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Water collection purification system

Identifying CF capabilities and requirements and assessing off-the-shelf purification systems

Lt(N) Bernadette Quémerais

Defence R&D Canada – Toronto
Technical Report
DRDC Toronto TR 2006-125
August 2006

Canada

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Abstract

The Water Collection Purification System project is part of the Shelter and Survival Equipment project (12cy) sponsored by DLR. The objective is to provide to the military a water purification system suitable for all operational/environmental conditions. The capabilities of the CF in terms of both purification and testing have been assessed. Users of the current system as well as PMed technicians have been contacted in order to discuss both the capabilities and the requirements. An assessment based on manufacturer specifications of the off-the-shelf purification systems has been done. The identification of commercial system capabilities and their validation will be done during the next two years.

Résumé

Le projet Water Collection Purification System fait partie du projet Shelter and Survival Equipment (12cy) financé par DLR. L'objectif du projet est de fournir aux militaires un système de purification d'eau capable de fonctionner dans toute condition opérationnelle ou environnementale. La capacité des Forces Canadiennes en termes de purification et de contrôle ont été identifiées. Les utilisateurs du système actuel ainsi que les techniciens PMed ont été contactés pour discuter à la fois de la capacité et des besoins des Forces Canadiennes. Une évaluation, basée sur les spécifications du manufacturier, des systèmes commerciaux portatifs disponibles pour la purification de l'eau a été effectuée. L'identification des possibilités des systèmes commerciaux et leur validation seront effectuées durant les deux prochaines années.

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Executive summary

Water collection purification system: Identifying CF capabilities and requirements and assessing off-the-shelf purification systems

Quémerais, Bernadette; DRDC Toronto TR 2006-125; Defence R&D Canada – Toronto; August 2006.

The Water Collection Purification System project is part of the Shelter and Survival Equipment project (12cy) sponsored by DLR. The initial planning was to provide to the military a portable system that will operate in all operational/environmental conditions and that will produce drinking water of good quality to the troops. The project was divided in four different stages: identify Canadian Forces requirements and capabilities, perform an assessment of the off-the-shelf water purification systems based on manufacturer specifications, perform usability and/or field trial(s), and provide input detailing water purification and testing requirements for the CF. To the present, the capabilities of the CF have been identified in terms of both purification and testing. Users of the current Reverse Osmosis Water Purification Unit (ROWPU) system (field engineers and WFE technicians) as well as PMed technicians were contacted in order to discuss with them capabilities and requirements. In addition, discussions have been conducted with other scientists specialized in toxicology and drinking water quality. Selection criteria for the systems have been identified and an assessment of the off-the-shelf purification systems has been done based on manufacturer specifications. The identification of system capabilities and their validation will be done this year.

Sommaire

Water collection purification system: Identifying CF capabilities and requirements and assessing off-the-shelf purification systems

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Le projet Water Collection Purification System fait partie du projet Shelter and Survival Equipment (12cy) financé par DLR. Le projet initial était de fournir aux militaires un système portatif capable de fonctionner en toute condition opérationnelle ou environnementale et produisant de l'eau potable de bonne qualité aux troupes. Ce projet a été divisé en quatre étapes : identifier les besoins et la capacité des Forces Canadiennes, effectuer une évaluation des systèmes commerciaux de purification d'eau basée sur les spécifications du manufacturier, vérifier les possibilités d'utilisation ou effectuer des tests sur le terrain, et fournir un avis détaillant les besoins des Forces Canadiennes en matière de purification et de contrôle de l'eau. Jusqu'à présent la capacité des FC en termes de purification et de contrôle a été identifiée. Les utilisateurs du système actuel d'Unité de Purification d'Eau par Osmose Inverse (ROWPU) (ingénieurs de combat et techniciens WFE) ainsi que les techniciens PMed ont été contactés afin de discuter de la capacité et des besoins des FC. En outre, des discussions ont eu lieu avec d'autres scientifiques spécialisés en toxicologie et en qualité de l'eau potable. Les critères de sélection des systèmes ont été déterminés et une évaluation des systèmes de purification disponibles sur le marché a été effectuée selon les critères fournis par le manufacturier. L'identification de la capacité des systèmes et leur validation seront effectuées cette année.

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Acknowledgements

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1. Introductions

The Water Collection Purification System project is part of the Shelter and Survival Equipment project (12cy) financed by the Directory of Land Requirement (DLR). The objective is to provide to the military a system that will operate in all operational/environmental conditions and that will produce drinking water of good quality to the troops. The water quality is assessed against the Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998). The system must be a portable water purification unit used in case of survival conditions only. (The Canadian Forces (CF) already have efficient water purification systems available for thousands of people as well as for a small group of people (20 persons).) In the scope of this project, it was decided to identify the current methods used in the CF, including larger systems such as ROWPU (Reverse Osmosis Water Purification Unit), in terms of purification as well as testing, to identify the capabilities of these methods and finally to identify the requirements for the CF. ROWPU capabilities were assessed in order to identify properly the needs of the CF. Although testing was not in the initial planning, DRDC (Defence Research and Development Canada) scientists believed that it is essential to ensure the good quality of drinking water. The requirements have been determined and the industry off-the-shelf systems have been evaluated against CF requirements. Systems that meet those requirements will be tested and validated. If no commercial system is suitable for the CF needs, then a new system will be developed.

2. Scope and schedule of project

The project was divided into four stages:

- Identify CF requirements and capabilities.
- Perform an assessment of off-the-shelf water purification systems.
- Perform usability and/or field trial(s).
- Provide input detailing the water purification and testing requirements for the CF.

The first two stages of the project were completed in March 2004. The third and fourth ones will be completed in March 2007.

2.1 Identify Canadian Forces actual capabilities

First, it is important to know what the CF are currently using as water purification systems and what type of testing is being done.

After discussion with preventive medicine technicians (PMeds), by checking with Army field engineers, water, fuel and environment technicians (WFEs), and Zenon Environmental Inc. web sites, three systems have been identified. All of the systems are Reverse Osmosis Water Purification Units (ROWPU), also used by the US military. Zenon Environmental Inc. provides three different types: the SUWPU (Sub-Unit Water Purification Unit, also called Mini ROWPU), the ROWPU and the SROD (Shipboard Reverse Osmosis Desalination). The first system has a smaller production rate (only 100 L/hr) and can be transported by two persons and the last one is installed aboard ships. Presently, the CF have 20 ROWPU and 7 SUWPU systems.

