biomonitors		
Oxidation reduction potential	Biological oxygen demand		
$UV_{254/280}$[47]	Oxidation reduction potential		
Biomonitors	ammonia		
Toxicity indicators			
Ammonia			

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Generally when comparing options for which particular instruments should be implemented, the primary factors should be the performance characteristics of the instruments. Such performance characteristics include:

1. The capabilities of the set of instruments whose data are analyzed together. including: whether the measures are complementary and the ability to cross-correlate data.
2. Characteristics and constraints of the site such as: size constraints, power and telecom requirements and availability (for example, SCADA availability),

environmental conditions such as humidity and temperature, and access to water flow and waste disposition.

3. Operational considerations, particularly: maintenance (software and hardware updates, spare parts,), durability, human factors, calibration, testing, housekeeping and disposal considerations (for example, reagents, etc.), and onboard data analysis.
4. Budgetary factors such as: cost of the instruments, installations costs, maintenance cost, and cost of employing new professionals or training of incumbent staff members.

After choosing an instrument, the next important move is the placement or location of these instruments throughout the water supply distribution in order to cover all segments of the system in which contamination presents a risk. An important factor will be the importance of the information that will be measured and obtained in that segment of the water supply system. Table 13 below shows the potential locations for instruments as well as the advantages and disadvantages of locating these instruments at these locations:

TABLE 13: Potential Locations for Instruments in the Water Supply System (ASCE, et al, 2004)

LOCATION	ADVANTAGES	DISADVANTAGES
Source waters	Covers large segment or all of system Long lead time for response Long time for corroboration For navigable source waters threat of contamination can be relatively high To be of concern to public health, large quantities of contaminant needed— therefore easier to detect	Threat of intentional contamination of source waters is relatively low for source waters on which no commercial traffic flows
End of water transport or aqueducts	Threat of intentional contamination is slightly higher than for sources Covers large segment or all of system	Low threat for intentional contamination
Treatment plant	Threat of intentional contamination is slightly higher than for source or transport Insider threat higher	Relatively low threat for intentional contamination because access is limited and there is potential for discovery
Finished water reservoirs	Threat of intentional contamination considerably higher	There may be many of them requiring coverage
Early distribution system	Moderate threat, particularly at sites to which access can be gained (including valves, pumps and check points) Relatively long time available for warning and responseM	Need several platforms to cover entire system
Mid distribution system	Higher threat, covers many of the likely contamination entry points including valves, pumps and inspection ports	Need multiple platforms to get full coverage, moderate to little warning time
Entry pipes for likely targeted customers	Higher risk area; expect better cooperation from such customers	Locating so close to user leaves very little time for effective response

9. CASE STUDY

In the course of the thesis work, a visit to the first Vienna water spring mains located at Kaiserbrunn in lower Austria was undertaken. During the visit, I had a firsthand viewing of how the source water for the Viennese municipal water supply is being safeguarded and protected. I saw how the spring mains tunnels were physically protected from the public with physical locks as well as barred public entrance. I also saw real time online monitoring equipment specifically made for this spring mains. In general I witnessed real time online source water monitoring for the Viennese water supply. The online monitoring instrument was immersed in the spring mains (Figure 23) and supplied with electricity by a battery (Figure 24) and both were in turn connected to a board screen where the processed data is displayed (Figure 25). The instrument is used to measure turbidity and temperature which are the surrogate parameters in this location. The processed data is continuously displayed on a board screen.

I also had the opportunity to see where the major source water for the Viennese municipal water supply is being meticulously monitored. A network of computers is used as a kind of SCADA (supervisory control and data acquisition) system (Figure 26) to integrate and monitor all the springs in this region. All access to the facilities is completely monitored by the SCADA system and any security breach can be promptly dealt with. Also the water quality parameters for each spring mains are continuously measured and any deviation from the set thresholds is immediately noticed. All processed data is centrally registered and is intermittently printed by a printing machine connected to the computer network (Figure 27), thereby enabling a hard copy documentation of the online monitoring processes. Provisions are also made to trigger alarm in case of unauthorized entrance to any of the spring mains or any abnormality in the water quality data.