The ROWPU system was tested at DRDC Suffield for nuclear and chemical simulants (Wellon and Soucey, 1987), for chemical agents (Wellon *et al.*, 1987a) and for biological simulants (Wellon *et al.*, 1987b). Nuclear, chemical and biological simulants were chosen to simulate for nuclear, chemical and biological warfare agents. Chemical agents were general industrial and agricultural contaminants. A detailed list of tested products is provided in the different reports.

For individual water purification system, the CF are presently using iodine tablets. No filtration or further purification is done. One tablet is dissolved in the canteen. An individual has to wait 20 minutes before drinking the water in order to allow the destruction of bacteria. Unfortunately, iodine is not strong enough to kill cysts and viruses.

In terms of testing, the ROWPU treated water is tested every day, by WFEs, for microbiological contamination. It is tested only once every six months, by WFEs, for chemicals or when contamination is suspected (Department of National Defence, 1975). Water is tested for TDS (Total Dissolved Solids), conductivity, pH, temperature, chlorine, hydrocarbons, salinity, mercury, arsenic, cyanide, mustard gas, and nerve agents. Field engineers and WFEs are in charge of the testing. Additional testing for microbiological contamination, fecal coliforms only, is done by PMeds to ensure a quality control. PMeds test purified water once every two weeks and raw water once every month if the ROWPU system provides water for less than 2,000 persons. For more than 2,000 persons, purified water is tested every week and raw water every two weeks (Department of National Defence, 1976).

2.2 Identify Canadian Forces requirements

In order to identify CF requirements, it was necessary to discuss these with the individuals in charge of the project at DLR as well as with the users of the various systems. It is then possible to look at all of the issues in order to ensure that a system will be suitable for all operational/environmental conditions.

2.2.1 Meetings with users

- A meeting took place in July 2003 with DLR who is in charge of the project in Ottawa. DLR indicated that the Army is presently interested in a system that will work for an individual, that it will be lightweight (i.e., each soldier will carry his/her own system) and that it can provide pure water for 48 hours. Water must meet Canadian Drinking Water Quality Guidelines as described in the Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998).
- The field engineers in charge of the ROWPU systems, as well as WFEs, were contacted and their feedback is recorded below.
- The life cycle manager for the ROWPU (WFE), and a PMed specialist (DFHP) were also contacted. Their expert advice on the existent capabilities, as well as what type of system would be necessary, was recorded.

2.2.1.1 Evaluation of the ROWPU system

The field engineers' and WFEs' assessment as users of a ROWPU system is summarized below:

- Users answered that they were satisfied with the system and that it works properly if it is maintained properly. Only one person seems to think that the system is getting old and that it should be replaced. No Unsatisfactory Condition Reports (UCRs) seem to exist for the ROWPU (MWO Lorrain, Ottawa, personal communication). Its maintenance is normal except if the water is hard because of mineral salts or very polluted.
- The ROWPU was tested in laboratory conditions with different types of water contamination including NBC contaminants. One of the weaknesses of the reverse osmosis membrane is that it deteriorates rapidly in the presence of petroleum, oil and lubricants (POL) and chlorine. When the water is too hard, it causes scaling on the membranes and high maintenance becomes necessary. The water can be produced within 45 minutes but it takes 48 hours to get the microbiological tests required in order to be able to drink it.
- In terms of water quality, it is difficult to know if people are getting sick because of the water, other factors such as food and good hygiene practices being as important as water (MWO Campbell, DFHP, Ottawa, personal communication). To engineers' and WFEs' knowledge, the ROWPU produces water of good quality, which is verified by their daily testing.
- All field engineers think that it is necessary that ROWPU water be tested every day. They also pointed out that source water should be tested also for the same contaminants.
- For a small portable system, the engineers replied that they would like a system that works as well as the ROWPU and that some systems are already

available on the market. They said that the system has to be compact, has to produce good quality water with no bad taste or odour, and that it should not be fragile but reliable. They also think a small RO system would be useful.

In conclusion, the ROWPU system has been used for the past 16 years and is recognized for its ability to produce water of good quality. The water is tested daily for microbiological contaminants by the WFEs and every six months for chemicals (or when a problem is suspected). DRDC finds that current testing is considered appropriate. However, more testing of raw water could be done. As suggested by the persons interviewed, the contaminants analyzed on the treated water could also be analyzed on the raw water on the same basis (i.e., every six months).

2.2.1.2 Requirement for testing

Although the client (DLR) did not require testing, as he did not think testing of purification capability was required, we wanted to investigate if testing the treated water would be necessary for a small portable system. The testing issue was discussed with DFHP, some ROWPU system users, and scientists specialized in water contamination from Ontario Ministry of the Environment. The common recommendation given was that testing is not necessary for the following reasons:

- Water sampling and analysis is a very complicated issue. In order to obtain accurate and reliable results, sampling and analysis should be done only by field and laboratory technicians as well as scientists that are experienced and properly trained. As well, results should be interpreted only by personnel specialized in drinking water quality. Water sampling and analysis is normally performed using approved protocols and analysis is performed in accredited laboratories.
- The primary goal in drinking water purification is to eliminate biological contamination to avoid waterborne diseases such as cholera, dysentery and typhoid as they pose a serious threat for human health (Canadian Council of Resource and Environment Ministers, 1998; Viessman and Hammer, 2004). Approved protocols for measuring such contamination require a 24 to 48 hours incubation period, which does not meet the purpose of this type of system. That is because it will be used only in emergency cases when no other type of water will be available and users will not be able to stay 24 to 48 hours without drinking fluids.

The recommendation is made that all of the selected systems be thoroughly tested in a laboratory and in the field for an extensive list of contaminants in order that the best available system can be identified. As well, testing of these systems will allow one to determine standard operating procedures for using and maintaining the system. Once the procedures will be ready, users can be properly trained in how to use and maintain the filtration unit. Discussion with DFHP also illustrated that the most important testing is microbiological in nature as exposure to high levels of chemical contaminants will probably be limited to very specific environmental conditions as surface waters generally meet drinking water guidelines for chemical contaminants. In addition, as most contaminants are adsorbed on water particles and colloids, filtration should allow the removal of an important percentage of these contaminants.

As a conclusion, it would be preferable to test the systems for both microbiological and chemical contaminants to ensure that the best system will be provided to the users. However, if it becomes

difficult to test for chemical contaminants, then a thorough testing for biological contaminants should be sufficient in an emergency system.

2.2.2 Selection criteria

The initial project was to provide the Land Forces with a water system that will operate in various operational/environmental conditions. As such the following criteria where identified:

- Environment
  - Arctic
  - Tropical
  - Desert
  - Saltwater
  - NBC
- Human factors
  - Size (small)
  - Weight (lightweight)
  - Time to produce potable water
- Occupational health
  - Health risks
  - Contaminant removal
- Instrumentation/engineering
  - Capabilities of the system
  - Simplicity of the system
  - Ruggedness

2.2.3 Identification of gaps

- The ROWPU system is a large system, very efficient, but not portable, and it cannot be used for a small group of people.
- The SUWPU is suitable for a small group of people, being a portable system. However, this system is too heavy to be carried only by one person and would not be suitable for one person lost and in survival conditions.
- Current procedure for soldiers going on patrols is to fill their canteen with ROWPU water. If the soldiers get lost and are in survival conditions, they have iodine tablets to purify the water. Unfortunately, the iodine tablets are very limited in use; they do not remove the sediments or chemicals, and they are not very efficient against biological contamination.

It is then necessary to assess a portable system from industry that will be useful for a single individual in survival conditions. The system should meet CF requirements and criteria as specified above (see paragraph 2.2.2). Moreover, testing is not necessary for an emergency system.

Thus, it is essential to look at systems that will be suitable for a single individual. This system could also be used for anybody in the CF that has no access to either ROWPU or bottled water (such as UN observers).

2.3 Assessment of off-the-shelf water purification systems

Many water purification systems are available on the market for military/humanitarian and/or leisure/home purpose. There are also systems available to desalt the water for ships/sailboats. All of these systems have been assessed in this study as one or more may be suitable for CF requirements. About one hundred systems have been identified and assessed. The assessment was done using manufacturer specifications in terms of size, weight, treated water production rate, purification process and capabilities as well as ruggedness.

In order to assess these systems properly, it is important to understand water chemistry, water quality as well as the different types of purification available for potable water production.

2.3.1 Surface water chemistry and quality

2.3.1.1 Chemistry of surface waters

Surface waters have a very complex chemistry, which can strongly influence the efficiency of the filtration unit. Water is composed of the dissolved phase and the particulate phase. However, it is difficult to put a limit in between dissolved and particulate phase as particle size range from 1 nm to few millimetres (Stumm and Morgan, 1996).

Suspended particles have size in a range from 1 μm to few millimetres (Stumm and Morgan, 1996). Their composition and concentration in surface waters depends upon the geology and the climate of the area. They are normally separated from the dissolved phase by using filters of 0.5 μm porosity. Insoluble chemicals will adsorb on the surface of these particles and will be then removed by filtration. The amount of adsorption depends upon the composition and the size of the particles (Stumm and Morgan, 1996).

Another important type of particles are colloids. Colloids are ubiquitous in the environment with concentrations as high as 10^9 particles/L (Stumm and Morgan, 1996). Many types of colloids are present in natural waters. Colloids can be derived from soil (kaolinite particles, humic and fulvic colloids, plant debris, iron hydroxides and aluminium oxides), they can be river-borne particles (iron and manganese oxides, phytoplankton, humic and fulvic acids), they can be organic and biological (microorganisms, viruses) or they can come from the sediments (iron and manganese oxides, sulphide and polysulfide colloids) (Stumm and Morgan, 1996). Colloids adsorb heavy metal ions and waterborne pollutants, which will be removed if colloids are removed. Colloids size varies from 0.001 to about 100 μm in natural waters (Stumm and Morgan, 1996). Conventional membrane filters can retain colloids even if their size is smaller than the defined pore size. When the water has a high concentration of colloids and suspended particles, it is likely that the filter will clog with time and that the porosity will decrease.

The dissolved phase is normally composed of dissolved ions such as calcium, sodium, sulphates, and carbonates.

Generally, waters with high suspended sediment concentration are also high in colloids. Waters with high colloid content are generally brown water even after filtration with conventional membranes (0.2 to 0.5 μm porosity) and are difficult to filter due to clogging of the filter. Waters with low colloid content are generally clear and are easier to filter.

2.3.1.2 Water quality

Drinking water needs to meet biological and chemical standards in order to protect human health (Canadian Council of Resource and Environment Ministers, 1998).

Biological contaminants are the reason for waterborne diseases and a small quantity of them can make a person seriously sick very rapidly. Contaminants include bacteria, viruses, protozoa and worms. The most serious bacterial diseases are cholera, dysentery and typhoid. Hepatitis is caused by viruses and protozoa cause mainly diarrhea and dysentery (Viessman and Hammer, 2004).

Bacteria are in a range from 0.5 to 5 μm. Viruses are smaller, in a range from 0.02 to 0.1 μm. Protozoan cysts are in a range from 5 to 15 μm and worm eggs are from 40 to 60 μm.

Although bacteria, protozoan cysts and worm eggs can easily be removed by conventional membranes of 0.2-0.5 μm, viruses cannot be removed that way. A membrane with a smaller porosity or the use of a disinfectant is necessary to eliminate them.

There are thousands of chemicals that can be found in natural waters due to anthropogenic inputs. They are classified as inorganic and organic compounds. Inorganic compounds are heavy metals (lead, mercury, nickel, cadmium), and come from activities such as mining or the steel industry. Organic compounds include pesticides, hydrocarbons, chlorinated compounds, plastics, resins and come from agricultural and industrial activities. In addition, high content in arsenic may be found naturally in groundwater. However, it is unlikely that chemical concentrations will be high enough to pose a direct threat for human health, as the filtration unit is only an emergency system that will be used only for 24 to 48 hours. Arsenic in surface water should not pose a threat either. In addition, as chemical are generally adsorbed on colloids and suspended particles, removing colloids and particles will induce removal of the chemicals.