FIGURE 23: An online monitoring instrument immersed in the spring mains

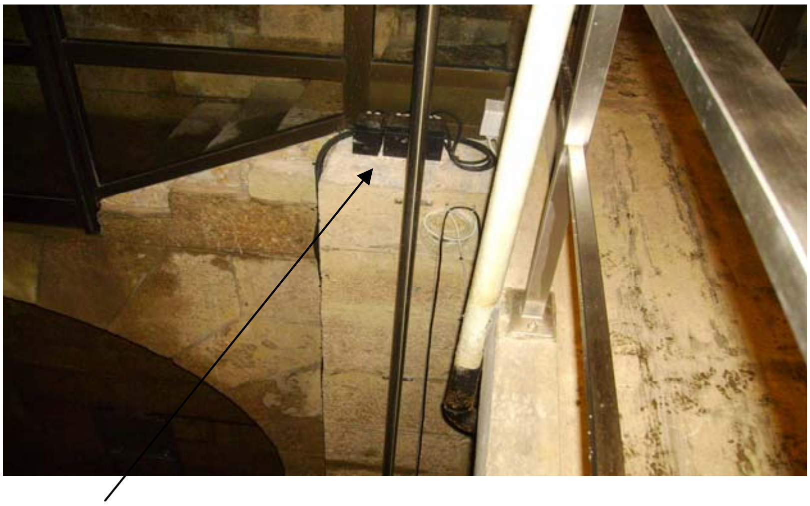

FIGURE 24: Battery supplying power to the online instrument above.

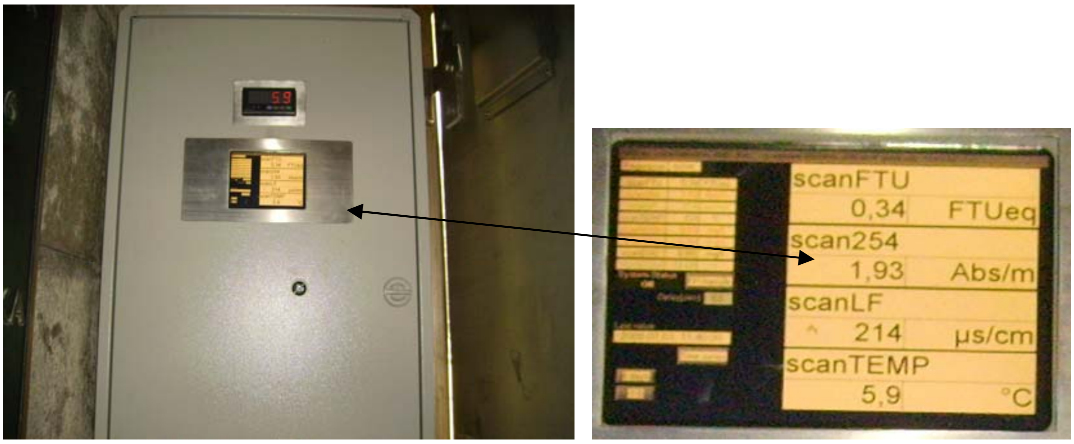

FIGURE 25: Board screen displaying processed data.