2.3.2 Choice of type of purification

A literature review has been done in order to evaluate the different types of water treatments and filters. Most of the papers concern water treatment plants. However, they give a good description of the different types of treatments, especially the different types of membranes for treatment. Conventional water treatments include sedimentation, coagulation and flocculation and filtration on sand filters followed by the use of a disinfectant (Viessman and Hammer, 2004). The new trend in water treatment is the use of membrane filtration. These processes and their evaluation are well described in Jacangelo and Montgomery, 2002.

2.3.2.1 Reverse osmosis (RO)

The filtration is done by applying pressure across the membrane to overcome the difference in osmotic pressure between the feed and the permeate. It has been essentially used for saltwater and brackish water desalination. It is a very efficient type of filtration that removes organic and inorganic chemicals and natural organic matter. It is now being used for the removal of microorganisms. Water produced through reverse osmosis is of a very high quality. All particles and colloids are removed, as well as dissolved ions. All microorganisms are also removed. This is the type of membrane used for the ROWPU system. Katadyn offers various RO systems but only one that is portable.

2.3.2.2 Nanofiltration (NF)

This process uses membranes with very low cut-off (molecular weight from 250 to 1,000 Daltons). It works under a pressure of 75 to 125 psi. It is very efficient for the removal of natural organic matter and has being originally used for the removal of major ions. It removes all particles, even colloids. Porosity is low enough to eliminate all type of microorganisms. However, it is not available for portable systems.

2.3.2.3 Ultrafiltration (UF)

These membranes cover a wide range of molecular weight although the cut-off is for bigger molecules than NF (from 1,000 to 10,000 Daltons). They can be used for partial organic matter removal but their primary use is the removal of microorganisms. These membranes remove all types of microorganisms but they are not available for portable systems.

2.3.2.4 Microfiltration (MF)

These membranes have the largest pore size (from 0.05 to 5 μm) and that is what makes the difference between MF and UF. The main application is for the removal of particles as well as microorganisms. This is the type of membranes that are being used for the portable water purification systems such as the Katadyn ceramic filters.

All of these membranes present very good removal of microorganisms although it depends upon the pore size, especially in the case of MF where only microorganisms bigger than the pore size can be retained (Jacangelo and Montgomery, 2002).

Most portable filters have a porosity of 0.2 μm, which will not allow filtration of viruses. All other microorganisms should be removed as long as the filter is still in good condition. Suspended particulate matter will also be removed as well as most colloids. Chemicals can normally be removed only by reverse osmosis. However, as seen before, a large amount of chemicals can be expected to be removed with colloids and particulate matter. Dissolved chemicals will not be removed except by reverse osmosis.

2.3.3 List of systems assessed

A detailed list of systems assessed, with all their specifications, is given in Annex A. All types of systems were investigated, i.e., big military systems, intermediate size military/humanitarian systems, camping gears, survival kits as well as home systems. Some of these systems are good for removing biological contaminants only and others eliminate chemicals also. Katadyn offers the only portable system using a Reverse Osmosis (RO) membrane. Some systems also come with a pre-filter that can be useful when the water carries high sediment loads. Some systems are filters that rest on top of a water bottle. Here is a list of the most suitable portable systems:

- Katadyn is the brand that offers the largest variety of filters, however, these seem to be efficient only on bacteria and parasites:
  - Bottle filters (pre-filter/iodine resin/carbon filter)
  - Ceramic filters impregnated with silver powder (one combination is available with a carbon filter)
  - Glass fibre filters with activated carbon filter (come with a pre-filter)
  - RO filters

- Pre-Mac has survival kits composed of a pre-filter and an iodine resin that should be efficient for biological contaminants only.
- Seychelle Water uses carbon depth filters that are efficient for both biological and chemical contaminants.
- General Ecology Inc. uses matrix filters efficient for both biological and chemical contaminants; one of them also uses a pre-filter.
- TFO has a bottle filter that is efficient against both biological and chemical contaminants.
- MSR uses ceramic filters coupled with a solid carbon block.
- SweetWater has a labyrinth depth filter with an activated carbon surrounding layer but it is not suitable for chemicals.
- DMSI/PASSPORT has a filter composed of an iodine purification resin and a granular activated carbon filter that is efficient for both biological and chemical contaminants.

All of these systems are used for camping and hiking (Pre-Mac is for military use, likely the British Army) and they are all very light (generally under 500 g). The Katadyn RO system is the heaviest one at 1.13 kg.

The use of a very low porosity system can be a problem for filtration. As discussed before, waters with high suspended sediment concentrations and high colloid contents will be very difficult to filter even with a porosity of 0.2 μm. It can take hours to filter one litre of water. Although most of these systems do not have a pre-filter, it is recommended that one be added in case there is a high sediment load in the stream. This should ease the filtration process. A porosity of 50 μm should be sufficient to remove most of the suspended particles.

Filters containing activated carbon are expected to remove partly dissolved chemicals (particularly organic compounds) as activated carbon has a very high adsorption capacity. They should be efficient to remove particles causing bad taste and odour from the filtered water (Viessman and Hammer, 2004).

2.3.4 Recommendations

The recommendation is made that various types of filters, originating from different companies should be tested. Most of the off-the-shelf systems work with microfilters but use different media so it is important to test all media available. As there is only one system provided with an RO filter, it is also recommended that it should be tested. A list of the systems likely to meet Army needs that are recommended to be tested (see specifications in Table 1), include:

- Orinoco bottle and filter (Extream)
- Pocket filter (Katadyn)
- Combi Plus filter (Katadyn)
- PUR Hiker (Katadyn)
- Suvivor-06 (Katadyn, RO system)
- Model SWP (Pre-Mac)
- Flip Top bottle (Seychelle Water)

- First Need Deluxe portable water purifier (General Ecology Inc.)
- Nature Pure water purifier (General Ecology Inc.)
- Gatekeeper (TFO)
- MiniWorks EX (MSR)
- Guardian microfilter (SweetWater)
- Traveller II (DSMI/PASSPORT)