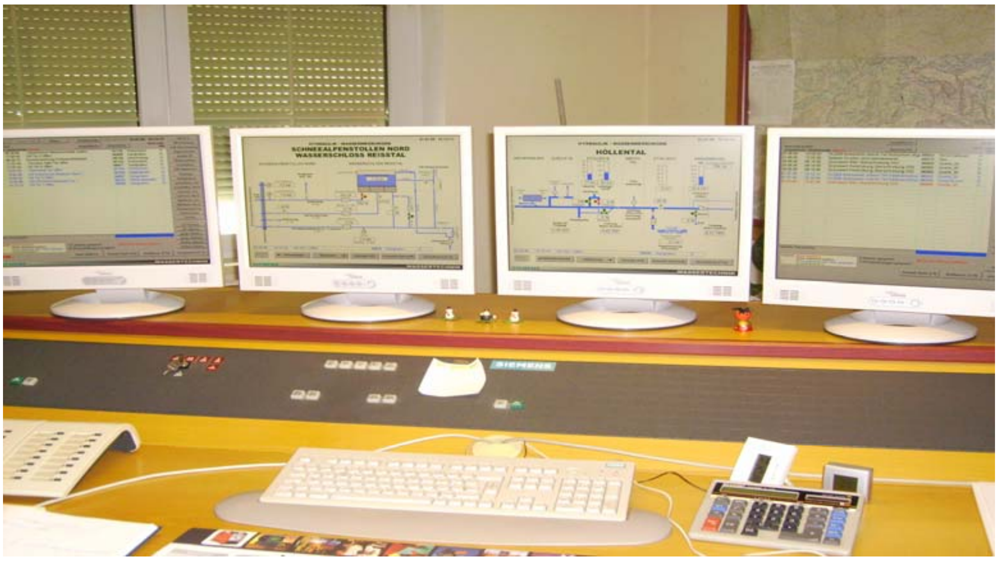

FIGURE 26: Computer network (SCADA like) monitoring all access to the spring mains and measuring water quality online, with all processed data centrally registered.

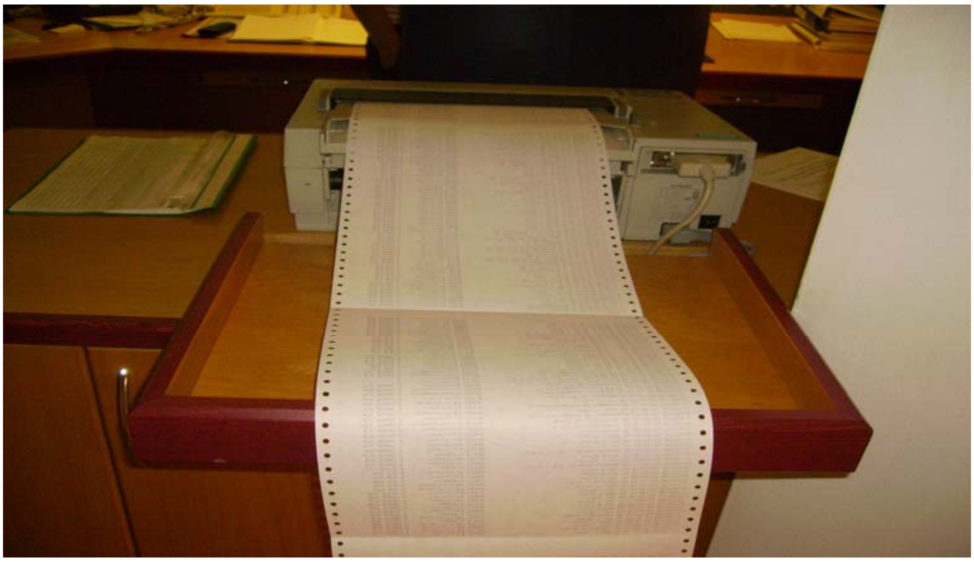

FIGURE 27: Printing machine connected to the computer network to print out processed data.

10 SUMMARY

This master's thesis is basically centered on the threats of accidental or purposeful contamination of drinking water and/or the whole water supply systems. It highlights the current strategic management approaches such as the water safety plans and also describes the commercially available instruments can be used to prevent, monitor and eventually stop these threats.

Chapter one to three introduces the thesis, laid out the problem statement that stresses the need for new approaches and instruments and stated the main objectives of the thesis respectively. Chapter four goes on to describe the main threats facing the water supply sector, analyzing those that will most likely happen and illustrating contamination agents of the most concern to public health. In chapter five the general standards in regular drinking water was briefly described with the framework of the world health organization, the European Union and the United States of America.

Chapter six presents the proposed approaches and instruments that can be implemented to successfully influence everyday operation in drinking water supply systems and the detection methods employed by the various technical tools; while chapter seven describes in-depth, commercially available instruments with pictures. Impressions from real time online monitoring equipment and supervisory control and data acquisition (SCADA) systems station specifically made for the first Vienna water spring mains located at Kaiserbrunn in Lower Austria was briefly described and illustrated with pictures in chapter nine. An annex giving specific details of current European Project researches regarding online water quality monitoring was also illustrated in a simple table.

Contamination threats of water supply systems accidentally or intentionally by biological, chemical, radiological contaminants or by physical destruction water supply systems infrastructures is now a well established fact and efforts are being undertaken to mitigate them. Early detection of these contaminants through an online contaminants monitoring systems or the use of other instruments that trigger warning at an early stage have been identified as a possible way of detecting these contaminants and thereby protecting public health.

More so, for the physical threats, the use of physical means aimed at preventing, deterring, delaying and responding have also been identified as a feasible way to provide early warning in some cases. Other ways of countering these contamination events is the implementation of the water safety plans with which an organized and structured system is used to minimize the chances of failure or unforeseen events (WHO, 2004)

Experiences have shown that water safety plans development and implementation takes many months and requires significant resources. Its implementation within an organization requires genuine and strong commitment at all levels within that organization; at least, one person within the water supply organization needs to be dedicated to coordinating the Water Safety Programme development and implementation process in a full time capacity. Numerous additional employees will need to provide timely significant and substantive inputs to the process to make it work (WHO, 2006). Although immediate health benefits may be difficult to demonstrate, most probably, there will be evidence of risk reduction related to potential accidental situations as well as favoring transparency, communication, and confidence along the supply chain (Loret et al, 2008.).

The purpose of any detection program is to detect contaminants at the lowest possible level. In addition to detecting intentional threat contaminants in a distribution system, real-time monitoring offers the secondary benefit of providing valuable water quality data that may be key to detecting routine water quality compromises associated with line breaks, backflow events, treatment plant failures, or seasonal biofilm sloughing. An online, real-time, contaminant detection system can provide early warning. Also, because these systems are very expensive, their implementation has to be justified by ensuring that, the benefits outweigh the cost of implementation. (ASCE et al, 2004).

The method of “integrated online UV/Vis spectrometry” has also opened a new perspective for detecting changes in water quality composition. The performance and the reliability of UV/Vis spectroscopy has already contributed to several early warning systems for drinking water protection. Enhancement of source water monitoring capabilities of the well established s::can spectro::lyser™ has resulted in the realization of online and real time access to monitoring stations at remote locations with the date being transferred to and stored on a central server in real time, which can be accessed over web application (Van de Broeke, Techneau 2007).

The overall goal of implementing these instruments is for the continuous monitoring of the water supply system. This will give room for detecting any contamination event, intentionally or accidental and thereby improves the whole operational system of the water supply. To effectively achieve this goal, education and training is needed for everyone involved in the daily operation of water supply.

Further research on monitoring instruments will be to design an online contaminant monitoring system that detects contaminants with precise information on their location and characterizes the contaminants by identifying the class, indicating the concentration, calculating their spread within the system, and determining the duration of the contamination event. (ASCE et al, 2004)

Future designers of water supply systems need to be educated to consider security at the beginning of the design process. Water supply system operators and their vendors need to understand and assess the potential security risks in their systems and develop ways to manage, mitigate, or otherwise reduce those risks. The public needs to be educated to help protect their water supply and to understand why water delivery methods may need to change. And collectively, the water supply systems will be able to continuously provide safe water and their infrastructures will be made unattractive targets for terrorism (Danneels, 2001).

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12. ANNEX

Table 14 gives a brief summary of current and completed European Union project researches relating to "on-line water quality monitoring"

TABLE 14: EU PROJECT RESEARCHES ON ON-LINE WATER QUALITY MONITORING. (http://cordis.europa.eu/search/index.cfm?fuseacti...e=100&q=A6688CE0CF41367C2F6A137805760230&type=pro; Visited 30.06).)