In case not all these systems can be tested, it is important that the following systems should be tested as a priority:

- Combi Plus filter (Katadyn)
- Suvivor-06 (Katadyn, RO system)
- Model SWP (Pre-Mac)
- First Need Deluxe portable water purifier (General Ecology Inc.)
- Guardian microfilter (SweetWater)
- Traveller II (DSMI/PASSPORT)

Table 1. Specifications of selected water purification systems

System	Type of filtration	Weight (kg)	Estimated removal efficiency[1]
Orinoco bottle and filter (Extream)	Pre-filter, penta-iodine resin, ion-release technology and coconut-carbon scrubber	N/A	Microbiological, chemical
Pocket filter (Katadyn)	0.2 μm ceramic filter impregnated with silver powder	0.45	Bacterial (not good for viruses)
Combi Plus filter (Katadyn)	0.2 μm ceramic filter impregnated with silver powder, activated carbon filter	N/A	Bacterial (not good for viruses), should be good for some chemicals
PUR Hiker (Katadyn)	130 μm pre-filter, 0.3 μm glass fiber media, activated carbon filter (optional)	0.50	Bacterial (not viruses)
Suvivor-06 (Katadyn, RO system)	Reverse osmosis	1.13	Good for desalination, should be good for microbiological and chemical as well
Model SWP (Pre-Mac)	Pre-filter, iodine resin	0.06	Microbiological
Flip Top bottle (Seychelle Water)	Carbon depth filter	N/A	Microbiological, chemical
First Need Deluxe portable water purifier (General Ecology Inc.)	Matrix filter	0.43	Microbiological, chemical
Nature Pure water purifier (General Ecology Inc.)	Ultrafine filter	N/A	Microbiological
Gatekeeper (TFO)	Polypropylene, activated carbon, silver	0.01	Microbiological, chemical
MiniWorks EX (MSR)	Ceramic filter, solid block carbon	0.45	Microbiological
Guardian microfilter (SweetWater)	0.2 μm labyrinth depth filter, activated carbon surrounding layer	0.32	Microbiological
Traveller II (DSMI/PASSPORT)	Iodinated purification resin, granular activated carbon	0.60	Microbiological, chemical

[1] Estimation is based on type of filtration and/or manufacturer specifications

N/A: non applicable

These systems have been selected in order that they cover all of the range of filtration methods and media that are used for water purification. The expected results (good for biological and/or chemical contamination) were also criteria for that list as was the system weight.

Although none of these filtration units may be sufficient to remove all types of microorganisms, it is always possible to add a disinfectant (preferably chlorine) to the filtered water in order to complete potable water purification.

2.4 Identification of systems capabilities

These systems will be tested in various operational/environmental conditions to verify if they meet CF requirements. Then they will be tested in the field/laboratory to ensure that good quality drinking water is effectively provided. This part of the project will be done from April 2006 to March 2007.

It is recommended that the selected systems be tested in priority for the removal of microorganisms. However, if time and money allow it, testing for chemicals should be done as well to ensure that the best system is delivered to the troops.

Testing should also be done using different types of unfiltered waters as filtration efficiency will differ greatly with water composition.

2.5 Validation of the systems

When all of the testing is done, it will be possible to determine if any commercial system is suitable for the needs of the Army. If no commercial system is available, then it will be necessary to develop a new system that will meet the requirements. The project should be completed at the end of March 2007, although the project may be extended for a year if further development is needed.

3. Conclusion

This study has shown that the CF already has efficient water purification systems available for thousands of people as well as a small group of people (20 persons). However, in case of an emergency situation, the soldiers only have iodine tablets to purify water, which is not really sufficient especially for the protection against contaminating chemicals. As a result, most soldiers go to outdoor stores and buy their own system that has not been tested and approved by the CF (MWO Campbell (PMed, DFHP), Capt Chesne (engineer, CFB Pettawawa) and Capt Coté (engineer CFB Valcartier) personal communications).

The main recommendation of this study is that different types of systems available on the market (see list in paragraph 2.3.3) should be assessed by evaluating the type of purification, the weight and portability, the ease of use, and the expected efficiency. As these systems have been developed for outdoor activities, it is expected that they will work in various environmental conditions.

Ideally, the selected system should be able to eliminate all types of microorganisms and should decrease chemical contamination. It should also be lightweight, small, easy to use and have a rapid filtration time. Other points such as how often the filter has to be changed and the initial and maintenance prices should also be considered in the choice.

These systems should be tested in the laboratory as well as in the field to ensure that the best one is selected and that proper standard operating procedures are to be provided for using and maintaining the filtration unit. Iodine or chlorine tablets can still be provided to the soldiers as they can be used to obtain additional purification of the filtered water. Chlorine is preferable as it is more efficient than iodine. In case of doubt of the quality of the filtered water in terms of microbiological contamination, the purified water can be boiled for at least 20 minutes to kill any remaining microorganisms. All of these issues should be raised when developing the standard operating procedures for the selected system.

It is not recommended that a testing kit be provided to the soldiers with the purification system, as water sampling and analysis should be performed only by trained personnel using approved protocols in an accredited laboratory.

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Annex A List of systems assessed