PROJECT NAME: MOBILE WATER QUALITY SENSOR SYSTEM					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
MOBESENS	223975	Execution	36 months	2008-06-01	2011-05-31
Organization Name	CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT				
Region	ESPACE MITTELLAND Neuchâtel, Switzerland.				
Objective:	MOBESENS provides a modular and scalable ICT based solution for water quality monitoring. It enables data to be gathered quickly and reported across wide areas. The low power wireless sensor network gathers data samples, which are time and location stamped and automatically entered into the grid based information system to facilitate analysis and issue alarms if needed. Mobility is a unique feature of MOBESENS, which are capable of navigation and both surface and subsurface measurements. This extends range, enables 3D area measurements and facilitates operation, even in bad weather. MOBESENS may form ad-hoc networks enabling rapid and reliable reporting as well as relative localization and tracking (e.g. of contaminants). Opportunistic communication between MOBESENS and both fixed and mobile buoys is envisioned. Renewable energy sources are studied for self-sustained MOBESENS operation.				

PROJECT NAME: TECHNEAU: TECHNOLOGY ENABLED UNIVERSAL ACCESS TO SAFE WATER					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
TECHNEAU	18320	Execution	60 months	2006-01-01	2010-12-31
Organization Name:	KIWA WATER RESEARCH B.V.				
Region:	NEDERLAND (Holand)				

Objective:	It is the vision of TECHNEAU that, in order to cope with present and future challenges, water supply systems should consider a transformation from mono-scale to flexible multi-scale systems i.e. interlinked centralized and decentralized satellite treatment, monitoring and control systems. TECHNEAU will develop and demonstrate adaptive supply system options and new and improved supply and monitoring technologies and management practices. Treatment strategies will be based on robust multi-barrier schemes and control methodologies, providing safety against a broad spectrum of chemical and microbiological contaminants and avoiding organoleptic problems at the tap. Monitoring technologies will provide online and at the site information on water quality including parameters that relate to malicious contamination. Practices for risk assessment/risk management, operation and maintenance, and models for consumer acceptance will constitute the framework for these technologies. These technologies and management practices will enable end-users to make informed choices, appropriate to their own circumstances and constraints, for costeffective and sustainable source-to-tap solutions for the provision of safe high quality drinking water that has the trust of the consumer. This step-change will be achieved by a critical mass of researchers, technology developers and users from across Europe and developing countries.

PROJECT NAME: "DEVELOPMENT OF A CONTINUOUS, INTELLIGENT, AUTONOMOUS, REAL TIME MONITORING AND ALARMING SYSTEM FOR RADON DETECTION IN GROUND-WATER"

Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
RADWAT	EVK1-CT-2001-30016	Completed	24 months	2002-03-01	2004-02-29
Organisation Name:	N/A				
Region:	N/A				
Objective:	The project can be expected to provide a significant improvement on the current situation. A significant part of the project proposal is the development of a continuous realtime monitoring station which is able to detect with a high degree of accuracy even a very low radon concentration in water. The development of this station requires a structured approach by establishing the appropriate design parameters for prototype instrumentation, involving all participants in clearly defining operational requirements, engineering framework, consolidating research, prototype development and laboratory testing of all the key modules. The resulted engineering specification would allow rapid transfer of this technology into manufacture in addition to the determination of operational specifications, thus allowing a complete appraisal of the market potential. The target levels will be selected for the further remedial actions based on the relevant ecological conditions and human health to be protected. Again, suggestions will be made on feasible remedial actions to remove water contamination or to reduce the risks.				

ARTIFICIAL RECHARGE DEMONSTRATION PROJECT					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
ARTDEMO	EVK1-CT-2002-00114	Completed	36 months	2002-12-01	2005-11-30
Organisation Name:	DHI - INSTITUTE OF WATER & ENVIRONMENT				
Region:	Danmark Århus amt, Dänemark.				
Objective:	The term Artificial Recharge (AR) covers a range of technologies that typically utilise the natural cleaning capacity of natural subsoil systems to produce drinking water from surface water. This project will contribute to achievement of the overall objective by demonstrating a management tool that uses sophisticated monitoring systems linking automatic real-time data acquisition and available on-line sensor systems and fast field analysis kits with intelligent decision support software, which compile and communicate digested data to action protocol. The increased surveillance will be combined with development and implementation of operations schemes that will decrease the risk of contaminated drinking water and at the same time ensures a stable water production				

PROJECT NAME: WATER MANAGEMENT SYSTEM BASED ON INNOVATIVE MONITORING EQUIPMENT AND DSS					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
WATER MONITOR	EVK1-CT-2002-30022	Completed	24 months	2003-01-01	2004-12-31
Organisation Name:	P.P.T. S.R.L				
Region:	NORD EST VENETO Verona, Italy.				
Objective:	WATER MONITOR project will provide a monitoring system of water sources, both quantitative and qualitative, on the basis of a new analysis technology set up. This innovative instrumentation, an UV-Vis spectrometer, enables the tests of water quality in real time, providing a complete monitoring of water characteristics measuring in stable way the concentration of important substances present in the liquid such as nitrates, organic carbon and detergents. Through the combination and optimisation of data acquired from optics sensor and electronics sensor, the spectroscope make effective the analysis of the collected champions and translate instantaneously the data collected in an optical spectra. The instrument can be connected with the main transmission and processing devices therefore transmitting in real time the processed spectra.				

PROJECT NAME: PHOTOCATALYTIC DESTRUCTION OF CYANOTOXINS AND PATHOGENS IN POTABLE (DRINKING) WATER (PHOTOX)					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
PHOTOX	EVK1-CT-2000-00077	Completed	39 months	2000-12-01	2004-02-29
Organisation Name:	THE ROBERT GORDON UNIVERSITY				
Region:	SCOTLAND GRAMPIAN				
Objective:	The objective of this project is the development of a novel photo catalytic reactor with an on-line monitoring system for the destruction of cyanotoxins and pathogens in potable (drinking) water. Traditional water treatment systems have been shown to limit effectiveness in destroying a number of biotoxins including cyanotoxins such as microcystins. Laboratory studies carried out by the applicants have established that photocatalysis is extremely effective at destroying such biotoxins specifically fulfilling the criteria outlined in priority 1.3.1 of research programme 1.1.4. An in-site microcystin monitoring system will also be developed and incorporated into the reactor. At the conclusion of the project the a novel and effective system will be developed which will decontaminate drinking water containing cyanotoxins and potential pathogens rendering it safe for human consumption.				
URL:	http://www2.rgu.ac.uk/subj/mes/cee/main/photoxfront.htm				

PROJECT NAME: BARRIERS AGAINST CYANOTOXINS IN DRINKING WATER					
Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
TOXIC	EVK1-CT-2002-00107	Completed	36 months	2002-09-01	2005-08-31
Organisation Name:	DEUTSCHE VEREINIGUNG DES GAS- UND WASSERFACHES E.V.				
Region:	SACHSEN Dresden, Kreisfreie Stadt, Germany.				
Objective:	TOXIC will focus on the reduction of the human health risk due to the occurrence of potentially toxic cyanobacteria and cyanotoxins in drinking water sources. The proposed project contains multidisciplinary aspects				

	ranging from raw water monitoring and cyanotoxin identification and analysis to the behaviour of cyanobacteria and their toxins during water treatment processes, including cost evaluation, application and exploitation of the results by potential end-users. With respect to the WHO Guideline Value of 1.0 ùg/L for microcystin-LR in drinking water, TOXIC will provide tools for early warning in the case of massive algal blooms as well as cost-effective and problem-driven treatment approaches. An Internet-based cyanobacteria platform, "Best practice" guidance for raw water monitoring, analysis and treatment as well as a commercially available software package for treatment simulation will expected as highlighted project results.
URL:	http://www.cyanotoxic.com/

PROJECT NAME: KNOWLEDGE CAPTURE FOR ADVANCED SUPERVISION OF WATER DISTRIBUTION NETWORKS

Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
WATERNET	22186	Completed	24 months	1996-06-01	1998-05-31