Product Name	Company	Type of purification
High production rate		
Reverse Osmosis Water Purification Unit (ROWPU)	Zenon Environmental Inc.	50 um and 5 um pre-filters + RO + Chlorine
Mini-ROWPU	Zenon Environmental Inc.	50 um and 5 um pre-filters + RO + Chlorine
ADROWPU	Zenon Environmental Inc.	50 um and 5 um pre-filters + RO + Chlorine
SROD	Zenon Environmental Inc.	50 um and 5 um pre-filters + RO + Chlorine
ROWPU	Tecwar	50 um and 5 um pre-filters + RO + Chlorine
Light Weight Water Purifier	PAWS	Reverse osmosis
Aquaozon32	TAM AS	
The nomad	Noah Water Systems	Pre-filter + sediment filter + carbon block filter + UV treatment
High to medium production rate		
PWP-C	Aqua Sun	Strainer + 5 um pre-filter + UV + 0.5 um carbon block post-filter
SPWP-C	Aqua Sun	Heavy metals polishing filter (1 um) + UV
PWP-V	Aqua Sun	Sediment filter + 0.5 um carbon block filter + UV
PWP-S	Aqua Sun	Sediment filter + 0.5 um carbon block filter + UV
PWP-10	Aqua Sun	Sediment filter + 0.5 um carbon block filter + UV
SWP-S2	Aqua Sun	Sediment filter + 0.5 um carbon block filter + UV
Model JWP4	Pre-Mac	3 um pre-filter + activated carbon filter + iodine resin
Model JWP8	Pre-Mac	3 um pre-filter + activated carbon filter + iodine resin
Model SW8	Pre-Mac	3 um pre-filter + activated carbon filter + iodine resin
Model IWP	Pre-Mac	3 um pre-filter + activated carbon filter + iodine resin
Model IWP(P)	Pre-Mac	3 um pre-filter + activated carbon filter + iodine resin
The Trekker	Noah Water Systems	Pre-filter + sediment filter + carbon block filter + UV treatment
Expio	Aquagenex Inc.	pre-filter + carbon filter + ozone
Low production rate		
Safari Outback	Bota of Boulder	Polymer filter in a Nalgene water bottle
Military water ourification tablets	Navy shop	Iodine tablets
Water purification tablets	Potable Aqua	Iodine tablets + tablets to remove iodine taste
Water treatment system	Potable Aqua	Iodine tablets + tablets to remove iodine taste
The Orinoco	Exstream	Pre-filter + penta-iodine resin + ion-release technology + coconut-carbon srcubbers
The Mackenzie	Exstream	Pre-filter + penta-iodine resin + ion-release technology + coconut-carbon srcubbers
Pocket filter	Katadyn	0.2 um ceramic filter impregnated with silver powder
Combi plus filter	Katadyn	0.2 um ceramic filter impregnated with silver powder + activated carbon filter
Camp gravity filter	Katadyn	0.2 um ceramic filter impregnated with silver powder
Siphon filter	Katadyn	0.2 um ceramic filter impregnated with silver powder
KFT Expedition filter	Katadyn	0.2 um ceramic filter impregnated with silver powder
Drip filter	Katadyn	0.2 um ceramic filter impregnated with silver powder or 0.2 um activated carbon filter
PUR Guide	Katadyn	130 um pre-filter + 0.3 um glass fiber media + activated carbon filter (optional)
PUR Hiker	Katadyn	130 um pre-filter + 0.3 um glass fiber media + activated carbon filter (optional)
Mini Ceramic Filter	Katadyn	0.2 um ceramic filter impregnated with silver powder
MP1 Emergency Drinking Water Tablets	Katadyn	Chlorine Dioxide Tablets
Survivor-06	Katadyn	Reverse osmosis
Survivor-35	Katadyn	Reverse osmosis
Survivor-40E	Katadyn	Reverse osmosis
Survivor-80E	Katadyn	Reverse osmosis
Survivor-160E	Katadyn	Reverse osmosis
Model SWP	Pre-Mac	Pre-filter + iodine resin
Model MWP	Pre-Mac	Pre-filter + iodine resin
Model PWP	Pre-Mac	Pre-filter + iodine resin
Water purification system	Pristine	Chloride dioxide solution
Flip Top Bottle	Seychelle Water	Carbon depth filter
Bottom's Up	Seychelle Water	Carbon depth filter
Pres 2 Pure Canteen	Seychelle Water	Carbon depth filter
Chlorine tablets	Seychelle Water	Chlorine tablets
Fisrt Need Deluxe portable water purifier	General Ecology Inc.	Matrix filter
Fisrt Need Deluxe water purifier Collector's edition	General Ecology Inc.	Matrix filter
Fisrt Need Trav-L-Pure portable water purifier	General Ecology Inc.	Matrix filter

Fisrt Need Base Camp portable water purifier	General Ecology Inc.	Pre-filter + matrix filter
Microlite collector's edition	General Ecology Inc.	Filter
Seagull IV water purifier	General Ecology Inc.	Structured Matrix
Nature Pure water purifier	General Ecology Inc.	Ultrafine filter
Aquamira water bottle and filter	McNett	Activated carbon filter
Aquamira water treatment	McNett	Chlorine dioxide
Gatekeeper	TFO	Polypropylene + activated carbon + silver
MiniWorks EX	MSR	Ceramic filter + solid block carbon
WaterWorks EX	MSR	Ceramic filter + solid block carbon
Guardian Microfilter	SweetWater	0.2 um labyrinth depth filter + activated carbon surrounding layer
ViralStop	SweetWater	Chlorine solution
Big Berkey	British Bekerfeld	Ceramic filter + activated carbon + final filter
Timberline filter	Timberline	0.2 um filter
Traveller II	DSMI/PASSPORT	Iodinated purification resin + granular activated carbon

Home

Water filters	Crystal Clear Supply Inc.	3 stages filtration + electrochemical/oxydo-reduction + adsorption (activated carbon)
Reverse osmosis	Crystal Clear Supply Inc.	Semi-permeable membrane
Carbon filter	Ohio Pure Water Co	Activated carbon
Multi-media	Ohio Pure Water Co	Sand and silica dioxide of different grain sizes
Birm media filter	Ohio Pure Water Co	Specific resin for iron when water does not have a rotten egg odor
Manganese greensand filter	Ohio Pure Water Co	Specific resin for iron and manganes when water has a rotten egg odor
Terminator filters	Ohio Pure Water Co	Same than Birm filter but with air injection system to add oxygen in the mixture
Nitrate filter	Ohio Pure Water Co	Specific resin to remove nitrate
Tannin filter	Ohio Pure Water Co	Specific resin to remove tannin
Calcite filter	Ohio Pure Water Co	Calcite filter for water that has low pH (neutralize)
Good water machine	Cullingan	Reverse osmosis
Cullingan water tower	Culligan	Filtration
Culligan preferred series	Culligan	Various types of filters
PuriTec CT-12	PuriTec	3-stage water filter (activated carbon)
PuriTec CT-UV	PuriTec	0.5 um carbon block filter + UV light
PuriTec CTD-12	PuriTec	1 um activated carbon + 0.4 um ceramic filter
HydroTech HTF-25	PuriTec	Reverse osmosis
CBR-2	Pro Star	CBR Heavy metal filter - 0.5 um
FI-CERAMZ.ST	Pro Star	KX- Ceramik submicron, hiperformance filter - 0.5 um carbon imbedded in ceramic
FI-AAC010	Pro Star	0.25 gpm flow removes fluoride - max pH is 9
FI-ALS010	Pro Star	Phosphate and carbon filter
CD28-10.15.01	Pro Star	Dual stage filter: outer shell for taste and ordor - centre for bacteria and cysts
FI-CAL010	Pro Star	GAC-Calcite filter
FI-PB1010B	Pro Star	Matrix PBI
FI-SED2001BA	Pro Star	HARMSCO absolute PP-BB-20 Big Blue Pleated
FI-PB1020B	Pro Star	Matrix PBI

Product Name	Length (m)	Width (m)	Height (m)	Weight (kg)	Production rate (L/h)
High production rate					
Reverse Osmosis Water Purification Unit (ROWPU)	5.85	2.28	2.15	8,600.00	2,400-5,000
Mini-ROWPU					159-340
ADROWPU					
SROD					
ROWPU					
Light Weight Water Purifier	1.30	0.71	1.22	908.00	278-463
Aquaozon32					
The nomad	0.86	0.74	0.97	272.40	5700
High to medium production rate					
PWP-C	1.51	0.43	0.23	17.25	222
SPWP-C	0.51	0.43	0.23	15.89	370
PWP-V	1.51	0.43	0.23	9.08	240
PWP-S	1.51	0.43	0.23	17.25	370
PWP-10	0.61	0.61	1.32	34.05	3,300
SWP-S2		0.89	0.51	20.43	740
Model JWP4	0.50	0.30	0.42	16.00	240
Model JWP8	0.62	0.30	0.42	19.00	240
Model SW8	0.95	0.42	0.55	40.00	240-360
Model IWP	0.55	0.36	0.13	7.00	210
Model IWP(P)	0.57	0.57	0.24	13.50	210
The Trekker	0.43	0.23	0.53	12.00	222
Expio	0.51	0.20	0.43	20.00	180
Low production rate					
Safari Outback					
Military water ourification tablets					
Water purification tablets					
Water treatment system					
The Orinoco					
The Mackenzie					
Pocket filter		0.10	0.30	0.45	60
Combi plus filter					60
Camp gravity filter		0.10	0.30	1.23	5
Siphon filter		0.08	0.25	0.73	5
KFT Expedition filter			0.58	5.45	240
Drip filter	0.25	0.25	0.46	3.41	4
PUR Guide			0.24	0.64	60
PUR Hiker			0.17	0.50	60
Mini Ceramic Filter	0.09	0.04	0.18	0.36	30
MP1 Emergency Drinking Water Tablets					
Survivor-06	0.13	0.06	0.02	1.13	0.89
Survivor-35	0.14	0.09	0.56	3.20	4.5
Survivor-40E	0.42	0.39	0.17	11.33	5.7
Survivor-80E	0.53	0.43	0.24	22.20	12.9
Survivor-160E	0.41	0.36	0.15	16.30	25.4
Model SWP	0.14	0.02		0.06	12
Model MWP	0.14	0.05		0.18	24
Model PWP	0.14	0.10		0.50	6
Water purification system					
Flip Top Bottle					
Bottom's Up					
Pres 2 Pure Canteen					
Chlorine tablets					
Fisrt Need Deluxe portable water purifier	0.14	0.07	0.10	0.43	102
Fisrt Need Deluxe water purifier Collector's edition	0.14	0.07	0.10	0.43	102
Fisrt Need Trav-L-Pure portable water purifier	0.17	0.08	0.11	0.63	75
Fisrt Need Base Camp portable water purifier	0.27	0.13	0.13		114
Microlite collector's edition	0.14	0.07	0.07	0.20	28

Seagull IV water purifier	0.28	0.13	0.13		228
Nature Pure water purifier	0.26	0.10	0.10		114
Aquamira water bottle and filter	0.08	0.08	0.27	0.18	
Aquamira water treatment	0.11	0.07	0.03	0.09	
Gatekeeper				0.01	
MiniWorks EX				0.45	60
WaterWorks EX				0.54	60
Guardian Microfilter	0.19	0.05	0.05	0.32	75
ViralStop					
Big Berkey	0.22	0.22	0.51	3.41	3.7
Timberline filter				1.70	9.5
Traveller II	0.39	0.07	0.07	0.60	120
Home					
Water filters					
Reverse osmosis	0.36	0.08	0.15		12
Carbon filter					1,000-2,000
Multi-media					1,000-4,000
Birm media filter					1,000-2,000
Manganese greensand filter					1,000-2,700
Terminator filters				800-1,000	
Nitrate filter					1,000-1,300
Tannin filter					1,000-1,300
Calcite filter					1,000-1,500
Good water machine					
Cullingan water tower					
Culligan preferred series					
PuriTec CT-12					
PuriTec CT-UV					
PuriTec CTD-12					
HydroTech HTF-25					
CBR-2					
FI-CERAMZ.ST					
FI-AAC010					
FI-ALS010					
CD28-10.15.01					
FI-CAL010					
FI-PB1010B					
FI-SED2001BA					
FI-PB1020B					