Organisation Name:	Estec - Estudos E Tecnologias Da Informação
Region:	CONTINENTE LISBOA E VALE DO TEJO Grande Lisboa, PORTUGAL.
Objective:	WATERNET aims at designing and developing an evolutionary knowledge capture and management system towards the control, optimal operation and decision support of drinking water distribution networks, to minimize the costs of exploitation, guarantee the continuous supply of water through better quality monitoring, save energy consumption and minimize the waste of natural resources. In order to accomplish its goals the WATERNET project will develop open reference architecture for water distribution networks and a supervision system integrating: a distributed information management subsystem, a machine learning subsystem, an optimization subsystem and, a water quality monitoring subsystem.

PROJECT NAME: ENVIRONMENTAL MONITORING AND MANAGEMENT SYSTEMS

Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**

EM2S	22442	Completed	36 months	1996-06-01	1999-05-31
Organisation Name:	Lyonnaise des Eaux - Citi				
Region:	BASSIN PARISIEN PICARDIE Oise, France.				
Objective:	To develop and install: Regional environmental management systems to provide global real-time information. Water quality monitoring and assessment methods for providing on-line quality information, allowing automatic, remote and intelligent monitoring stations. Active decision support for operators to adapt the process control to sudden changes in the environment Focusing mainly on the integration of emerging software technologies in a framework that will allow easy interfacing to existing SCADA systems and - through one of the partners - integration in a new generation of such systems for the Water Industry. This particularly implies: – Advanced algorithms for sensor data fusion and validation such as Kohonen Maps and Fuzzy Logic. – Knowledge-based and case-based reasoning techniques for decision support. – Presentation techniques addressing all levels of users, from operator to authorities. – An agent-oriented software framework integrating these techniques allowing efficient adaptation to and configuration of specific application requirements.				

PROJECT NAME: WATER QUALITY MONITORING BY LUMINESCENT CYANOBACTERIAL BIOSENSORS: A NOVEL EARLY WARMING SYSTEM AGAINST ALGAL BLOOMS

Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
ENV 2C	ENV4970493	Completed	36 months	1997-12-01	2000-11-30
Organisation Name:	Centre National de la Recherche Scientifique				
Region:	ÎLE DE FRANCE Ile de France Paris, France.				
Objective:	To construct a set of cyanobacterial biosensors, that produce a real-time signal dependent on the bioavailability of specific nutrients. It is believed that these new tools, once developed, will be accurate, sensitive and cheap. The strategy suggested for achieving this aim is to fuse two genetic elements: (a) promoter regions of selected cyanobacterial genes regulated by either N, P or Fe availability, that will serve as the sensing element of the final construct; (b)bacterial (lux) bioluminescence genes, to serve as the reporting/ signaling element. Plasmids containing these fusions will be used to transform unicellular cyanobacterial strains; successful transformants will emit light in response to N, P or Fe availability.				

	These genetically engineered tools will serve a double purpose: (1) they will function as an early warning system against the development of conditions allowing cyanobacterial blooms and (2) they will help in providing a partial solution to the still largely unanswered question of what are the roles that specific nutritional factors play in the development of such blooms.

PROJECT NAME: OPTICAL BIOSENSING TECHNIQUES FOR MONITORING ORGANIC POLLUTANTS IN THE AQUATIC ENVIRONMENT

Project Acronym:	**Project Reference:**	**Project Status:**	**Duration:**	**Start Date:**	**End Date:**
ENV 1C	EV5V0067	Completed	N/A	1992-12-01	1996-01-31
Organisation Name:	Marconi Underwater Systems Ltd.				
Region:	SOUTH EAST (UK) HAMPSHIRE, ISLE OF WIGHT Hampshire, United Kingdom.				
Objective:	The objective of this project is to develop optically-based analytical techniques for the detection and measurement of low concentrations of organic pollutants in the aquatic environment. The project, which will span three years, aims to investigate a number of techniques which will enable the development of highly sensitive biosensing instruments for the measurement of pesticides and herbicides in surface, ground and drinking waters.				

NOTE: N/A implies none available.