Product Name	Comments	Use
High production rate		
Reverse Osmosis Water Purification Unit (ROWPU)	Can be used in either single or double-pass	Military
Mini-ROWPU	Two-stage purification process	Military
ADROWPU	Can be used in either single or double-pass	Military
SROD	Installed aboard ships	Military
ROWPU	Used by US military	Military
Light Weight Water Purifier	Used by US military	Military
Aquaozon32		Military/Humanitary
The nomad	Contained in a case	Humanitary
High to medium production rate		
PWP-C	Works with solar or 12 V	Military/Humanitary
SPWP-C	Works with solar or 12 V - Can be used at home	Military/Humanitary
PWP-V	Works with 12 V	Military/Humanitary
PWP-S	Works with solar energy	Military/Humanitary
PWP-10	Works with solar or 12 V - Can be used at home	Military/Humanitary
SWP-S2	Works with solar energy	Military/Humanitary
Model JWP4	Works electric or manual pump	Military/Humanitary
Model JWP8	Works electric or manual pump	Military/Humanitary
Model SW8	Solar powered	Military/Humanitary
Model IWP	In-line water purifier	Military/Humanitary
Model IWP(P)	In-line water purifier	Military/Humanitary
The Trekker	Contained in a case	Humanitary
Expio	Contained in a case	Humanitary
Low production rate		
Safari Outback	22 oz or 32 oz water bottle	Camping
Military water ourification tablets	Not very efficient/US military	Military
Water purification tablets	Not very efficient	Camping
Water treatment system	Not very efficient	Camping
The Orinoco	26 oz bottle - can purify up to 100 L	Camping
The Mackenzie	34 oz bottle - can purify up to 100 L	Camping
Pocket filter	Does not remove viruses or chemicals	Camping
Combi plus filter	Does not remove viruses - remove some chemicals	Camping
Camp gravity filter	Does not remove viruses or chemicals	Camping
Siphon filter	Does not remove viruses or chemicals	Camping
KFT Expedition filter	Does not remove viruses or chemicals	Camping
Drip filter	Does not remove viruses or chemicals	Camping
PUR Guide	Does not remove viruses or chemicals	Camping
PUR Hiker	Does not remove viruses or chemicals	Camping
Mini Ceramic Filter	Does not remove viruses or chemicals	Camping
MP1 Emergency Drinking Water Tablets	1 tablet treats 1 L of water	Camping
Survivor-06	Good for salted water	Camping/Sailing
Survivor-35	Good for salted water	Camping/Sailing
Survivor-40E	Good for salted water - works with 12 V	Camping/Sailing
Survivor-80E	Good for salted water - works with 12 V	Camping/Sailing
Survivor-160E	Good for salted water - works with 12 V	Camping/Sailing
Model SWP	Survival kit	Military
Model MWP	Survival kit	Military
Model PWP	Outdoor use	Military
Water purification system	Efficient only for biological contamination	Camping
Flip Top Bottle	Efficient for biological and chemical	Camping
Bottom's Up	Efficient for biological and chemical	Camping
Pres 2 Pure Canteen	Efficient for biological and chemical	Camping
Chlorine tablets	Efficient for biological	Camping
Fisrt Need Deluxe portable water purifier	Efficient for both biological and chemicals	Camping
Fisrt Need Deluxe water purifier Collector's edition	Efficient for both biological and chemicals + bottle	Camping
Fisrt Need Trav-L-Pure portable water purifier	Efficient for both biological and chemicals	Camping
Fisrt Need Base Camp portable water purifier	Efficient for both biological and chemicals	Camping
Microlite collector's edition	Not efficient for viruses/bacteria, need iodine	Camping

Seagull IV water purifier	Does not seem to remove salt	Sailing
Nature Pure water purifier	Does not remove chemicals	Camping
Aquamira water bottle and filter	Not efficient against chemicals	Camping
Aquamira water treatment	Not efficient against chemicals	Camping
Gatekeeper	Efficient against chemicals and biologicals	Camping
MiniWorks EX	Does not remove chemicals	Camping
WaterWorks EX	Does not remove chemicals	Camping
Guardian Microfilter	Does not remove chemicals	Camping
ViralStop	Does not remove chemicals	Camping
Big Berkey	Efficient for both biological and chemicals	Camping
Timberline filter	Not efficient for chemicals, bacteria, viruses	Camping
Traveller II	Efficient with both biological and chemicals	Camping/Travelling

Home

Water filters	Top or under counter	Home
Reverse osmosis	Connect directly on the faucet	Home
Carbon filter	To put in-line with the water system	Home
Multi-media	To put in-line with the water system	Home
Birm media filter	To put in-line with the water system	Home
Manganese greensand filter	To put in-line with the water system	Home
Terminator filters	To put in-line with the water system	Home
Nitrate filter	To put in-line with the water system	Home
Tannin filter	To put in-line with the water system	Home
Calcite filter	To put in-line with the water system	Home
Good water machine	To put in-line with the water system	Home
Cullingan water tower	To put in-line with the water system	Home
Culligan preferred series	To put in-line with the water system	Home
PuriTec CT-12	On the top of the counter	Home
PuriTec CT-UV	On the top of the counter	Home
PuriTec CTD-12	On the top of the counter	Home
HydroTech HTF-25	Under the counter	Home
CBR-2		Home
FI-CERAMZ.ST		Home
FI-AAC010		Home
FI-ALS010		Home
CD28-10.15.01		Home
FI-CAL010		Home
FI-PB1010B		Home
FI-SED2001BA		Home
FI-PB1020B		Home

List of symbols/abbreviations/acronyms/initialisms

DND	Department of National Defence
CF	Canadian Forces
ROWPU	Reverse Osmosis Water Purification Unit
PMed	Preventive Medicine
WFEs	Water, Fuel and Environment technicians
RO	Reverse Osmosis
NF	Nanofiltration
UF	Ultrafiltration
MF	Microfiltration
UCR	Unsatisfactory Condition Report
POL	Petroleum, Oil and Lubricants
DLR	Directorate of Land Requirements
DFHP	Directorate Force Health Protection
SUWPU	Sub-Unit Water Purification Unit
SROD	Shipboard Reverse Osmosis Desalination System
TDS	Total Dissolved Solids
DRDC	Defence Research and Development Canada
US	United States
UN	United Nations
NBC	Nuclear, Biological and Chemical

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Water Collection Purification System − Identifying CF capabilities and requirements, and assessing off−the−shelf purification systems (U)
Système de Collecte et de Purification d'Eau − Identifier la capacité et les besoins des FC, et évaluer les systèmes commerciaux

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

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(U) The Water Collection Purification System project is part of the Shelter and Survival Equipment project (12cy) sponsored by DLR. The objective is to provide to the military a water purification system suitable for all operational/environmental conditions. The capabilities of the CF in terms of both purification and testing have been assessed. Users of the current system as well as PMed technicians have been contacted in order to discuss both the capabilities and the requirements. An assessment based on the manufacturer specifications of the off−the−shelf purification has been done. The identification of commercial system capabilities and their validation will be done during the next two years.

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(U) water; water purification system.

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